

# FY 2015 PRESIDENT'S BUDGET REQUEST SUMMARY

Budget Authority (\$ in millions)	Fiscal Year						
	Actual 2013	Enacted 2014	Request 2015	Notional 2016	Notional 2017	Notional 2018	Notional 2019
<b>NASA Total</b>	<b>16,865.2</b>	<b>17,646.5</b>	<b>17,460.6</b>	<b>17,635.3</b>	<b>17,811.5</b>	<b>17,989.7</b>	<b>18,169.7</b>
<b>Science</b>	<b>4,781.6</b>	<b>5,151.2</b>	<b>4,972.0</b>	<b>5,021.7</b>	<b>5,071.9</b>	<b>5,122.6</b>	<b>5,173.9</b>
Earth Science	1,659.2	1,826.0	1,770.3	1,815.5	1,837.6	1,861.9	1,886.3
Planetary Science	1,274.6	1,345.0	1,280.3	1,304.9	1,337.1	1,355.7	1,374.1
Astrophysics	617.0	668.0	607.3	633.7	651.2	696.8	933.0
James Webb Space Telescope	627.6	658.2	645.4	620.0	569.4	534.9	305.0
Heliophysics	603.2	654.0	668.9	647.6	676.6	673.3	675.5
<b>Aeronautics</b>	<b>529.5</b>	<b>566.0</b>	<b>551.1</b>	<b>556.6</b>	<b>562.2</b>	<b>567.8</b>	<b>573.5</b>
Space Technology	614.5	576.0	705.5	712.6	719.7	726.9	734.2
Exploration	3,705.5	4,113.2	3,976.0	4,079.9	4,049.4	4,107.7	3,673.4
Exploration Systems Development	2,883.8	3,115.2	2,784.4	2,863.3	2,905.9	2,982.1	3,106.6
Commercial Spaceflight	525.0	696.0	848.3	872.3	791.7	730.9	172.0
Exploration Research and Development	296.7	302.0	343.4	344.3	351.8	394.7	394.7
<b>Space Operations</b>	<b>3,724.9</b>	<b>3,778.0</b>	<b>3,905.4</b>	<b>3,951.9</b>	<b>4,062.8</b>	<b>4,085.6</b>	<b>4,601.8</b>
Space Shuttle	38.8	--	--	--	--	--	--
International Space Station	2,775.9	--	3,050.8	3,126.5	3,266.9	3,290.3	3,818.6
Space and Flight Support	910.2	--	854.6	825.4	795.9	795.3	783.2
<b>Education</b>	<b>116.3</b>	<b>116.6</b>	<b>88.9</b>	<b>89.8</b>	<b>90.7</b>	<b>91.6</b>	<b>92.6</b>
<b>Cross Agency Support</b>	<b>2,711.0</b>	<b>2,793.0</b>	<b>2,778.6</b>	<b>2,806.4</b>	<b>2,834.4</b>	<b>2,862.8</b>	<b>2,891.4</b>
Center Management and Operations	1,991.6	--	2,038.8	2,059.2	2,079.7	2,100.5	2,121.6
Agency Management and Operations	719.4	--	739.8	747.2	754.7	762.3	769.8
<b>Construction and Environmental Compliance and Restoration</b>	<b>646.6</b>	<b>515.0</b>	<b>446.1</b>	<b>379.0</b>	<b>382.7</b>	<b>386.6</b>	<b>390.4</b>
Construction of Facilities	589.5	--	370.6	302.7	305.7	308.8	311.8
Environmental Compliance and Restoration	57.0	--	75.5	76.3	77.0	77.8	78.6
<b>Inspector General</b>	<b>35.3</b>	<b>37.5</b>	<b>37.0</b>	<b>37.4</b>	<b>37.7</b>	<b>38.1</b>	<b>38.5</b>
<b>NASA Total</b>	<b>16,865.2</b>	<b>17,646.5</b>	<b>17,460.6</b>	<b>17,635.3</b>	<b>17,811.5</b>	<b>17,989.7</b>	<b>18,169.7</b>

Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.

FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.

Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.

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	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2013	2014	2015	2016	2017	2018	2019
<b>NASA Total</b>	<b>16,865.2</b>	<b>17,646.5</b>	<b>17,460.6</b>	<b>17,635.3</b>	<b>17,811.5</b>	<b>17,989.7</b>	<b>18,169.7</b>
<b>Science</b>	<b>4,781.6</b>	<b>5,151.2</b>	<b>4,972.0</b>	<b>5,021.7</b>	<b>5,071.9</b>	<b>5,122.6</b>	<b>5,173.9</b>
<b>Earth Science</b>	<b>1,659.2</b>	<b>1,826.0</b>	<b>1,770.3</b>	<b>1,815.5</b>	<b>1,837.6</b>	<b>1,861.9</b>	<b>1,886.3</b>
<b>Earth Science Research</b>	<b>422.9</b>	--	<b>449.9</b>	<b>477.1</b>	<b>453.9</b>	<b>445.9</b>	<b>448.6</b>
Earth Science Research and Analysis	316.7	--	329.2	332.5	310.9	295.4	299.2
Computing and Management	106.2	--	120.7	144.6	143.0	150.4	149.4
<b>Earth Systematic Missions</b>	<b>816.2</b>	--	<b>786.2</b>	<b>856.7</b>	<b>880.4</b>	<b>894.3</b>	<b>927.2</b>
Global Precipitation Measurement	91.4	--	18.7	19.6	14.2	15.3	15.3
Ice, Cloud, and land Elevation Satellite	165.9	140.7	109.5	118.4	27.1	14.1	10.9
Soil Moisture Active and Passive	210.3	88.3	74.9	15.9	11.3	11.3	11.3
GRACE Follow-On	50.1	--	64.4	74.3	71.7	20.0	12.0
Other Missions and Data Analysis	298.5	--	518.8	628.4	756.1	833.5	877.7
<b>Earth System Science Pathfinder</b>	<b>176.7</b>	--	<b>266.1</b>	<b>209.5</b>	<b>227.0</b>	<b>243.2</b>	<b>231.9</b>
OCO-2	80.3	--	21.0	12.5	7.9	12.0	12.0
Venture Class Missions	51.5	--	206.6	163.6	185.1	200.0	189.7
Other Missions and Data Analysis	44.8	--	38.5	33.5	34.0	31.2	30.2
<b>Earth Science Multi-Mission Operations</b>	<b>162.2</b>	--	<b>176.1</b>	<b>179.6</b>	<b>181.0</b>	<b>183.2</b>	<b>183.3</b>
<b>Earth Science Technology</b>	<b>48.9</b>	--	<b>55.6</b>	<b>54.5</b>	<b>55.6</b>	<b>55.6</b>	<b>55.6</b>
<b>Applied Sciences</b>	<b>32.5</b>	--	<b>36.3</b>	<b>38.0</b>	<b>39.7</b>	<b>39.7</b>	<b>39.7</b>

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	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2013	2014	2015	2016	2017	2018	2019
<b>Planetary Science</b>	<b>1,274.6</b>	<b>1,345.0</b>	<b>1,280.3</b>	<b>1,304.9</b>	<b>1,337.1</b>	<b>1,355.7</b>	<b>1,374.1</b>
<b>Planetary Science Research</b>	<b>195.8</b>	<b>--</b>	<b>255.8</b>	<b>280.5</b>	<b>284.4</b>	<b>283.3</b>	<b>278.4</b>
Planetary Science Research and Analysis	128.6	130.0	165.4	165.5	165.5	165.4	165.4
Directorate Management	3.9	--	4.0	7.1	7.4	7.4	7.4
Near Earth Object Observations	20.5	40.5	40.0	40.0	40.0	40.0	40.0
Other Missions and Data Analysis	42.8	--	46.4	67.9	71.5	70.6	65.6
<b>Lunar Quest Program</b>	<b>63.8</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
<b>Discovery</b>	<b>215.5</b>	<b>285.0</b>	<b>230.8</b>	<b>163.0</b>	<b>174.2</b>	<b>280.2</b>	<b>377.8</b>
InSight	122.7	--	170.0	92.1	13.3	8.7	--
Other Missions and Data Analysis	92.8	--	60.8	70.9	160.9	271.5	377.8
<b>New Frontiers</b>	<b>158.8</b>	<b>258.0</b>	<b>281.5</b>	<b>254.7</b>	<b>110.0</b>	<b>51.1</b>	<b>45.9</b>
Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer	125.5	218.7	224.8	193.7	44.0	26.1	43.1
Other Missions and Data Analysis	33.3	--	56.6	61.0	66.0	25.0	2.8
<b>Mars Exploration</b>	<b>369.5</b>	<b>288.0</b>	<b>279.3</b>	<b>381.7</b>	<b>547.8</b>	<b>573.1</b>	<b>518.8</b>
<b>Outer Planets</b>	<b>147.8</b>	<b>159.0</b>	<b>95.7</b>	<b>82.2</b>	<b>84.5</b>	<b>27.8</b>	<b>9.1</b>
<b>Technology</b>	<b>123.4</b>	<b>146.0</b>	<b>137.2</b>	<b>142.9</b>	<b>136.3</b>	<b>140.1</b>	<b>144.1</b>
<b>Astrophysics</b>	<b>617.0</b>	<b>668.0</b>	<b>607.3</b>	<b>633.7</b>	<b>651.2</b>	<b>696.8</b>	<b>933.0</b>
<b>Astrophysics Research</b>	<b>155.8</b>	<b>--</b>	<b>191.0</b>	<b>216.2</b>	<b>221.2</b>	<b>234.6</b>	<b>261.2</b>
Astrophysics Research and Analysis	65.0	--	66.0	70.2	71.5	71.5	71.5
Balloon Project	33.0	32.9	38.3	34.2	34.3	37.3	37.4
Other Missions and Data Analysis	57.8	--	86.6	111.8	115.3	125.8	152.2
<b>Cosmic Origins</b>	<b>218.9</b>	<b>--</b>	<b>120.3</b>	<b>106.4</b>	<b>108.2</b>	<b>114.2</b>	<b>105.8</b>
Hubble Space Telescope	93.3	98.3	75.3	91.8	88.2	92.3	83.9
Stratospheric Observatory for Infrared Astronomy	77.5	--	12.3	--	--	--	--
Other Missions and Data Analysis	48.1	--	32.7	14.6	20.0	21.9	21.9
<b>Physics of the Cosmos</b>	<b>124.5</b>	<b>--</b>	<b>108.8</b>	<b>100.9</b>	<b>86.6</b>	<b>89.4</b>	<b>142.4</b>
<b>Exoplanet Exploration</b>	<b>52.8</b>	<b>--</b>	<b>47.5</b>	<b>46.4</b>	<b>60.4</b>	<b>89.8</b>	<b>237.3</b>
<b>Astrophysics Explorer</b>	<b>65.1</b>	<b>--</b>	<b>139.7</b>	<b>163.7</b>	<b>174.9</b>	<b>168.7</b>	<b>186.4</b>
Transiting Exoplanet Survey Satellite	34.8	--	98.8	100.8	102.7	13.9	9.1
Other Missions and Data Analysis	30.3	--	40.9	63.0	72.2	154.7	177.2

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	2013	2014	2015	2016	2017	2018	2019
<b>James Webb Space Telescope</b>	<b>627.6</b>	<b>658.2</b>	<b>645.4</b>	<b>620.0</b>	<b>569.4</b>	<b>534.9</b>	<b>305.0</b>
<b>Heliophysics</b>	<b>603.2</b>	<b>654.0</b>	<b>668.9</b>	<b>647.6</b>	<b>676.6</b>	<b>673.3</b>	<b>675.5</b>
<b>Heliophysics Research</b>	<b>165.3</b>	--	<b>217.4</b>	<b>158.3</b>	<b>167.6</b>	<b>169.7</b>	<b>169.9</b>
Sounding Rockets	56.1	--	65.6	48.0	53.0	53.0	53.0
Research Range	20.5	--	21.3	21.6	21.7	21.7	21.7
Heliophysics Research and Analysis	35.1	--	33.9	34.0	33.9	33.9	33.9
Other Missions and Data Analysis	53.5	--	96.7	54.6	59.1	61.1	61.4
<b>Living with a Star</b>	<b>174.9</b>	--	<b>266.4</b>	<b>355.8</b>	<b>378.2</b>	<b>398.9</b>	<b>282.7</b>
Solar Probe Plus	108.2	104.8	145.6	219.2	212.3	345.1	180.4
Solar Orbiter Collaboration	19.1	--	76.5	88.8	117.8	6.7	35.4
Other Missions and Data Analysis	47.6	--	44.3	47.8	48.2	47.0	66.8
<b>Solar Terrestrial Probes</b>	<b>203.9</b>	--	<b>61.4</b>	<b>41.5</b>	<b>42.1</b>	<b>30.5</b>	<b>129.4</b>
Magnetospheric Multiscale	183.3	120.9	39.5	20.2	12.3	2.7	0.0
Other Missions and Data Analysis	20.6	--	21.9	21.3	29.8	27.8	129.4
<b>Heliophysics Explorer Program</b>	<b>59.1</b>	<b>95.2</b>	<b>123.6</b>	<b>91.9</b>	<b>88.7</b>	<b>74.3</b>	<b>93.4</b>
ICON	18.2	--	78.2	49.8	41.0	7.5	1.0
Other Missions and Data Analysis	40.9	--	45.4	42.2	47.7	66.8	92.4
<b>Aeronautics</b>	<b>529.5</b>	<b>566.0</b>	<b>551.1</b>	<b>556.6</b>	<b>562.2</b>	<b>567.8</b>	<b>573.5</b>
<b>Aeronautics</b>	<b>529.5</b>	--	<b>551.1</b>	<b>556.6</b>	<b>562.2</b>	<b>567.8</b>	<b>573.5</b>
<b>Airspace Operations and Safety Program</b>	--	--	<b>131.0</b>	<b>132.7</b>	<b>134.6</b>	<b>135.9</b>	<b>137.3</b>
<b>Advanced Air Vehicles Program</b>	--	--	<b>213.6</b>	<b>211.4</b>	<b>205.8</b>	<b>203.3</b>	<b>205.3</b>
<b>Integrated Aviation Systems Program</b>	--	--	<b>127.0</b>	<b>125.8</b>	<b>128.0</b>	<b>133.4</b>	<b>134.8</b>
<b>Transformative Aeronautics Concepts Program</b>	--	--	<b>79.5</b>	<b>86.8</b>	<b>93.8</b>	<b>95.2</b>	<b>96.2</b>
<b>Aviation Safety</b>	<b>77.6</b>	--	--	--	--	--	--
<b>Airspace Systems</b>	<b>89.8</b>	--	--	--	--	--	--
<b>Fundamental Aeronautics</b>	<b>167.7</b>	--	--	--	--	--	--
<b>Aeronautics Test</b>	<b>74.6</b>	--	--	--	--	--	--
<b>Integrated Systems Research</b>	<b>99.0</b>	--	--	--	--	--	--
<b>Aeronautics Strategy and Management</b>	<b>21.0</b>	--	--	--	--	--	--
<b>Space Technology</b>	<b>614.5</b>	<b>576.0</b>	<b>705.5</b>	<b>712.6</b>	<b>719.7</b>	<b>726.9</b>	<b>734.2</b>
<b>Space Technology</b>	<b>614.5</b>	--	<b>705.5</b>	<b>712.6</b>	<b>719.7</b>	<b>726.9</b>	<b>734.2</b>
<b>Partnerships Development and Strategic Integration</b>	<b>28.8</b>	--	<b>33.8</b>	<b>33.7</b>	<b>33.7</b>	<b>33.9</b>	<b>33.9</b>
<b>SBIR and STTR</b>	<b>165.4</b>	--	<b>190.7</b>	<b>200.9</b>	<b>212.1</b>	<b>212.1</b>	<b>212.1</b>
<b>Crosscutting Space Tech Development</b>	<b>247.3</b>	--	<b>256.6</b>	<b>190.1</b>	<b>185.9</b>	<b>198.5</b>	<b>203.5</b>
<b>Exploration Technology Development</b>	<b>173.0</b>	--	<b>224.5</b>	<b>287.9</b>	<b>288.0</b>	<b>282.4</b>	<b>284.7</b>



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	2013	2014	2015	2016	2017	2018	2019
<b>Exploration</b>	<b>3,705.5</b>	<b>4,113.2</b>	<b>3,976.0</b>	<b>4,079.9</b>	<b>4,049.4</b>	<b>4,107.7</b>	<b>3,673.4</b>
<b>Exploration Systems Development</b>	<b>2,883.8</b>	<b>3,115.2</b>	<b>2,784.4</b>	<b>2,863.3</b>	<b>2,905.9</b>	<b>2,982.1</b>	<b>3,106.6</b>
<b>Orion Multi-Purpose Crew Vehicle</b>	<b>1,113.8</b>	<b>1,197.0</b>	<b>1,052.8</b>	<b>1,096.3</b>	<b>1,119.8</b>	<b>1,122.9</b>	<b>1,126.7</b>
Crew Vehicle Development	1,089.9	--	1,042.3	1,085.8	1,109.3	1,112.4	1,116.2
MPCV Program Integration and Support	23.9	--	10.5	10.5	10.5	10.5	10.5
<b>Space Launch System</b>	<b>1,414.9</b>	<b>1,600.0</b>	<b>1,380.3</b>	<b>1,356.9</b>	<b>1,353.8</b>	<b>1,418.0</b>	<b>1,526.9</b>
Launch Vehicle Development	1,376.4	--	1,350.7	1,313.5	1,268.6	1,332.8	1,441.8
SLS Program Integration and Support	38.5	--	29.6	43.4	85.2	85.2	85.1
<b>Exploration Ground Systems</b>	<b>355.1</b>	<b>318.2</b>	<b>351.3</b>	<b>410.1</b>	<b>432.3</b>	<b>441.2</b>	<b>453.0</b>
Exploration Ground Systems Development	355.1	--	320.6	390.9	417.1	425.9	437.7
EGS Program Integration and Support	--	--	30.7	19.1	15.3	15.3	15.3
<b>Commercial Spaceflight</b>	<b>525.0</b>	<b>696.0</b>	<b>848.3</b>	<b>872.3</b>	<b>791.7</b>	<b>730.9</b>	<b>172.0</b>
<b>Commercial Crew</b>	<b>525.0</b>	<b>696.0</b>	<b>848.3</b>	<b>872.3</b>	<b>791.7</b>	<b>730.9</b>	<b>172.0</b>
<b>Exploration Research and Development</b>	<b>296.7</b>	<b>302.0</b>	<b>343.4</b>	<b>344.3</b>	<b>351.8</b>	<b>394.7</b>	<b>394.7</b>
<b>Human Research Program</b>	<b>146.7</b>	<b>--</b>	<b>160.5</b>	<b>167.8</b>	<b>173.6</b>	<b>178.2</b>	<b>178.2</b>
<b>Advanced Exploration Systems</b>	<b>150.0</b>	<b>--</b>	<b>182.9</b>	<b>176.5</b>	<b>178.2</b>	<b>216.6</b>	<b>216.6</b>

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	2013	2014	2015	2016	2017	2018	2019
<b>Space Operations</b>	<b>3,724.9</b>	<b>3,778.0</b>	<b>3,905.4</b>	<b>3,951.9</b>	<b>4,062.8</b>	<b>4,085.6</b>	<b>4,601.8</b>
<b>Space Shuttle</b>	<b>38.8</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
<b>Space Shuttle Program</b>	<b>38.8</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>
Program Integration	16.5	--	--	--	--	--	--
Flight and Ground Operations	21.5	--	--	--	--	--	--
Flight Hardware	0.8	--	--	--	--	--	--
<b>International Space Station</b>	<b>2,775.9</b>	<b>--</b>	<b>3,050.8</b>	<b>3,126.5</b>	<b>3,266.9</b>	<b>3,290.3</b>	<b>3,818.6</b>
<b>International Space Station Program</b>	<b>2,775.9</b>	<b>--</b>	<b>3,050.8</b>	<b>3,126.5</b>	<b>3,266.9</b>	<b>3,290.3</b>	<b>3,818.6</b>
ISS Systems Operations and Maintenance	1,418.2	--	1,207.9	1,211.9	1,337.7	1,347.2	1,347.3
ISS Research	317.5	--	312.2	312.2	312.2	312.2	312.2
ISS Crew and Cargo Transportation	1,040.3	--	1,530.7	1,602.4	1,617.0	1,630.9	2,159.1
<b>Space and Flight Support</b>	<b>910.2</b>	<b>--</b>	<b>854.6</b>	<b>825.4</b>	<b>795.9</b>	<b>795.3</b>	<b>783.2</b>
<b>21<sup>st</sup> Century Space Launch Complex</b>	<b>39.0</b>	<b>39.6</b>	<b>25.9</b>	<b>25.9</b>	<b>11.8</b>	<b>11.8</b>	<b>--</b>
<b>Space Communications and Navigation</b>	<b>641.4</b>	<b>--</b>	<b>591.8</b>	<b>553.5</b>	<b>535.4</b>	<b>534.8</b>	<b>534.5</b>
Space Communications Networks	574.3	--	532.1	459.0	394.7	383.2	383.3
Space Communications Support	67.0	--	59.7	94.5	140.7	151.6	151.2
<b>Human Space Flight Operations</b>	<b>102.6</b>	<b>--</b>	<b>108.1</b>	<b>112.0</b>	<b>112.0</b>	<b>112.0</b>	<b>112.0</b>
<b>Launch Services</b>	<b>81.2</b>	<b>--</b>	<b>83.0</b>	<b>86.7</b>	<b>89.1</b>	<b>89.1</b>	<b>89.1</b>
<b>Rocket Propulsion Test</b>	<b>45.9</b>	<b>47.8</b>	<b>45.8</b>	<b>47.2</b>	<b>47.6</b>	<b>47.6</b>	<b>47.6</b>
<b>Education</b>	<b>116.3</b>	<b>116.6</b>	<b>88.9</b>	<b>89.8</b>	<b>90.7</b>	<b>91.6</b>	<b>92.6</b>
<b>Education</b>	<b>116.3</b>	<b>116.6</b>	<b>88.9</b>	<b>89.8</b>	<b>90.7</b>	<b>91.6</b>	<b>92.6</b>
<b>Aerospace Research and Career Development</b>	<b>54.0</b>	<b>58.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>
National Space Grant College and Fellowship Project	37.2	40.0	24.0	24.0	24.0	24.0	24.0
Experimental Project to Stimulate Competitive Research	16.7	18.0	9.0	9.0	9.0	9.0	9.0
<b>STEM Education and Accountability</b>	<b>62.3</b>	<b>58.6</b>	<b>55.9</b>	<b>56.8</b>	<b>57.7</b>	<b>58.6</b>	<b>59.6</b>
Minority University Research Education Project	27.9	30.0	30.0	30.0	30.0	30.0	30.0
STEM Education and Accountability	34.4	28.6	25.9	26.8	27.7	28.6	29.6

# FY 2015 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2013	2014	2015	2016	2017	2018	2019
<b>Cross Agency Support</b>	<b>2,711.0</b>	<b>2,793.0</b>	<b>2,778.6</b>	<b>2,806.4</b>	<b>2,834.4</b>	<b>2,862.8</b>	<b>2,891.4</b>
<b>Center Management and Operations</b>	<b>1,991.6</b>	<b>--</b>	<b>2,038.8</b>	<b>2,059.2</b>	<b>2,079.7</b>	<b>2,100.5</b>	<b>2,121.6</b>
Center Management and Operations	1,991.6	--	2,038.8	2,059.2	2,079.7	2,100.5	2,121.6
Center Institutional Capabilities	1,539.7	--	1,584.3	1,600.1	1,615.9	1,632.0	1,648.4
Center Programmatic Capabilities	451.8	--	454.5	459.1	463.8	468.5	473.2
<b>Agency Management and Operations</b>	<b>719.4</b>	<b>--</b>	<b>739.8</b>	<b>747.2</b>	<b>754.7</b>	<b>762.3</b>	<b>769.8</b>
Agency Management	372.3	--	365.6	369.3	373.0	376.7	380.3
<b>Safety and Mission Success</b>	<b>172.5</b>	<b>--</b>	<b>163.7</b>	<b>165.4</b>	<b>167.0</b>	<b>168.8</b>	<b>170.5</b>
Safety and Mission Assurance	46.3	--	46.4	46.9	47.4	47.9	48.4
Chief Engineer	84.5	--	83.7	84.5	85.3	86.2	87.1
Chief Health and Medical Officer	4.2	--	4.2	4.3	4.3	4.4	4.4
Independent Verification and Validation	37.5	39.1	29.4	29.7	30.0	30.3	30.6
<b>Agency IT Services</b>	<b>148.0</b>	<b>--</b>	<b>183.6</b>	<b>185.3</b>	<b>187.2</b>	<b>189.0</b>	<b>190.9</b>
IT Management	13.3	--	14.6	14.6	14.6	14.6	14.6
Applications	59.1	--	62.5	62.5	62.5	62.5	62.5
Infrastructure	75.5	--	106.5	108.2	110.1	111.9	113.8
<b>Strategic Capabilities Assets Program</b>	<b>26.6</b>	<b>--</b>	<b>26.9</b>	<b>27.2</b>	<b>27.5</b>	<b>27.8</b>	<b>28.1</b>
<b>Construction and Environmental Compliance and Restoration</b>	<b>646.6</b>	<b>515.0</b>	<b>446.1</b>	<b>379.0</b>	<b>382.7</b>	<b>386.6</b>	<b>390.4</b>
<b>Construction of Facilities</b>	<b>589.5</b>	<b>--</b>	<b>370.6</b>	<b>302.7</b>	<b>305.7</b>	<b>308.8</b>	<b>311.8</b>
Institutional CoF	313.1	--	299.7	302.7	305.7	308.8	311.8
Science CoF	3.0	--	--	--	--	--	--
Exploration CoF	252.6	--	52.3	--	--	--	--
Space Operations CoF	20.8	--	18.6	--	--	--	--
<b>Environmental Compliance and Restoration</b>	<b>57.0</b>	<b>--</b>	<b>75.5</b>	<b>76.3</b>	<b>77.0</b>	<b>77.8</b>	<b>78.6</b>
<b>Inspector General</b>	<b>35.3</b>	<b>37.5</b>	<b>37.0</b>	<b>37.4</b>	<b>37.7</b>	<b>38.1</b>	<b>38.5</b>
<b>NASA Total</b>	<b>16,865.2</b>	<b>17,646.5</b>	<b>17,460.6</b>	<b>17,635.3</b>	<b>17,811.5</b>	<b>17,989.7</b>	<b>18,169.7</b>

Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.

FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.

Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.

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## MESSAGE FROM THE ADMINISTRATOR

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For more than 50 years, NASA has been an important part of America's global leadership in innovation, exploration, technology, and discovery. Building on another year of milestones and successes, NASA's fiscal year 2015 budget will continue to provide the necessary resources to advance a common vision for space exploration and ensure that the United States remains the world's leader in aeronautics research, space exploration, and scientific discovery. NASA's work is critical to the advancement of national priorities in science, technology development, and job creation – the keys to a better tomorrow for our nation and for future generations.

With this budget, we will continue to advance our sustainable campaign of human space exploration, leading to an eventual human expedition to Mars. The International Space Station (ISS) is the cornerstone of this plan, providing a unique platform for NASA to learn how to live and work in space. This budget supports the extension of the ISS to at least 2024, allowing this important research to continue, while catalyzing commercial opportunities and scientific research that will directly benefit life on Earth.

Fundamental to our full utilization of the ISS is NASA's commitment to developing a vibrant American commercial space industry to provide transportation to and from U.S. soil to low Earth orbit. Our commercial cargo and crew investments have already resulted in two partners now successfully undertaking regular resupply missions to the ISS. Our private sector partners are making progress to the return of human spaceflight launches from the U.S. by 2017. The budget provides funding to move this essential work forward as NASA focuses on the farther horizons of exploration.

Under this budget, we will sustainably advance our capabilities to reach Mars by first exploring destinations in the Earth-moon system. To that end, this budget supports the continued development of NASA's Asteroid Redirect Mission designed to robotically encounter and redirect an asteroid into a stable orbit around the Moon. There it will be sampled by astronauts aboard NASA's next generation crew capsule, Orion, launched by NASA's heavy lift rocket, the Space Launch System. This mission will provide an early demonstration of the capabilities needed to operate in deep space, and directly extend our progress toward a human expedition to Mars.

This year we continue to build on our strong record of scientific discoveries. Missions will reach farther into the solar system, reveal unknown aspects of our universe, and provide critical knowledge about our home planet.

NASA aeronautics is implementing a new and compelling strategic vision that will help us address global challenges facing aviation in the coming decades. We are also focused on substantially reducing fuel consumption, emissions and noise and making the Next Generation Air Transportation System a reality.

NASA's request includes additional funds in the Opportunity, Growth, and Security Initiative, which invests in the nation's economic growth and job creation. The Initiative represents new funding to revive America's manufacturing prowess and prepare young people for the jobs of today and tomorrow. This funding will strengthen NASA's long-range plans to reach new destinations and develop new technologies.

NASA makes every effort to ensure that performance data are subject to the same attention to detail as is devoted to our scientific and technical research. With this in mind, I can provide reasonable assurance that the performance data included in the Annual Performance Report are reliable and complete. Any data limitations are documented in the performance report sections of this budget.

## **MESSAGE FROM THE ADMINISTRATOR**

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While reaching for new heights in air and space, we're helping fuel the nation's economy for years to come. The inspiration we provide, and the breakthroughs and discoveries we make, are moving us to a bright future with tangible benefits for our nation and people around the globe.

A handwritten signature in black ink, appearing to read 'C. Bolden', with a long, sweeping horizontal line extending to the right.

Charles F. Bolden, Jr.

NASA Administrator

## BUDGET HIGHLIGHTS

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The National Aeronautics and Space Act of 1958 challenged our Nation to grow our technical and scientific abilities in air and space. In support of the goals set forward in the Act, NASA helped to recharge the U.S. economy, by creating highly-skilled high-paying jobs in science, engineering, project management, and a host of specialized fields. NASA investments in research and development (R&D) enabled the creation of high quality goods and services across the country. Since the 1970s, numerous economic reports and articles have demonstrated that NASA investments helped grow the U.S. economy. Perhaps most importantly, in addition to direct support in terms of jobs and procurements, NASA-funded R&D helped stimulate our long-term capacity for innovation and economic growth within the government, at universities, and at industrial companies. And the disciplines were many – including new and composite materials, computing and electronics, fuels, radio communications, safety, and even human health.

In the FY 2015 President's Budget Request, NASA addresses the challenge of advancing U.S. leadership in space exploration, space and Earth science, and aeronautics in the current fiscal climate. In formulating this budget, projects and programs have been reviewed and their costs and benefits assessed to ensure the highest scientific return on the dollar. Funding profiles have been considered and streamlined. The potential contributions of partner agencies, nations, and industries were evaluated. In developing this budget, the Agency faced and made tough decisions to fully support its highest priority programs. Progress on attaining our highest priorities can continue in a productive, efficient, and safe manner only if other worthy, but less tightly aligned missions are deferred or suspended. This budget presents a balanced portfolio of NASA investments, but one focused on success for the long-term.

This budget advances the Nation's space exploration, technology development, and scientific research plans and maintains the U.S. posture as a world leader through the development of a next-generation deep space transportation system. It fosters the development of a commercial space industry that will expand the research use of the ISS. The budget ensures we continue to learn about and protect life on our home planet, Earth. It invests in R&D, technology development, and a scientific infrastructure that enables exploration today, tomorrow, and generations from now. Moreover, the FY 2015 budget continues to create jobs, demand highly-skilled services, and stimulates the U.S. economy.

In FY 2015, NASA continues to plan and refine the requirements for its first-of-a-kind mission to encounter and redirect an asteroid and visit it with astronauts. In support of this cross-agency activity, scientists, mission managers, technologists, and operations specialists are working on a multi-segment mission that will advance our deep space exploration capabilities as a step toward future human missions to Mars, and will improve the ability of our Nation and others to protect the planet from asteroid impacts. In the first segment, fundamental research conducted within the Science Mission Directorate is accelerating knowledge growth about near-Earth asteroids and will enable scientists to select an asteroid target for this mission.

This supports an Asteroid Grand Challenge to develop new partnerships and collaborations to accelerate NASA's existing planetary defense work, and the Asteroid Redirect Mission. The Asteroid Grand Challenge is to find all asteroid threats to human population and know what to do about them. Identified asteroids could also become candidate asteroids for the mission. The challenge is an effort to reach beyond traditional boundaries and encourage partnerships and collaboration with a variety of organizations to solve this global problem.

Within the second segment of the Asteroid Redirect Mission, NASA is planning a robotic mission to capture and redirect a near-Earth asteroid into a stable orbit around the Moon. Today's technology

## BUDGET HIGHLIGHTS

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development in advanced solar electric propulsion, as managed by the Space Technology Mission Directorate, will provide the spacecraft with sufficient energy and thrust so it is able to capture a small, non-threatening asteroid and redirect it. Designers of the mission spacecraft will also incorporate anticipated technological advances in lightweight materials, communication, data storage and transfer, and space navigation. In the third segment of the mission, NASA will employ the Orion Multi-Purpose Crew Vehicle (Orion) to send human crews deep into space to examine and collect samples from the redirected asteroid by 2025. More information about the technical aspects of the missions can be found in the Science, Space Technology, and Exploration account sections of this document.

The FY 2015 budget request fully supports the plan for crewed exploration of deep space. NASA is committed to the development of the Orion and remains on schedule and budget for advanced testing in 2014, an uncrewed Space Launch System (SLS)/Orion test flight in FY 2018, and a first crewed flight by FY 2021-2022. The outyear budget also fully supports to evolve the SLS development of heavy-lift rocket with capability to bring an unprecedented 130 metric tons of payload to orbit.

In January 2014, the President's Science Advisor announced plans to extend ISS operations to at least 2024. Doing so increases the Nation's ability to conduct fundamental and applied research necessary to developing spacecraft and human life support systems for deep space exploration. The ISS extension is made possible in large part because of the success of our commercial space partners in developing low-cost and highly-reliable systems for delivering supplies and equipment to the ISS. The burgeoning U.S. commercial space marketplace is already providing mission support, which lessens American reliance on foreign services, and creates highly-skilled jobs across the Nation.

This budget request strongly supports ISS research. Scientists and engineers will develop and execute experiments and technology demonstrations in diverse disciplines including physics, biology, materials science, robotics, communications, and human physiology. Insights gained from these studies will be essential for planning missions to Mars and to other points deeper in space. The Center for the Advancement of Science in Space (CASIS), the research management organization for the ISS National Laboratory, will continue to enable federal, academic, and commercial research activities. Exciting research will include potential medicines and interventions that will improve human health both in space and here on Earth.

This budget request continues to fund a strategic suite of missions about the Earth, sun, solar system, and deep space. Earth observations continue to allow unprecedented study of climate change and weather prediction. NASA investments in improved IT systems capable of managing "big data" will provide researchers with unparalleled access to data about the Earth. By fostering collective and collaborative research, the scientific insights gained from NASA missions will increase profoundly.

The James Webb Space Telescope (JWST) remains on track for launch in 2018. Once operational, scientists will be able to look farther out into space than ever before, gaining new insights to the formation and evolution of stars and galaxies. A robust planetary science program includes data analysis of ongoing missions, and development of the next Mars rover. NASA will also begin scoping a mission to Europa, Jupiter's icy moon which, data suggests, may have organic material on its surface.

NASA continues to minimize the barriers to human and robotic exploration of space by identifying and working solutions for both near and long-term needs. The Agency's investments in Space Technology in FY 2015 include demonstrations of maturing technologies, and novel "game-changing" basic and applied R&D that may eventually save time and costs while increasing scientific return on investment. Focus

## **BUDGET HIGHLIGHTS**

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areas in 2015 include solar electric propulsion, which is necessary for a deep space asteroid mission; cryogenic storage and transfer; laser communications; and human-robotic interfaces. NASA's Space Technology program also supports Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs. Through these competitive opportunities, NASA is able to draw on the innovation of small local engineering and technology companies. These programs are a "win-win" as NASA benefits from the creativity and flexibility of small teams, and the companies grow and may be able to "spin off" NASA-inspired technologies to new commercial markets.

The FY 2015 budget request for Aeronautics research reflects its focus on six strategic areas: safe, efficient growth in global operations; innovation in commercial supersonic aircraft; ultra-efficient commercial vehicles; transition to low-carbon propulsion; real-time, system-wide safety assurance; and assured autonomy for aviation transformation. Across its portfolio of aeronautics investments, NASA continues to develop and test solutions that strengthen the air travel and transportation industry while minimizing environmental impact.

NASA supports efforts to improve the quality and depth of teaching and education in science, technology, engineering, and mathematics (STEM). The Office of Education will continue to coordinate with the Department of Education, the National Science Foundation, and the Smithsonian Institution on STEM issues in order to maximize NASA's unique resources that support the reorganization initiative. NASA will continue to provide opportunities for students and educators to engage in activities that tie directly to NASA's science, technology, and engineering activities.

The FY 2015 budget makes efficient use of NASA's assets, including its workforce, equipment, and one-of-a-kind facilities. The budget also includes reinvigorated efforts to protect these assets, particularly from cyber threats. NASA continues to evaluate its current and future needs for existing facilities and invests in preventative repairs that will reduce future costs of refurbishment or replacement. The Agency is also proactively seeking means to reduce its operating costs. NASA is reducing its energy footprint, working with other agencies to share and leverage facilities usage, and using reimbursable agreements to support external customers who seek NASA's unique capabilities.

In its more than 50 years, NASA has advanced our technical knowledge and human abilities. Our engineers are now building spacecraft capable of carrying humans to another planet or a moving asteroid. What we now know about the stars would astound the earliest scientists who documented the seasonality of constellations, or those who later studied the heavens through simple lenses and prisms. In many respects, NASA has made science fiction a reality by investing in disciplines that may have seemed like fantasy in 1958 robotics, space habitats, analyzing the surface of Mars, and healing the sick through telemedicine. But in one important respect, NASA continues to do what it's always done. It serves as a stimulus to U.S. creativity and innovation, our competitiveness on the global stage, and economic growth that benefits all Americans.

## **BUDGET HIGHLIGHTS**

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### **SCIENCE IS ANSWERING ENDURING QUESTIONS IN, FROM, AND ABOUT SPACE**

NASA's Science account funds exploration of our planet, other planets and planetary bodies, our star system in its entirety, and funds observations out into our galaxy and beyond. Through the development of space observatories and probes that enable exploration and discovery, NASA will continue to inspire the next generation of scientists, engineers, and explorers. The FY 2015 budget request for Science is \$4,972 million.

JWST, a successor to the Hubble telescope is on schedule for a 2018 launch. JWST will be 100 times more capable than Hubble, becoming the premier astronomical observatory of the next decade. The request also funds ongoing study of a possible WFIRST/AFTA mission, the next major observatory beyond JWST, for a potential start of formulation activities later this decade. Other astrophysics missions in formulation and development include the Astro-H Soft X-Ray Spectrometer, and the TESS and NICER Explorer missions selected in 2013.

NASA continues to learn more about Earth. The launch and operation of Global Precipitation Measurement (GPM) will advance our understanding of Earth's water and energy cycles and improve the forecasting of extreme events that cause natural disasters. The Orbiting Carbon Observatory-2 (OCO-2) mission will collect global measurements of atmospheric CO<sub>2</sub> with the precision to characterize the distribution of CO<sub>2</sub> and is essential to improving predictions and potential impacts on the climate. The request also fully funds Soil Moisture Active-Passive (SMAP); Ice, Cloud, and land Elevation Satellite (ICESat-II); Gravity Recovery and Climate Experiment (GRACE-FO); and several other future Earth Science missions.

The Mars Atmosphere and Volatile Evolution (MAVEN) mission will go into orbit around Mars on Sept. 21, 2014. MAVEN will determine the role that escape of gas from the atmosphere to space has played in changing the climate throughout the planet's history. InSight and Mars 2020 are future Mars lander missions, and the OSIRIS-REx spacecraft will travel to a near-Earth asteroid in 2018 and be the first U.S. mission to carry samples from an asteroid back to Earth. The request funds continued study of a potential future mission to Jupiter's moon Europa.

The request fully funds several major missions to advance our understanding of the Sun and its impact on the Earth, including Magnetospheric Multiscale, Solar Probe Plus, and Solar Orbiter Collaboration. The request also funds the ICON and GOLD Explorer missions selected in 2013.

### **AERONAUTICS RESEARCH TO ADDRESS AVIATION'S CHALLENGES**

NASA conducts aeronautics research to bring transformational advances in the safety, capacity, and efficiency of the air transportation system while minimizing negative impacts on the environment. The FY 2015 budget request for the Aeronautics account is \$551.1 million.

The air transportation system of today is an integral part of the US and Global economies. It is the primary mechanism for connecting countries across the world, not only through mobility of populations, but also through mobility of goods and services. NASA Aeronautics guides its research efforts using a strategic vision that embraces the multiple roles of aviation and expands the understanding of those roles to the global stage, while working to address tomorrow's challenges. NASA develops cutting-edge technologies and demonstrates their feasibility to enable revolutionary new vehicle performance, dramatically more efficient operations, and assured safety levels for the nation's air transportation. These



## **BUDGET HIGHLIGHTS**

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technologies will expand airspace capacity with more fuel-efficient flight planning, diminish delays on the ground and in the sky, reduce fuel consumption, reduce the overall environmental footprint of aviation, and continue to improve safety.

NASA recently developed a new and compelling strategic vision for the Aeronautics Research programs. To reach this vision, the Aeronautics research has been aligned to focus on newly defined strategic thrust areas. These areas were identified to be responsive to a growing demand for mobility, severe challenges to sustainability of energy and the environment, and technology advances in information, communications, and automation technologies.

### **SPACE TECHNOLOGY DELIVERS INNOVATION**

Space Technology conducts rapid development and incorporation of transformative space technologies that enable NASA's missions, of human exploration and space science and improve technological capabilities for NASA and the Nation. The FY 2015 budget request for Space Technology is \$705.5 million.

NASA prepares for future technology needs by maturing new technologies and capabilities. Significant progress in technology areas such as high-power solar electric propulsion, life support and resource utilization, entry, descent, and landing, space robotic systems, optical communications and navigation, lightweight structures, and instruments for space observatories, are essential for future science and human exploration missions. They also will enable other government agencies and private industry to carry out more capable and affordable missions and help to open up the space frontier.

In FY 2013, Space Technology funded more than 400 research and development activities with U.S. academic institutions engaging the Nation's brightest minds to solve some of the most difficult technological challenges. This year will bring completion of the Composite Cryogenic Propellant Tank project by scaling up the successful prototype (completed in FY 2013) to test and validate a full-scale 5.5-meter diameter tank, which will significantly reduce the structural mass of future launch vehicles and consequently dramatically increase their payload mass to orbit. In FY 2015, Space Technology will continue development of a high-powered solar electric propulsion system that will enable orbit transfer and accommodate increasing power demands for satellites, and power the robotic segment of the asteroid redirect mission. In addition, Space Technology will execute seven launches in 24 months including: deep space atomic clock for advanced navigation, green propellant and four small spacecraft demos of pioneering new technologies. Finally, this funding supports a high-altitude, supersonic demonstration of advanced parachutes and inflatable entry, descent and landing technologies that will offer at least three times improvement in landed mass at Mars over Curiosity, and offer a pathway to landed masses as high as 15 metric tons for human missions.

The programs within Space Technology develop and demonstrate near term and far reaching technological solutions as well as enhancements that increase capability and reduce technological risk, making space activities more affordable and reliable. Space Technology drives the cadence of new technology starts to be conducted by the NASA workforce, academia, small businesses, and the aerospace enterprise, to ensure a steady pipeline of innovation by engaging the Nation's brightest minds. As efforts complete, appropriate technologies will be transferred and commercialized to benefit a wide range of users to ensure the full economic value and societal benefit of these innovations is realized. NASA contributes to the demands of larger national technology goals by investing in Space Technology.

## **BUDGET HIGHLIGHTS**

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### **EXPANDING HUMAN EXPLORATION OF THE SOLAR SYSTEM**

The work of NASA ensures the United States remains the leader in the human exploration of space. The Exploration account develops systems and capabilities required for deep space exploration and ensures reliable and cost-effective crew access to low Earth orbit by U.S. commercial providers. The FY 2015 budget request for Exploration is \$3,976.0 million.

The Exploration account invests in crew transportation to and beyond Earth orbit; research and countermeasures aimed at maintaining astronaut health and function during long-term missions; and technologies to advance capabilities and minimize the cost of crewed deep space missions. In FY 2015, the program will focus on preparing for the first Exploration Mission – an uncrewed test flight to lunar orbit, which will be the first pairing of the Orion crew vehicle with the Space Launch System. The multi-day flight will validate spacecraft design and operations.

The Agency will continue fabrication of a next-generation spacesuit, which includes a more flexible, lightweight design, powered by an advanced battery system. In the Commercial Crew program, NASA's commercial partners will continue development efforts towards flights in 2017 by performing risk reduction and technical readiness testing. In addition, the Agency will continue to transition industry partners from Space Act Agreements to fixed-price, milestone based contracts to support the next phase of commercial crew transportation systems.

### **LIVING AND WORKING IN SPACE**

Space Operations funds critical NASA capabilities that create pathways for discovery and human exploration of space. These capabilities include research on and operation of the International Space Station, affordable and reliable launches of NASA science missions, and critical communication links to crewed and robotic spacecraft. In addition to supporting NASA's activities, Space Operations also provides a platform for research and space transportation for non-NASA users. The FY 2015 budget request for Space Operations is \$3,905.4 million.

In the Space Operations account, NASA will also mature capture mechanisms to redirect uncooperative targets and planning for an asteroid redirect mission. Activities will provide dependable communications for human and science missions, including download of science data, and provide expertise and oversight for successful launch of NASA science spacecraft. The account also maintains the facilities and expertise needed for testing critical propulsion components for the SLS, NASA's commercial partners, and other Government customers.

### **NASA'S UNIQUE ASSETS MADE AVAILABLE TO SUPPORT THE NATION'S STEM EFFORTS**

Investments in NASA's Education account advance high-quality STEM education using NASA's unique capabilities. NASA's expertise and resources are key contributions towards shaping the Nation's STEM education portfolio. In support of the Administration's Five-Year Federal Strategic Plan on STEM Education, NASA will fundamentally reorganize the Agency's education program funded through the Office of Education (OE). OE will coordinate closely with other Federal agencies in pursuit of the Administration's STEM education goals. The FY 2015 budget request for Education is \$88.9 million.

## **BUDGET HIGHLIGHTS**

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Additionally, the budget provides \$15 million to NASA's Science Mission Directorate to fund the best application of NASA Science assets to meet the Nation's STEM education goals.

NASA will organize the education functions, assets and efforts of the Aeronautics Research Mission Directorate, Science Mission Directorate, Human Exploration and Operations Mission Directorate, and NASA Field Centers into a single coordinated STEM Education and Accountability Project. This project will fund, on a competitive basis, the best education and public outreach efforts throughout the agency. In addition, NASA's education investments within the National Space Grant and Fellowship Program (Space Grant), Experimental Program to Stimulate Competitive Research (EPSCoR), and Minority University Research and Education Project (MUREP), are critical and unique components that NASA can integrate into STEM coordination efforts with other agencies.

NASA will build on its past year's efforts by making its assets available to the five priority STEM education investment areas in support of a coordinated Federal strategy. NASA will continue its inter-agency coordination and collaboration through lead agencies (National Science Foundation, Smithsonian Institution and Department of Education) responsible for convening other CoSTEM agencies. NASA will capitalize on the excitement of the Agency's mission to stimulate innovative solutions, approaches, and tools that inspire learner and educator interest and proficiency in STEM disciplines.

### **EXCELLENCE IN OPERATIONS FOR MISSION SUCCESS**

NASA's Cross Agency Support account funds the essential day-to-day technical and business operations required to conduct NASA's aeronautics and space activities. These mission support activities provide the proper services, tools, and equipment to complete essential tasks, protect and maintain the security and integrity of information and assets, and ensure that personnel work under safe and healthy conditions. Planning, operating, and sustaining this infrastructure and our essential services requires a number of critical institutional capabilities including management of: human capital; finance; information technology; infrastructure; acquisitions; security; real and personal property; occupational health and safety; equal employment opportunity and diversity; small business programs; external relations; strategic internal and external communications; stakeholder engagement; and other essential corporate functions. In FY 2015 NASA will continue to provide strategic and operational planning and management over a wide range of functions and services to ensure that resources are available when needed, and they help NASA operate in a more efficient and sustainable manner. The FY 2015 budget request for Cross Agency Support is \$2,778.6 million.

Work conducted through the Construction and Environmental Compliance and Restoration account will continue to manage the Agency's facilities with a focus on reducing infrastructure, implementing efficiency and high performance upgrades, and prioritizing repairs to achieve the greatest return on investment. In FY 2015, NASA continues to consolidate facilities to achieve greater operational efficiency, replacing old, obsolete, costly facilities with fewer, high performance facilities. Institutional construction projects such as the Construction of the Human Health and Performance Laboratory at Johnson Space Center will replace deficient and obsolete facilities and correct deficiencies to support core capabilities within a smaller, more efficient footprint. Programmatic construction of facilities projects, such as the Modifications to Launch Complex 39-B at Kennedy Space Center, provide the specialized technical facilities required by the missions. NASA will decommission and continue preparations to dispose of property and equipment no longer needed for missions. To protect human health and the environment, and to preserve natural resources for future missions, environmental compliance and

## **BUDGET HIGHLIGHTS**

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restoration projects will clean up pollutants released into the environment during past NASA activities. The FY 2015 request for Construction and Environmental Compliance and Restoration is \$446.1 million.

## NOTES ON THE BUDGET

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### OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

The Bipartisan Budget Act of 2013 (BBA) replaced half the sequestration cut for 2014 and one fifth of the scheduled discretionary funding reductions for 2015. As a result, the BBA non-defense discretionary funding levels for 2015 are below the levels Congress provided in the bipartisan Consolidated Appropriations Act of 2014. They are also below the 2007 funding levels adjusted for inflation. For that reason, the Budget includes a separate, fully paid for \$56 billion Opportunity, Growth, and Security Initiative (OGSI), which is evenly split between defense and non-defense funding. The proposed allocation to NASA is \$885.5 million.

At NASA, the Opportunity, Growth, and Security Initiative will support multiple programs, notably Commercial Crew, SLS/Orion, and transportation to and from the ISS. Further detail can be found in the specific OGSI section of this budget.

### NASA'S WORKFORCE

NASA's workforce continues to be one of its greatest assets for enabling missions in space and on Earth. The Agency remains committed to applying this asset to benefit society, address contemporary environmental and social issues, lead or participate in emerging technology opportunities, collaborate and strengthen the capabilities of commercial partners, and communicate the challenges and results of Agency programs and activities. The civil service staffing levels proposed in the FY 2015 budget support NASA's scientists, engineers, researchers, managers, technicians, and business operations workforce. It includes civil service personnel at NASA Centers, Headquarters, and NASA-operated facilities. The mix of skills and distribution of workforce across the Agency is, however, necessarily changing.

NASA continues to adjust its workforce size and mix of skills to address changing mission priorities, with an emphasis on industry and academic partnerships, transferring work in-house from on and near site support contracts, and a leaner fiscal environment. A civil service workforce is critical for conducting mission-essential work in research and technology. As NASA continues to seek to have the right workforce to meet its requirements, some reduction to workforce levels is necessary. NASA will reduce the size of the civil service workforce by more than 300 full-time equivalents from FY 2014 to FY 2015, bringing the civil service workforce to approximately 17,400 full-time equivalents.

NASA will continue to explore opportunities across the Agency to insource work. The Agency will apply the valued civil service workforce to priority mission work, adjusting the mix of skills where appropriate. Centers will explore cross-mission retraining opportunities for employees whenever possible, offer targeted buyouts in selected surplus skill areas, and continue to identify, recruit, and retain a multi-generational workforce of employees who possess skills critical to the Agency.

### OPERATING EFFICIENTLY AND CUTTING WASTE

NASA continues to pursue cost savings throughout its operations. Savings targets comply with Executive Order 13576, *Delivering an Efficient, Effective and Accountable Government*, Executive Order 13589, *Promoting Efficient Spending*, and Office of Management and Budget Memorandum M-12-12 *Promoting Efficient Spending to Support Agency Operations*.

## **NOTES ON THE BUDGET**

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### **Data Center Consolidation**

The FY 2015 budget request keeps NASA on schedule to complete consolidation of the 79 NASA data centers down to 22 more cost efficient data centers by the end of FY 2015. NASA has reduced energy costs through more efficient use of existing conditioned spaces, employing best practices in room design, proper temperature settings, optimal rack and floor space densities, and lifecycle replacement of old and inefficient hardware.

### **Investing to Improve Efficiency and Reduce Utility Costs**

NASA has been working to reduce costs of energy, water, and other utilities. To reduce the energy burden, NASA is pursuing “green” building designs and renovations that make better use of natural light and temperatures, and replacing old and inefficient equipment with models that require less energy. NASA will also improve the operating efficiency of buildings by investing in projects that reduce energy consumption and cost. Installation of a chilled water thermal energy storage system at Kennedy Space Center will reduce energy costs by generating and storing chilled water during off-peak electricity rate hours for use during more expensive peak hours. At Marshall Space Flight Center, installation of a solar photovoltaic system will provide a renewable source of energy to reduce reliance on conventional electricity.

### **Right-Sizing Infrastructure**

The FY 2015 budget request includes funding to reduce the Agency’s footprint by replacing multiple aging, inefficient facilities with facilities that meet government Leadership in Energy and Environmental Design (LEED), standards. These projects support NASA’s core capabilities within a smaller, more efficient footprint. Projects include replacement of old, obsolete, and costly facilities with new, high performance facilities that consolidate core functions and improve flexibility over the life of the facilities. These replacement facilities incorporate new technologies and are designed with flexibility so they can address programmatic requirements, both known and still evolving over the next 40 years. NASA’s demolition program eliminates obsolete, un-needed infrastructure to improve efficiency and eliminate safety and environmental risks.

## **DELIVERING A 21<sup>ST</sup> CENTURY GOVERNMENT**

### **Assessing Performance**

The Agency continually evaluates progress against targets as programs and projects execute the performance plan. NASA leverages an internal performance assessment process to collect objective evidence of Agency performance. NASA’s work revolves around the creation of one-of-a-kind missions, a relatively large portion of the Agency’s research and development activities involve high-risk, high-reward research and development. Evaluating evidence of progress on R&D or R&T (research and technology), or predicting when you are going to discover an unknown, or invent a new capability is why NASA continually monitors its activities--to know when we can advance or need to change course. A complete overview of NASA’s performance assessment process, updated performance goals for FY 2015, and the FY 2013 Annual Performance Report can be found in the Management and Performance section of this document.

## NOTES ON THE BUDGET

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### **Finding New Ways to Do Business**

NASA is leveraging more public-private partnerships and harnessing the ingenuity of the American people to accomplish our work. We have spent nearly 50 years mastering the science and art of getting to low Earth orbit. We have done the research, proven the technologies, and put the infrastructure in place. Now, we are ready to employ the capabilities of emerging U.S. commercial partners who can provide cargo and crew services. Transferring low Earth orbit access to commercial providers allows us to focus our resources on pursuing the next frontier: mastering access to deep space. In addition, we are expanding our partnerships outside the traditional aerospace industry to share knowledge and expertise in areas such as manufacturing, information technology, and resource management. Also, recognizing the value of the American public as a strategic partner in addressing some of the country's most pressing challenges, NASA relies on the expertise, ingenuity, and creativity of the American public by enabling, accelerating, and scaling the use of open innovation methods including prizes, challenges, crowdsourcing, and citizen science across NASA.

### **Investing in Cutting-Edge Technologies**

As we prepare for the proposed missions to an asteroid and then to Mars, we are entering an exciting time in which we will push the very boundaries of research and technology development. We are implementing a new space technology development and test program with partners from industry, academia, and other nations. This program will facilitate our objectives of building, flying, and testing new technologies that have the potential to increase capabilities, decrease costs, and expand opportunities for future space activities.

### **Increasing Sustainability, Accountability, and Transparency**

We must invest wisely to ensure sustainable and reliable support for NASA's missions. This means careful management of our infrastructure and workforce. It may also require accepting higher risk on some mission activities. While we strive for sustainability, we must maintain our commitment to the American public to be responsible stewards of the resources entrusted to us. We are sharing our data, our successes, and our setbacks with the public at an unprecedented level. Through our transparency, we want the Nation to understand both why and how our challenging work will create a brighter future.

### **Strengthening Cyber Security**

In FY 2015, NASA will increase investments in cyber security. These investments will address continued implementation of a Continuous Diagnostic Mitigation and Information Security Continuous Monitoring strategy as well as the Administration's Cross-Agency Priorities goals, including continuous monitoring, providing trusted Internet connections, and requiring strong authentication. The Agency will also implement specific improvements as recommended by NASA's Office of Inspector General. The planned work will correct high-risk deficiencies and vulnerabilities, restore aging and inefficient infrastructure, and promote proactive and preventative practices.

### **Using Big Data to Understand Climate**

The FY 2015 budget includes support for the interagency Big Earth Data Initiative, which will improve coordination and management of Federal Earth system observations, data, and information. NASA will develop and implement an agency-wide framework for managing and curating data. NASA will also prioritize data sets to be treated, and a plan for completing this work, with the goal of 100 percent compliance of all agency data sets by the end of 2016. NASA's data sets will be used by Federal

## **NOTES ON THE BUDGET**

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scientists, academia, and the private sector to study and develop solutions for challenges in climate resilience, water sustainability, landscape-level management of lands and resources, understanding and valuing ecosystem services, and green infrastructure.



## **EXPLANATION OF BUDGET TABLES AND SCHEDULES**

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NASA presents the FY 2015 budget request in full-cost, where all project costs are allocated to the project, including labor funding for the Agency's civil service workforce. Note that budget figures in tables may not add because of rounding.

### **OUTYEAR FUNDING ASSUMPTIONS**

At this time, funding lines beyond FY 2015 should be considered notional. NASA accounts are inflated by 1 percent from the FY 2015 level, adjusted for the amounts transferred from programmatic accounts to the construction account in FY 2015.

### **EXPLANATION OF FY 2013 AND FY 2014 BUDGET COLUMNS**

#### **FY 2013 Column**

The FY 2013 Actual column in budget tables is consistent with the Agency spending plan (e.g. operating plan) control figures at the time of the budget release. Budget structure and figures are adjusted for comparability to the FY 2015 request. See note below.

All FY 2013 budget figures represent appropriations per the Commerce, Justice, Science, and Related Agencies Appropriations Act, 2013 (P.L. 113-6), adjusted for rescissions as specified in Division G., Section 2001(b)(1)(B) and Division G, Section 3004(c)(1). NASA also applied both rescission and Balanced Budget Emergency Deficit Control Act of 1985 (BBEDCA) or "sequester" reductions. These figures are also adjusted to include Congressionally-approved transfers and are consistent with the final operating plan levels for FY 2103.

Some FY 2013 budget columns are adjusted further to include:

- The supplemental appropriation to the Construction and Environmental Compliance and Restoration (CECR) account provided by the Disaster Relief Appropriations Act, 2013 (P.L. 113-2) for Superstorm Sandy. The net \$14.25 million increase reflects sequester reductions to the \$15.0 million appropriation;
- Rescission of remaining unobligated balances of American Recovery and Reinvestment Act funds in the Office of Inspector General account pursuant to section 1306 of the Dodd-Frank Wall Street Reform and Consumer Protection Act (P.L. 111-203); and
- A net \$1.0 million rescission to the Space Operations account. This results because the FY 2012 rescission of prior year was applied to the Space Operations account in FY 2013. The adjustment was made because it was not clear whether the prior year appropriations account had sufficient balances to cancel.

#### **FY 2014 Column**

The FY 2014 Enacted column in budget tables displays appropriations enacted through the Consolidated Appropriations Act, 2014 (P.L. 113-76). As of budget release, an initial FY 2014 operating plan has not been submitted to or approved by Congress. As a result, budget tables show only accounts, themes, or projects where appropriations are called out in P.L. 113-76 or in the Conference Report. Budget structures and figures are adjusted for comparability to the FY 2015 budget structure. See note below.

## **EXPLANATION OF BUDGET TABLES AND SCHEDULES**

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### **Comparability Adjustments**

Within the FY 2013 Actual and FY 2014 Enacted columns, budget figures have been adjusted to enable consistent programmatic comparisons to the FY 2015 budget request. These so-called comparability adjustments reflect movement of projects or activities and associated funding between programs, themes, or account and align to the structure of the FY 2015 budget request. This approach is essential to enabling year-to-year budget analysis. The Supporting Data section of the budget request includes a detailed crosswalk of non-comparable FY 2013 and FY 2014 budget figures and comparability adjustments to align to the FY 2015 budget structure.

Major comparability adjustments presented this year include:

- Restructuring of the Aeronautics Research Mission Directorate;
- Movement of a project and associated dollars from an independently reported “in development” budget line to an “Other Missions and Data Analysis” budget line. This typically reflects movement of mission into the “operations” stage after successful launch;
- Movement of a project and associated dollars from “pre-formulation” in “Other Missions and Data Analysis” or other R&A program to an independently reportable item; and/or
- Recast of an independent budget line to “Other Missions and Data Analysis” due to project termination.

### **Opportunity, Growth, and Security Initiative**

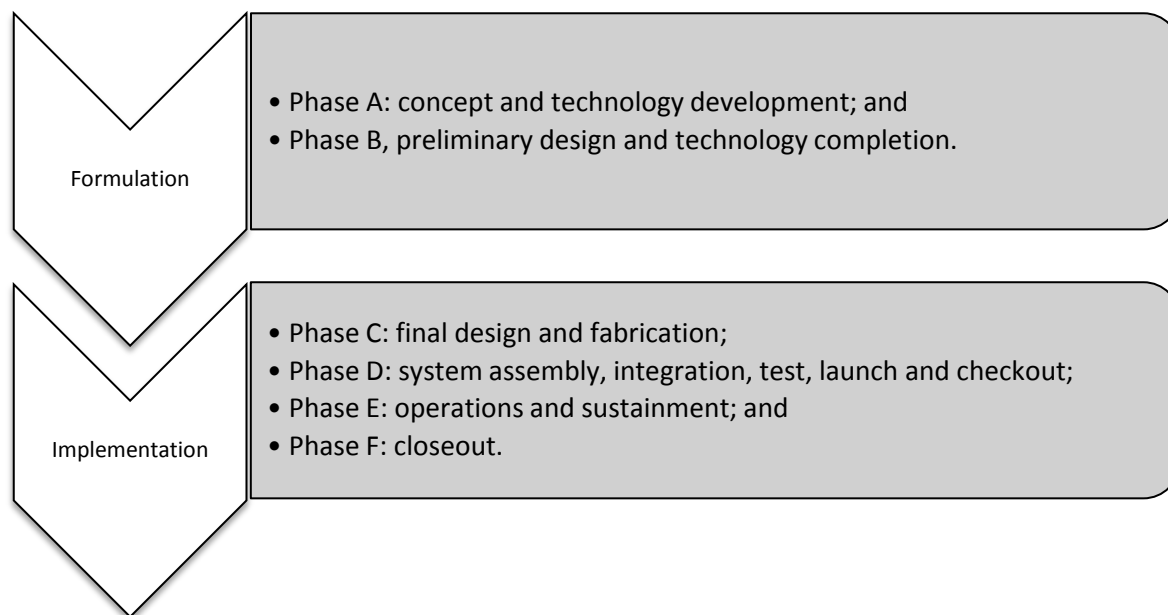
The Opportunity, Growth, and Security Initiative and its projects are presented in a separate budget table. Authority requested in support of this initiative is not included in agency, account, theme, program, project, or activity level budget tables.

## EXPLANATION OF BUDGET TABLES AND SCHEDULES

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### EXPLANATION OF PROJECT SCHEDULE COMMITMENTS AND KEY MILESTONES

Programs and projects follow their appropriate life cycle. The life cycle is divided into phases. Transition from one phase to another requires management approval at Key Decision Points (KDPs). The phases in program and project life cycles include one or more life-cycle reviews, which are considered major milestone events.



A life-cycle review is designed to provide the program or project with an opportunity to ensure that it has completed the work of that phase and an independent assessment of a program's or project's technical and programmatic status and health. The final life-cycle review in a given life-cycle phase provides essential information for the KDP that marks the end of that life-cycle phase and transition to the next phase if successfully passed. As such, KDPs serve as gates through which programs and projects must pass to continue.

The KDP decision to authorize a program or project's transition to the next life-cycle phase is based on a number of factors, including technical maturity; continued relevance to Agency strategic goals; adequacy of cost and schedule estimates; associated probabilities of meeting those estimates (confidence levels); continued affordability with respect to the Agency's resources; maturity and the readiness to proceed to the next phase; and remaining program or project risk (safety, cost, schedule, technical, management, and programmatic). At the KDP, the key program or project cost, schedule, and content parameters that govern the remaining life-cycle activities are established.

For reference, a description of schedule commitments and milestones is listed below for projects in Formulation and Implementation. A list of common terms used in mission planning is also included.

#### Formulation

NASA places significant emphasis on project Formulation to ensure adequate preparation of project concepts and plans and mitigation of high-risk aspects of the project essential to position the project for the highest probability of mission success. During Formulation, the project explores the full range of

## EXPLANATION OF BUDGET TABLES AND SCHEDULES

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implementation options, defines an affordable project concept to meet requirements, and develops needed technologies. The activities in these phases include developing the system architecture; completing mission and preliminary system designs; acquisition planning; conducting safety, technical, cost, and schedule risk trades; developing time-phased cost and schedule estimates and documenting the basis of these estimates; and preparing the Project Plan for Implementation.

<b>Formulation Milestone</b>	<b>Explanation</b>
KDP-A	<p>The lifecycle gate at which the decision authority determines the readiness of a program or project to transition into Phase A and authorizes Formulation of the project. Phase A is the first phase of Formulation and means that:</p> <ul style="list-style-type: none"> <li>• The project addresses a critical NASA need;</li> <li>• The proposed mission concept(s) is feasible;</li> <li>• The associated planning is sufficiently mature to begin activities defined for formulation; and</li> <li>• The mission can likely be achieved as conceived.</li> </ul>
System Requirements Review (SRR)	The lifecycle review in which the decision authority evaluates whether the functional and performance requirements defined for the system are responsive to the program's requirements on the project and represent achievable capabilities
System Definition Review or Mission Definition Review	The lifecycle review in which the decision authority evaluates the credibility and responsiveness of the proposed mission/system architecture to the program requirements and constraints on the project, including available resources, and determines whether the maturity of the project's mission/system definition and associated plans are sufficient to begin the next phase, Phase B.
KDP-B	<p>The lifecycle gate at which the decision authority determines the readiness of a program or project to transition from Phase A to Phase B. Phase B is the second phase of Formulation and means that:</p> <ul style="list-style-type: none"> <li>• The proposed mission/system architecture is credible and responsive to program requirements and constraints, including resources;</li> <li>• The maturity of the project's mission/system definition and associated plans is sufficient to begin Phase B; and</li> <li>• The mission can likely be achieved within available resources with acceptable risk.</li> </ul>
Preliminary Design Review (PDR)	The lifecycle review in which the decision authority evaluates the completeness/consistency of the planning, technical, cost, and schedule baselines developed during Formulation. This review also assesses compliance of the preliminary design with applicable requirements and determines if the project is sufficiently mature to begin Phase C.

## EXPLANATION OF BUDGET TABLES AND SCHEDULES

### Implementation

Implementation occurs when Agency management establishes baseline cost and schedule commitments for projects at KDP-C. The projects maintain the baseline commitment through the end of the mission. Projects are baselined for cost, schedule, and programmatic and technical parameters. Under Implementation, projects are able to execute approved plans development and operations.

Implementation Milestone	Explanation
KDP-C	<p>The lifecycle gate at which the decision authority determines the readiness of a program or project to begin the first stage of development and transition to Phase C and authorizes the Implementation of the project. Phase C is first stage of development and means that:</p> <ul style="list-style-type: none"> <li>• The project's planning, technical, cost, and schedule baselines developed during Formulation are complete and consistent;</li> <li>• The preliminary design complies with mission requirements;</li> <li>• The project is sufficiently mature to begin Phase C; and</li> <li>• The cost and schedule are adequate to enable mission success with acceptable risk.</li> </ul>
Critical Design Review (CDR)	The lifecycle review in which the decision authority evaluates the integrity of the project design and its ability to meet mission requirements with appropriate margins and acceptable risk within defined project constraints, including available resources. This review also determines if the design is appropriately mature to continue with the final design and fabrication phase.
System Integration Review (SIR)	The lifecycle review in which the decision authority evaluates the readiness of the project and associated supporting infrastructure to begin system assembly, integration, and test. The lifecycle review also evaluates whether the remaining project development can be completed within available resources, and determine if the project is sufficiently mature to begin Phase D.
KDP-D	<p>The lifecycle gate at which the decision authority determines the readiness of a project to continue in Implementation and transition from Phase C to Phase D. Phase D is a second phase in Implementation; the project continues in development and means that:</p> <ul style="list-style-type: none"> <li>• The project is still on plan;</li> <li>• The risk is commensurate with the project's payload classification; and</li> <li>• The project is ready for assembly, integration and test with acceptable risk within its Agency baseline commitment.</li> </ul>
Launch Readiness Date (LRD)	The date at which the project and its ground, hardware, and software systems are ready for launch.

### Other Common Terms for Mission Planning

Term	Definition
Decision Authority	The individual authorized by the Agency to make important decisions on programs and projects under their authority.
Formulation Authorization Document	The document that authorizes the formulation of a program whose goals will fulfill part of the Agency's Strategic Plan and Mission Directorate strategies. This document establishes the expectations and constraints for activity in the Formulation phase.
Key Decision Point (KDP)	The lifecycle gate at which the decision authority determines the readiness of a program or project to progress to the next phase of the life cycle. The KDP also establishes the content, cost, and schedule commitments for the ensuing phase(s).

## EXPLANATION OF BUDGET TABLES AND SCHEDULES

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Launch Manifest	This list that NASA publishes (the “NASA Flight Planning Board launch manifest”) periodically, which includes the expected launch dates for NASA missions. The launch dates in the manifest are the desired launch dates approved by the NASA Flight Planning Board, and are not typically the same as the Agency Baseline Commitment schedule dates. A launch manifest is a dynamic schedule that is affected by real world operational activities conducted by NASA and multiple other entities. It reflects the results of a complex process that requires the coordination and cooperation by multiple users for the use of launch range and launch contractor assets. Moreover, the launch dates are a mixture of “confirmed” range dates for missions launching within approximately six months, and contractual/planning dates for the missions beyond six months from launch. The NASA Flight Planning Board launch manifest date is typically earlier than the Agency Baseline Commitment schedule date to allow for the operationally driven delays to the launch schedule that may be outside of the project’s control.
Operational Readiness Review	The lifecycle review in which the decision authority evaluates the readiness of the project, including its ground systems, personnel, procedures, and user documentation, to operate the flight system and associated ground system(s), in compliance with defined project requirements and constraints during the operations phase.
Mission Readiness Review or Flight Readiness Review (FRR)	The lifecycle review in which the decision authority evaluates the readiness of the project, ground systems, personnel and procedures for a safe and successful launch and flight/mission.
KDP-E	The lifecycle gate at which the decision authority determines the readiness of a project to continue in Implementation and transition from Phase D to Phase E. Phase E is a third phase in Implementation and means that the project and all supporting systems are ready for safe, successful launch and early operations with acceptable risk.
Decommissioning Review	The lifecycle review in which the decision authority evaluates the readiness of the project to conduct closeout activities. The review includes final delivery of all remaining project deliverables and safe decommissioning of space flight systems and other project assets.
KDP-F	The lifecycle gate at which the decision authority determines the readiness of the project’s decommissioning. Passage through this gate means the project has met its program objectives and is ready for safe decommissioning of its assets and closeout of activities. Scientific data analysis may continue after this period.

For further details, go to:

- NASA Procedural Requirement 7102.5E NASA Space Flight Program and Project Management Requirements: <http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=7120&s=5E>
- NASA Procedural Requirement NPR 7123.1B - NASA Systems Engineering Processes and Requirements: [http://nodis3.gsfc.nasa.gov/npg\\_img/N\\_PR\\_7123\\_001B/\\_N\\_PR\\_7123\\_001B\\_.pdf](http://nodis3.gsfc.nasa.gov/npg_img/N_PR_7123_001B/_N_PR_7123_001B_.pdf)
- NASA Launch Services Web site: [http://www.nasa.gov/directorates/heo/launch\\_services/index.html](http://www.nasa.gov/directorates/heo/launch_services/index.html)

# SCIENCE

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
				FY 2017	FY 2018	FY 2019	
Earth Science	1659.2	1826.0	<b>1770.3</b>	1815.5	1837.6	1861.9	1886.3
Planetary Science	1274.6	1345.0	<b>1280.3</b>	1304.9	1337.1	1355.7	1374.1
Astrophysics	617.0	668.0	<b>607.3</b>	633.7	651.2	696.8	933.0
James Webb Space Telescope	627.6	658.2	<b>645.4</b>	620.0	569.4	534.9	305.0
Heliophysics	603.2	654.0	<b>668.9</b>	647.6	676.6	673.3	675.5
<b>Total Budget</b>	<b>4781.6</b>	<b>5151.2</b>	<b>4972.0</b>	<b>5021.7</b>	<b>5071.9</b>	<b>5122.6</b>	<b>5173.9</b>

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GRACE Follow-On .....	ES-29
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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Earth Science	1659.2	1826.0	<b>1770.3</b>	1815.5	1837.6	1861.9	1886.3
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Heliophysics	603.2	654.0	<b>668.9</b>	647.6	676.6	673.3	675.5
<b>Total Budget</b>	<b>4781.6</b>	<b>5151.2</b>	<b>4972.0</b>	<b>5021.7</b>	<b>5071.9</b>	<b>5122.6</b>	<b>5173.9</b>
Change from FY 2014			<b>-179.2</b>				
Percentage change from FY 2014			<b>-3.5%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA's Science Mission Directorate conducts scientific exploration enabled by observatories and probes that view Earth from space, observe and visit other bodies in the solar system, and gaze out into the galaxy and beyond. NASA's science programs deliver answers to profound questions, such as:

- How and why are Earth's climate and the environment changing?
- How does the Sun vary; and how does it affect Earth and the rest of the solar system?
- How do planets and life originate?
- How does the universe work, and what are its origin and destiny?
- Are we alone?

NASA science programs address the need to understand our place in the Universe, and provide information to policy makers who

address issues affecting all life on the planet. NASA is also working to improve its operations and is increasingly launching its science missions on schedule and on budget. Our discoveries continue to rewrite textbooks; inspire children to pursue careers in science, technology, education, and mathematics (STEM); and demonstrate US leadership worldwide.

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NASA uses the recommendations of the National Academies' decadal surveys for guidance in planning the future of its science programs. For over 30 years, decadal surveys have proven indispensable in establishing a broad consensus within the national science community on the state of the science, the highest priority science questions we can address, and actions we can take to address those priority science topics. NASA uses these recommendations to prioritize future flight missions, including space observatories and probes, as well as technology development and proposals for theoretical and suborbital supporting research. In that process, NASA must also adapt science-based decadal survey recommendations to actual budgets, existing technological capabilities, national policy, partnership opportunities, and other programmatic factors.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The budget request for Planetary Science enables continuation of high priority operating missions, including Cassini and Curiosity; support for OSIRIS-REx (2016), InSight (2016), and the Mars Rover 2020 mission; and release of a Discovery Announcement of Opportunity in FY 2014. It also continues NASA's efforts to find and map asteroids in the solar system, including those suitable for the Asteroid Redirect Mission.

Due to its high annual operating cost, the Administration greatly reduces funding for the Stratospheric Observatory For Infrared Astronomy (SOFIA) project. SOFIA has encountered technical and schedule challenges, and while the observatory will address emerging scientific questions, its contributions to astronomical science will be significantly less than originally envisioned. Funding for SOFIA, which costs almost \$80 million per year to operate, can have a larger impact supporting other science missions. NASA will work with current partner Germany and potential partners to identify a path forward for SOFIA with greatly reduced NASA funding. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.

Work on the Orbiting Carbon Observatory 3 (OCO-3) instrument, currently in formulation and planned for flight on the International Space Station in late 2016, will cease in FY 2014, as NASA expects other missions to provide sufficient data on atmospheric carbon levels.

The request includes funding for the Global Learning and Observations to Benefit the Environment (GLOBE) program. It also includes \$15 million for other high-priority STEM education activities within the Science Mission Directorate, pending an assessment of program effectiveness. This funding would be awarded through a competitive process to ensure that the most meritorious education activities within SMD are supported.

### ACHIEVEMENTS IN FY 2013

Recent discoveries and societal applications from NASA's Science programs are too numerous to list, but include:

In Earth Science, an effort with the California Department of Water Resources delivered improved methods to forecast water supply from snow cover data obtained by NASA satellites. NASA completed dozens of projects focused on the Gulf of Mexico region, including some to improve water management, disaster responses, and public health. An international team of scientists was able, for the first time, to reconcile prior estimates of global ice loss obtained with a variety of techniques. Based on an analysis of

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all data from 1992-2011, the team proved that melting in the Greenland and Antarctic ice sheets combined caused a global sea level rise of 11.1 +/- 3.8 millimeters.

In Planetary Science, the Mars Science Laboratory Curiosity rover, which successfully landed in August 2012, is collecting Martian soil and rock samples and analyzing them for organic compounds and environmental conditions that could have supported microbial life. The rover has traveled more than four kilometers (2.5 miles) since landing, and has already determined that water flowed on the surface, was of relatively neutral pH and low salinity, and contained the ingredients for life, showing that Mars could have supported microbial life. The past presence of flowing water also implies the existence of an atmosphere much thicker than Mars has today. Another key finding is the discovery that water accounts for approximately two percent of the weight of the examined Martian soil samples.

In Astrophysics, an analysis of data from the Kepler Space Telescope demonstrates that most stars in our galaxy have at least one planet, and suggests that the majority of stars in the night sky are likely to host planetary systems. Another analysis suggests that perhaps as many as one in five stars like the sun hosts a planet up to twice the size of Earth in its “habitable zone,” the region where temperatures could permit liquid water to exist.

In Heliophysics, Voyager 1 observations in 2012/13 made national and international headlines, suggesting that the spacecraft, which NASA launched in 1977, has crossed the heliopause, a boundary region far beyond the planets, into the space between the stars. Voyager 1 has traveled farther than anyone, or anything, in history and has enough electrical power to keep operating some of its science instruments through at least 2020.

Since the release of the President’s FY 2014 budget request, NASA launched Landsat 8 (formerly the Landsat Data Continuity Mission, LDCM); the InfraRed Imaging Spectrograph (IRIS) mission to study the Sun; the Lunar Atmosphere and Dust Environment Explorer (LADEE); and the Mars Atmosphere and Volatile Evolution (MAVEN) mission. These four missions continue a recent string of excellent technical, cost and schedule performance on Science missions. Each is working well; NASA launched all of them on (or ahead of) our promised schedule; and the two larger missions (Landsat 8 and MAVEN) each cost about 14 percent less than our promised budget. (IRIS and LADEE exceeded NASA’s cost commitment by about 1 percent and 14 percent respectively.)

Four Science missions currently under development are holding closely to their original cost and schedule baseline estimates.

- Global Precipitation Measurement (GPM, original baseline December 2009, experienced a schedule delay due to external factors)
- Magnetospheric MultiScale (MMS, original baseline June 2009)
- Soil Moisture Active/Passive (SMAP, original baseline June 2012)
- Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx, original baseline May 2013)

Two other Science missions under development experienced past cost and schedule growth, but are holding closely to their revised cost and schedule commitments.

- James Webb Space Telescope (JWST) is holding to its revised cost and schedule commitments from the rebaseline in September 2011.

## SCIENCE

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- Orbiting Carbon Observatory 2 (OCO-2) is holding to its revised cost and schedule commitments from the rebaseline in January 2013.

ICESat-2 is the only Science mission to experience major cost and schedule growth in the last year.

### WORK IN PROGRESS IN FY 2014

NASA continues support for over 55 operating Science missions, involving more than 70 spacecraft, many in collaboration with international partners or other US agencies. Work on over 35 missions in formulation and implementation continues; the GPM mission is progressing towards launch in February 2014. Suborbital research using aircraft, sounding rockets, and balloons is ongoing, as are more than 3,000 competitively selected research awards to scientists located at universities, NASA field Centers, and other government agencies.

Based on the results of the Science Definition Team effort from January to July 2013, NASA released a competitive Announcement of Opportunity (AO) on 24 September 2013 for scientific and exploration technology payloads to fly on the 2020 rover. NASA plans to make payload selections in April 2014. The Mars 2020 Project formally entered Phase A study in November 2013, working towards the start of Phase B preliminary design in approximately September 2014.

NASA plans to release competitive AOs for the Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) instruments in mid-2014; and for an Astrophysics Explorer Mission and Mission of Opportunity, in late FY 2014. NASA will release a draft AO for Discovery this spring, with final release by the end of FY 2014.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

NASA plans to launch the OCO-2, MMS, and SMAP missions in FY 2015. NASA will release an Earth Venture Instrument (EVI-3) AO by December 2014.

The Opportunity, Growth, and Security Initiative (OGSI), discussed elsewhere in this volume, offers an opportunity for additional exciting progress in Science. It proposes additional funding for key Earth Science activities (OCO-3, PACE, the President's Climate Action Plan, and the Big Earth Data Initiative), WFIRST/AFTA, radioisotope power systems, extended missions, and Research and Analysis. Please refer to the OGSI section for more detail.

## Themes

### EARTH SCIENCE

From space, NASA satellites can view Earth as a planet and enable the study of it as a complex, dynamic system of diverse components: the oceans, atmosphere, continents, ice sheets, and life. The Nation's scientific community can thereby observe and track global-scale changes, connecting causes to effects. Scientists can study regional changes in their global context, as well as observe the role that human civilization plays as a force of change. Through partnerships with agencies that maintain forecasting and

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decision support systems, NASA improves national capabilities to predict climate, weather, and natural hazards; manage resources; and support the development of environmental policy.

The budget request continues to advance key elements of Earth Science program established in NASA's 2010 Climate Initiative. SMAP is progressing well towards launch by March 2015. As previously mentioned, the ICESat-2 mission is making progress, although its schedule and budget are under review. NASA expects the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission to begin development in February 2014. The Surface Water Ocean Topography (SWOT) mission is in Phase A study and NASA expects it to enter Phase B preliminary design in early 2014. Other Climate Initiative missions are either in a pre-formulation phase or are conducting mission concept studies.

The budget request includes funding for a suite of climate-relevant observations, intended to continue the 30 plus-year data record for atmospheric ozone profiling, the Earth radiation budget, and total solar irradiance. The request also supports definition of a sustained, space-based, global land imaging capability for the nation, ensuring continuity following Landsat 8.



The image above represents the fleet of spacecraft that make continual land surface, biospheric, atmospheric, and oceanic observations of the Earth to study how its climate operates as a whole system and how it is changing over time.

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## PLANETARY SCIENCE

To answer questions about the solar system and the origins of life, NASA sends robotic space probes to the Moon, other planets and their moons, asteroids and comets, and the icy bodies beyond Neptune. NASA is in the midst of a sustained investigation of Mars, launching a series of orbiters, landers, and rovers, with the long-term goal of eventual human exploration. NASA has begun early planning activities for the next Mars rover, which will launch in 2020 and address key questions about the potential for life on Mars. NASA is operating spacecraft at Mercury and Saturn, returning to Jupiter, journeying to the largest asteroid Ceres, completing humankind's first reconnaissance of the solar system by flying by Pluto, and preparing to return samples from an asteroid to Earth.

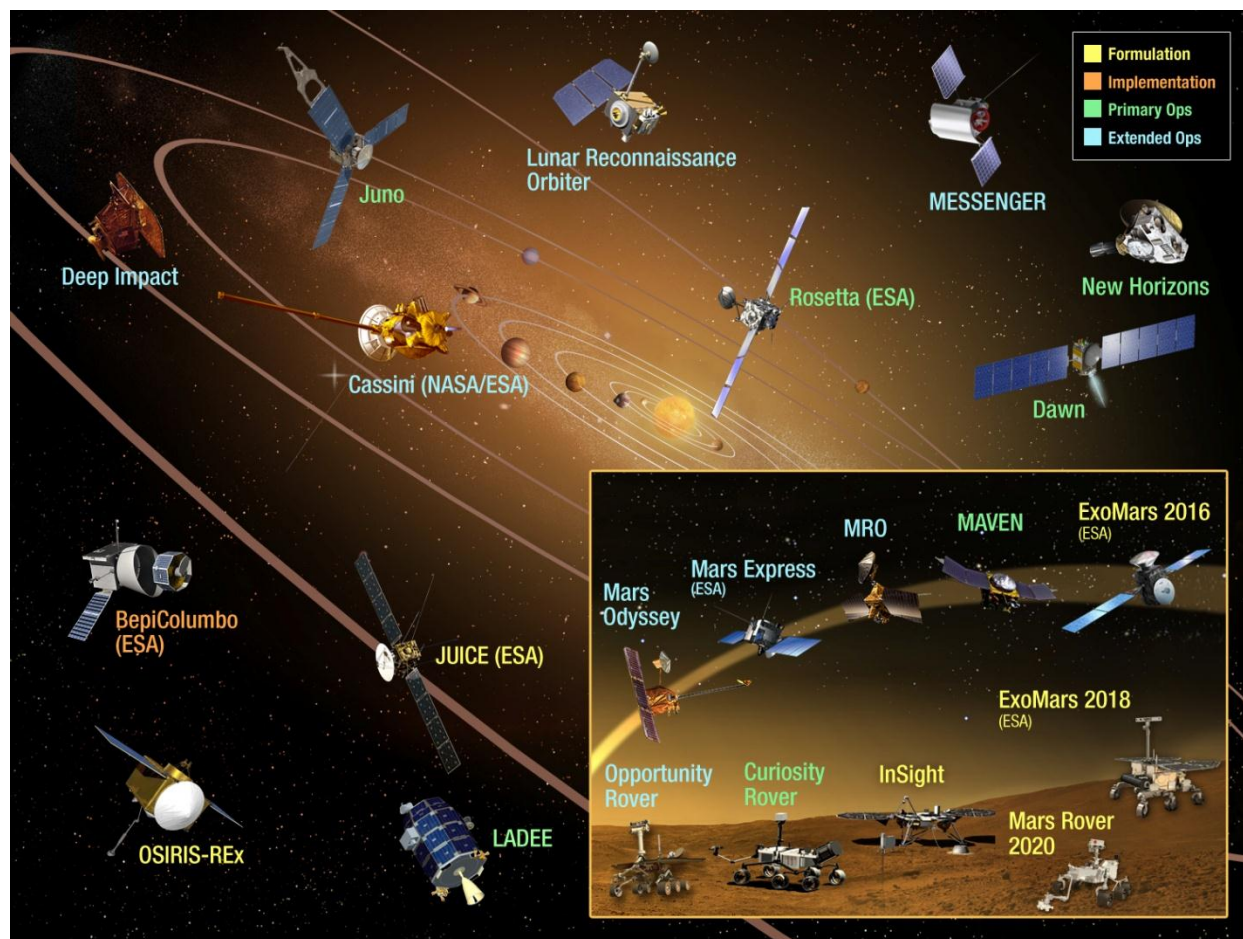
The budget request supports a robust Mars program. NASA is participating in the European Space Agency's Jupiter Icy moons Explorer (JUICE) mission, which will provide valuable data on Europa and the other Galilean moons to the U.S. science community. The request also provides funding to enable continued study in FY 2015 of a potential US-led mission to Europa.

The budget request includes aggressive efforts to identify and characterize potentially hazardous near Earth objects (NEOs), including asteroids that may be suitable for the Asteroid Redirect Mission. NASA is continuing an expanded observation program that increases the detection and characterization of NEOs of all sizes by lengthening the observation time on existing ground-based telescopes such as PanSTARRs.

To support future planetary missions in the 2020s and beyond, NASA is collaborating with the Department of Energy for plutonium-238 production. Plutonium-238 generates electrical power for missions where solar power is inadequate. We have recently produced small amounts of plutonium-238, and by optimizing the production process, we can produce about 1.5 to 2 kilograms per year by 2019. This amount will be enough to meet NASA's projected needs for future planetary missions. The Science budget request fully funds this requirement.



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This legion of spacecraft represents US and international partnerships in pursuit of new discoveries about our solar system. For real-time exploration of these missions, visit <http://eyes.jpl.nasa.gov>.

## ASTROPHYSICS

Some of the greatest minds of the last century discovered wondrous things about the physical universe: the Big Bang and black holes, dark matter and dark energy, and the interrelated nature of space and time. Their theories challenge scientists and NASA to use observations from space to test conventional understanding of fundamental physics. Having measured the age of the universe, the scientific community now seeks to explore its ultimate extremes: its birth, the edges of space and time near black holes, and the mysterious dark energy filling the entire universe. Scientists have recently developed astronomical instrumentation sensitive enough to detect planets around other stars. With hundreds of extrasolar planets now known, scientists are using current NASA missions in conjunction with ground-based telescopes to seek Earth-like planets in other solar systems.

The budget request supports all current missions, with the exception of SOFIA (discussed above) and most of the other core program recommendations of the recent decadal survey. NASA will release a new Astrophysics Explorer AO in late FY 2014. Balloon flights and competed research will continue at about the same level as in recent years. However, over the next few years until after the launch of JWST, work



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on a new Astrophysics flagship mission, such as the Wide-Field InfraRed Survey Telescope (WFIRST) and the possible use of the telescope assets made available to NASA, will be limited to early mission studies and technology efforts.



The image above represents the fleet of spacecraft and instruments that provide observations to help us understand how the universe works.

### JAMES WEBB SPACE TELESCOPE

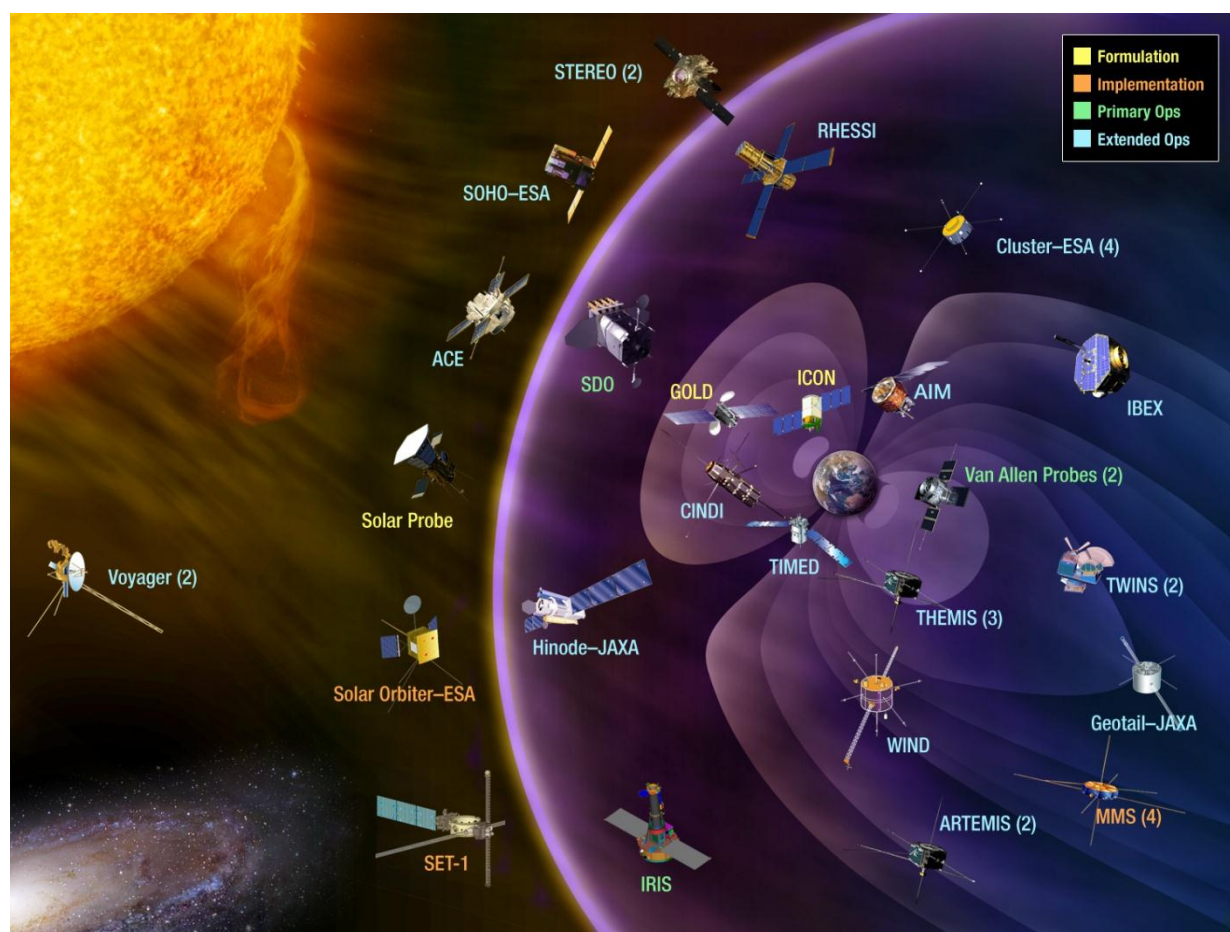
JWST is a large, space-based astronomical observatory. The mission is a logical successor to the Hubble Space Telescope, extending beyond Hubble's discoveries by looking into the infrared spectrum, where the highly red-shifted early universe is observable, where relatively cool objects like protostars and protoplanetary disks strongly emit infrared light, and where dust obscures shorter wavelengths. JWST is progressing well towards its scheduled launch in October 2018, within the cost and schedule baseline NASA established in 2011.

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## HELIOPHYSICS

The solar system is governed by the Sun, a typical small star midway through its life. The Sun wields its influence through its gravity, radiation, solar wind, and magnetic fields, all of which interact with the gravity, fields, and atmospheres of Earth to produce space weather, which can affect human technological infrastructure and activities. Using a fleet of sensors on various spacecraft in Earth orbit and throughout the solar system, NASA seeks to understand how and why the Sun varies, how Earth responds to the Sun, and how human activities are affected. The science of heliophysics enables the predictions necessary to safeguard life and society on Earth and the outward journeys of human and robotic explorers.

The budget request is consistent with the recommendations of the recent decadal survey. Following launch of MMS by March 2015, the largest part of the Heliophysics budget will be devoted to the Solar Probe Plus (SPP) project. NASA strongly supports SPP, which NASA expects to enter development in late FY 2014, in preparation for launch in July 2018.



A fleet of Heliophysics spacecraft patrols the environment of our Earth, from its life-sustaining sun out to the edges of our solar system. They reveal a dynamic interconnected system which engulfs our home planet, and through which robotic and human explorers must journey.

# EARTH SCIENCE

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Earth Science Research	422.9	--	<b>449.9</b>	477.1	453.9	445.9	448.6
Earth Systematic Missions	816.2	--	<b>786.2</b>	856.7	880.4	894.3	927.2
Earth System Science Pathfinder	176.7	--	<b>266.1</b>	209.5	227.0	243.2	231.9
Earth Science Multi-Mission Operations	162.2	--	<b>176.1</b>	179.6	181.0	183.2	183.3
Earth Science Technology	48.9	--	<b>55.6</b>	54.5	55.6	55.6	55.6
Applied Sciences	32.5	--	<b>36.3</b>	38.0	39.7	39.7	39.7
<b>Total Budget</b>	<b>1659.2</b>	<b>1826.0</b>	<b>1770.3</b>	<b>1815.5</b>	<b>1837.6</b>	<b>1861.9</b>	<b>1886.3</b>

## Earth Science

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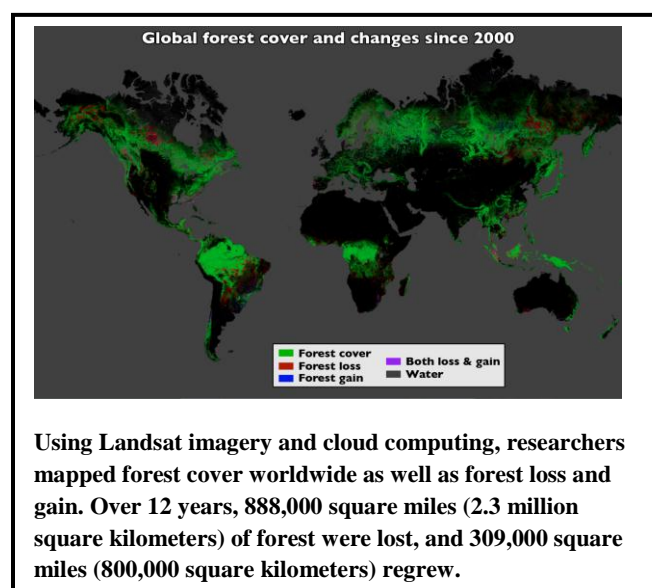
## EARTH SCIENCE RESEARCH

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Earth Science Research and Analysis	316.7	--	<b>329.2</b>	332.5	310.9	295.4	299.2
Computing and Management	106.2	--	<b>120.7</b>	144.6	143.0	150.4	149.4
<b>Total Budget</b>	<b>422.9</b>	<b>--</b>	<b>449.9</b>	<b>477.1</b>	<b>453.9</b>	<b>445.9</b>	<b>448.6</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA's Earth Science Research program develops a scientific understanding of Earth and its response to natural or human-induced changes. Earth is a system, like the human body, comprised of diverse components interacting in complex ways. Understanding Earth's atmosphere, crust, water, ice, and life as a single connected system is necessary in order to improve our predictions of climate, weather, and natural hazards.

The Earth Science Research program addresses complex, interdisciplinary Earth science problems in pursuit of a comprehensive understanding of the Earth system. This strategy involves six interdisciplinary and interrelated science focus areas, including:

- Climate Variability and Change: understanding the roles of ocean, atmosphere, land, and ice in the climate system and improving our ability to predict future changes;
- Atmospheric Composition: understanding and improving predictive capability for changes in the ozone layer, Earth's radiation budget, and air quality associated with changes in atmospheric composition;
- Carbon Cycle and Ecosystems: quantifying, understanding, and predicting changes in Earth's ecosystems and biogeochemical cycles, including the global carbon cycle, land cover, and biodiversity;
- Water and Energy Cycle: quantifying the key reservoirs and fluxes in the global water cycle, assessing water cycle change, and water quality;
- Weather: enabling improved predictive capability for weather and extreme weather events; and
- Earth Surface and Interior: characterizing the dynamics of the Earth surface and interior and forming the scientific basis for the assessment and mitigation of natural hazards and response to rare and extreme events.



## **EARTH SCIENCE RESEARCH**

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NASA's Earth Science Research program pioneers the use of both space-borne and aircraft measurements in all of these areas. NASA's Earth Science Research program is critical to the advancement of the interagency U.S. Global Change Research Program (USGCRP). NASA's Earth Science Research program also makes extensive contributions to international science programs such as the World Climate Research Programme.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

NASA continued Operation IceBridge with the Arctic 2013 campaign, conducting 26 science flights from bases in Greenland, and Fairbanks, Alaska. During these flights, IceBridge researchers flew an equivalent distance of more than two and a half times around the Earth at its equator and collected a vast amount of data on sea ice, ice sheets, and glaciers. Researchers also communicated with classrooms in several U.S. states and Chile, and hosted three science teachers. Operation IceBridge provided laser altimetry and radar-derived ice thickness data to the Bedmap2 effort, significantly increasing the density of measurements in key regional areas by providing new opportunities for detailed modeling of the past and future evolution of the Antarctic ice sheets. To complete a comprehensive survey of Antarctic ice shelves, researchers used these data sets together with ground-based radar echo sounding, satellite data, and reconstructions of surface accumulation. They discovered that ice shelves lose the most mass to melting as opposed to calving, which scientists thought to be the far-dominant mechanism for ice removal.

Using a state-of-the-art, high-performance computing and data access facility called NASA Earth Exchange at ARC to investigate the mechanisms underlying the relationship between carbon dioxide levels and increased temperatures, researchers analyzed data between 1959 and 2011 and studied outputs from several dynamic global vegetation models. The study results support the "carbon-climate feedback" hypothesis, asserting that a warming climate will accelerate carbon dioxide growth in the atmosphere from vegetation and soils.

NASA-funded scientists analyzed satellite microwave radar data collected between 2000 and 2009 over the Amazon rainforest. The observations included measurements of rainfall from NASA's Tropical Rainfall Measuring Mission and measurements of the moisture content and structure of the forest canopy (top layer) from the SeaWinds scatterometer on NASA's QuikScat spacecraft. Analysis showed that during the summer of 2005, 70 million hectares of pristine Amazonian forest experienced an extensive, severe drought. This drought caused drastic changes to the forest canopy that were detectable by satellite.

The year 2012 ranked as the ninth-warmest year since 1880. NASA scientific analysis of Earth's surface temperature at the Goddard Institute for Space Studies compares the average global temperature each year to the average from 1951 to 1980. This 30-year period provides a baseline from which to measure the warming that Earth experienced due to increasing atmospheric levels of heat-trapping greenhouse gases.

The Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS) airborne campaign commenced in August 2013, with initial U.S. flight campaigns. This mission utilized the DC-8 and the ER-2 in 18 flights deploying over 100 researchers in coordination with ground-based and satellite observations. Scientists use the data to understand the influence of

## **EARTH SCIENCE RESEARCH**

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aerosols on meteorology and climate and to understand the redistribution of pollution by convection in the atmosphere.

### **WORK IN PROGRESS IN FY 2014**

NASA's Earth Science Research program will continue funding investigations in competitively selected projects, including the newly selected projects to support the development of the Carbon Monitoring System. In addition, 14 projects selected from a recent solicitation to develop climate indicators will contribute to the National Climate Assessment (NCA) together with on-going NASA center projects.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015, in response to solicitations in Research Opportunities in Space and Earth Sciences 2014 (ROSES-14) and ROSES-13, NASA anticipates awarding over 200 new three-year research awards.

In addition, NASA will implement a field study focused on developing new approaches for optically characterizing key marine ecosystem properties by coordinating airborne and ship measurements. The program will conduct the field campaign on the research vessel Endeavor (a University-National Oceanographic Laboratory System (UNOLS) vessel out of Rhode Island) and will span 20 days at sea.

An additional \$18M investment is proposed under the Opportunity, Growth, and Security Initiative for the Earth Science Research program, including the Big Earth Data and Climate Data Initiatives. Please refer to the OGSi section for more information.

## **Program Elements**

### **CARBON CYCLE SCIENCE TEAM**

Carbon Cycle Science Team funds research on the distribution and cycling of carbon among Earth's active land, ocean, and atmospheric reservoirs.

### **GLOBAL MODELING AND ASSIMILATION OFFICE**

The Global Modeling and Assimilation Office creates global climate and Earth system component models using data from Earth science satellites and aircraft. Investigators can then use these products worldwide to further their research.

### **AIRBORNE SCIENCE**

The Airborne Science project is responsible for providing manned and unmanned aircraft systems that further science and advance the use of satellite data. NASA uses these assets worldwide in campaigns to investigate extreme weather events, observe Earth system processes, obtain data for Earth science modeling activities, and calibrate instruments flying aboard Earth science spacecraft. NASA Airborne

## **EARTH SCIENCE RESEARCH**

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Science platforms support mission definition and development activities. For example, these activities include:

- Conducting instrument development flights;
- Gathering ice sheet observations as gap fillers between missions (e.g., Operation IceBridge);
- Serving as technology test beds for Instrument Incubator Program missions; and  
Serving as the observation platforms for research campaigns, such as those that are competitively selected under the suborbital portion of Earth Venture.

The objectives of this project include:

- Conducting in-situ atmospheric measurement and remote sensing observations in support of scientific investigations;
- Demonstrating and exploiting the capabilities of autonomous aircraft for science investigations;
- Testing new sensor technologies in space-like environments; and
- Calibrating and validating space-based measurements and retrieval algorithms.

### **OZONE TRENDS SCIENCE**

The Ozone Trends Science project produces a consistent, calibrated ozone record used for trend analyses and other studies.

### **INTERDISCIPLINARY SCIENCE**

Interdisciplinary Science includes science investigations, as well as calibration and validation activities, that ensure the utility of space-based measurements. In addition, it supports focused fieldwork (e.g., airborne campaigns) and specific facility instruments upon which fieldwork depends.

### **EARTH SCIENCE RESEARCH AND ANALYSIS**

Research and Analysis is the core of the research program and funds the analysis and interpretation of data from NASA's satellites. This project funds the scientific activity needed to establish a rigorous base for the satellites' data and their use in computational models.

### **FELLOWSHIPS AND NEW INVESTIGATORS**

The project Fellowships and New Investigators supports graduate and early career research in the areas of Earth system research and applied science.

### **GLOBAL LEARNING AND OBSERVATIONS TO BENEFIT THE ENVIRONMENT**

GLOBE, previously funded under the former Earth Science Education and Outreach project, is a worldwide hands-on, primary and secondary school-based science and education program that promotes collaboration among students, teachers and scientists to conduct inquiry-based investigations about our environment. NASA works in close partnership with NOAA and NSF Earth System Science Projects to

## **EARTH SCIENCE RESEARCH**

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study the dynamics of Earth's environment, focused on atmosphere, hydrology, soil, and land cover. Students take measurements, analyze data, and participate in research in collaboration with scientists.

### **SPACE GEODESY**

The Space Geodesy project provides global geodetic positioning and support for geodetic reference frames necessary for climate change and geohazards research. Geodesy is the science of measuring Earth's shape, gravity and rotation, and how these change over time. The Space Geodesy project began in 2011. It is a GSFC and JPL partnership, with participation from the Smithsonian Astrophysical Observatory and the University of Maryland.

In FY 2014, NASA will focus on preparations for the deployment of the new network and will complete the development of modern geodetic analysis tools.

### **CARBON MONITORING SYSTEM**

Carbon Monitoring System complements NASA's overall program in carbon cycle science and observations by producing and distributing products to the community regarding the flux of carbon between the surface and atmosphere, as well as the stores of carbon on the surface.

### **EARTH SCIENCE DIRECTED RESEARCH AND TECHNOLOGY**

Earth Science Directed Research and Technology funds the civil service staff that work on emerging Earth Science flight projects, instruments, and research.

### **SCIENTIFIC COMPUTING**

The Scientific Computing project funds NASA's Earth Science Discover computing system, software engineering, and user interface projects at GSFC, including climate assessment modeling. Scientific Computing supports Earth science modeling activities based on data collected by Earth science spacecraft. The system is separate from the High End Computing Capability (HECC), so it can be close to the satellite data archives at the Center. The proximity to the data and the focus on satellite data assimilation makes the Discover cluster unique in the ability to analyze large volumes of satellite data quickly. The system currently has approximately 31,400 computer processor cores.

### **HIGH END COMPUTING CAPABILITY (HECC)**

High End Computing Capability focuses on the Endeavour, Merope, and Pleiades supercomputer systems and the associated network connectivity, data storage, data analysis, visualization, and application software support. It serves the supercomputing needs of all NASA mission directorates and NASA-supported principal investigators at universities. The Science funding supports the operation, maintenance, and upgrade of NASA's supercomputing capability, while the Strategic Capabilities Assets Program provides oversight. The three supercomputer systems, with approximately 170,000 computer processor cores, support NASA's aeronautics, human exploration, and science missions. For example, the systems are used to model the aerodynamic characteristics of the SLS at different attach angles and in



## EARTH SCIENCE RESEARCH

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different air speeds. The systems also analyze the Kepler mission observation data to search for habitable exoplanets.

### DIRECTORATE SUPPORT

The Directorate Support project funds the Science Mission Directorate's institutional and crosscutting activities including: National Academies' studies, proposal peer review processes, printing and graphics, information technology, the NASA Postdoctoral Fellowship program, working group support, independent assessment studies, procurement support for the award and administration of all grants, and other administrative tasks.

### Program Schedule

Date	Significant Event
Q2 FY 2014	ROSES-2014 solicitation
Q1 FY 2015	ROSES-2014 selection within six to nine months of receipt of proposals
Q2 FY 2015	ROSES-2015 solicitation
Q1 FY 2016	ROSES-2015 selection within six to nine months of receipt of proposals

### Program Management & Commitments

Program Element	Provider
Carbon Cycle Science Team	Provider: Various and defined in the acquisition strategy Lead Center: HQ Performing Center(s): HQ, JPL, GSFC Cost Share Partner(s): USGCRP and Subcommittee on Ocean Science and Technology (SOST) agencies
Global Modeling and Assimilation Office	Provider: Various Lead Center: HQ Performing Center(s): GSFC Cost Share Partner(s): N/A
Airborne Science	Provider: Various Lead Center: HQ Performing Center(s): AFRC, ARC, GSFC, Wallops Flight Facility (WFF) Cost Share Partner(s): Federal Aviation Administration (FAA), Department of Defense (DoD), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), National Science Foundation

## EARTH SCIENCE RESEARCH

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Program Element	Provider
Scientific Computing	Provider: GSFC Lead Center: HQ Performing Center(s): GSFC Cost Share Partner(s): DoD, DOE
Ozone Trends Science	Provider: Various and defined in the acquisition strategy Lead Center: HQ Performing Center(s): LaRC, GSFC Cost Share Partner(s): USGCRP and SOST agencies
Interdisciplinary Science	Provider: Various Lead Center: HQ Performing Center(s): HQ, JPL, GSFC, ARC, AFRC, GRC, LaRC, MSFC, JSC Cost Share Partner(s): USGCRP and SOST agencies
Earth Science Research and Analysis	Provider: Various and defined in the acquisition strategy Lead Center: Headquarters (HQ) Performing Center(s): All NASA Centers Cost Share Partner(s): USGCRP and SOST agencies
High-End Computing Capability	Provider: ARC Lead Center: HQ Performing Center(s): ARC Cost Share Partner(s): DOE
Directorate Support	Provider: HQ Lead Center: HQ Performing Center(s): Cost Share Partner(s); None
Fellowships and New Investigators	Provider: Various Lead Center: HQ Performing Center(s): All NASA Centers Cost Share Partner(s): N/A
Space Geodesy	Provider: Various Lead Center: GSFC Performing Centers: GSFC, JPL Cost Share Partners: None
Carbon Monitoring System	Provider: Various and defined in the acquisition strategy Lead Center: HQ Performing Center(s): JPL, GSFC, ARC Cost Share Partner(s): U.S. Forest Service, DOE, NOAA

## EARTH SCIENCE RESEARCH

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### **Acquisition Strategy**

NASA implements the Earth Science Research program via competitively selected research awards. NASA releases research solicitations each year in the ROSES NASA Research Announcements. All proposals in response to NASA ROSES are peer reviewed and selected based on defined criteria. The program competitively awards at least 90 percent of its research program funds to investigators from academia, the private sector, and NASA Centers.

### **MAJOR CONTRACTS/AWARDS**

None.

### **INDEPENDENT REVIEWS**

<b>Review Type</b>	<b>Performer</b>	<b>Date of Review</b>	<b>Purpose</b>	<b>Outcome</b>	<b>Next Review</b>
Relevance	NASA Advisory Council Earth Science Subcommittee	2013	To review progress towards Earth Science objectives in the NASA Strategic Plan.	All six science focus areas were rated “green” as documented in the FY 2013 Performance and Accountability Report	2014; annually thereafter

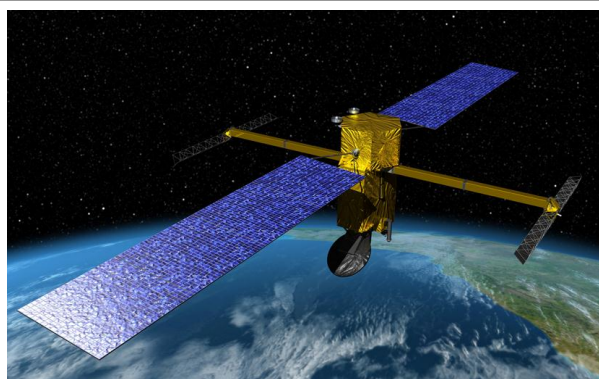
## EARTH SYSTEMATIC MISSIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Global Precipitation Measurement (GPM)	91.4	60.3	<b>18.7</b>	19.6	14.2	15.3	15.3
Ice, Cloud, and land Elevation Satellite (ICESat-II)	165.9	140.7	<b>109.5</b>	118.4	27.1	14.1	10.9
Soil Moisture Active and Passive (SMAP)	210.3	88.3	<b>74.9</b>	15.9	11.3	11.3	11.3
GRACE FO	50.1	--	<b>64.4</b>	74.3	71.7	20.0	12.0
Other Missions and Data Analysis	298.5	--	<b>518.8</b>	628.4	756.1	833.5	877.7
<b>Total Budget</b>	<b>816.2</b>	<b>--</b>	<b>786.2</b>	<b>856.7</b>	<b>880.4</b>	<b>894.3</b>	<b>927.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



An artist's conception shows the Surface Water Ocean Topography (SWOT) satellite, which entered the formulation phase in November 2012. SWOT will make high-resolution, wide-swath altimetric measurements of the world's oceans and fresh water bodies to understand their circulation, surface topography, and storage. This multi-disciplinary, cooperative international mission will produce science and data products that will allow for fundamental advances in the understanding of the global water cycle.

Earth Systematic Missions (ESM) includes a broad range of multi-disciplinary science investigations aimed at understanding the Earth system and its response to natural and human-induced forces and changes. Understanding these forces will help determine how to predict future changes, and how to mitigate or adapt to these changes.

The ESM program develops Earth-observing research satellite missions, manages the operation of these missions once on orbit, and produces mission data products in support of research, applications, and policy communities.

Interagency and international partnerships are a central element throughout the ESM program. Several of the on-orbit missions provide data products in near-real time for use by U.S. and international meteorological agencies and disaster responders. Five of the on-orbit missions involve significant international or interagency collaboration in development. The

Landsat Data Continuity Mission (LDCM), now operating on orbit as Landsat 8, involves collaboration with the U.S. Geological Survey. The Global Precipitation Measurement (GPM) mission, currently in development, is a partnership with the Japanese Aerospace Exploration Agency (JAXA), and the Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) mission is a partnership between NASA and the German Space and Earth Science agencies. The SWOT mission includes a significant collaboration with both the Centre National d'Etudes Spatiales (CNES) and the Canadian Space Agency (CSA).

## **EARTH SYSTEMATIC MISSIONS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

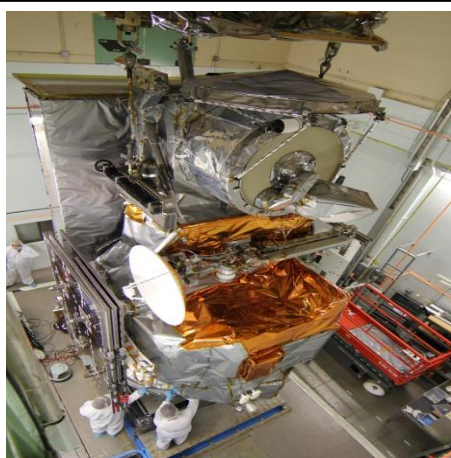
The delay in delivery of the European Space Agency's (ESA) Hexapod pointing system forced Stratospheric Aerosol and Gas Experiment (SAGE) III to replan with a commensurate delay in its launch date (from August 2014 to March 2016) and a small increase to its life cycle cost. The Senior Review panel recommended mission extensions for all currently operating missions. The operating missions' budgets now reflect these mission extensions.

## GLOBAL PRECIPITATION MEASUREMENT (GPM)

Formulation	Development		Operations	
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	349.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	349.2
Development/Implementation	377.0	76.4	65.9	0.0	0.0	0.0	0.0	0.0	0.0	519.3
Operations/Close-out	0.0	0.0	9.4	18.7	19.6	11.8	0.0	0.0	0.0	59.5
<b>2014 MPAR LCC Estimate</b>	<b>726.2</b>	<b>76.4</b>	<b>75.3</b>	<b>18.7</b>	<b>19.6</b>	<b>11.8</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>928.0</b>
<b>Total Budget</b>	<b>726.2</b>	<b>91.4</b>	<b>60.3</b>	<b>18.7</b>	<b>19.6</b>	<b>14.2</b>	<b>15.3</b>	<b>15.3</b>	<b>0.0</b>	<b>961.2</b>
Change from FY 2014				-41.6						
Percentage change from FY 2014				-69.0%						



GPM completed its test program and is shown here in the final stages of preparation for launch from its launch site in Japan. GPM data will reveal new information on hurricane eyewall development and intensity changes. It will also measure hazard-triggering rainfall events contributing to flooding and landslides and provide inputs to climate, weather, and land surface models for improved predictions.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

### PROJECT PURPOSE

The GPM mission will advance the measurement of global precipitation. A joint mission with JAXA, GPM will provide the first opportunity to calibrate measurements of global precipitation (including the distribution, amount, rate, and associated heat release) across tropical, mid-latitude, and Polar Regions.

The GPM mission has several scientific objectives:

- Advance precipitation measurement capability from space through combined use of active and passive remote-sensing techniques;
- Advance understanding of global water/energy cycle variability and fresh water availability;
- Improve climate prediction by providing the foundation for better understanding of surface water fluxes, soil moisture storage, cloud/precipitation microphysics and latent heat release in Earth's atmosphere;
- Advance numerical weather prediction skills through more accurate and frequent measurements of instantaneous rain rates; and

## GLOBAL PRECIPITATION MEASUREMENT (GPM)

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Formulation	Development	Operations
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- Improve high-impact natural hazard event (flood and drought, landslide, and hurricanes) and fresh water-resource prediction capabilities through better temporal sampling and wider spatial coverage of high-resolution precipitation measurements.

For more information, go to: <http://science.hq.nasa.gov/missions/earth.html>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PARAMETERS

The NASA-provided elements of the GPM project include a core observatory spacecraft and a GPM Microwave Imager instrument. The GPM Microwave Imager instrument is a conically scanning radiometer that will provide significantly improved spatial resolution over the Tropical Rainfall Measuring Mission (TRMM) Microwave Imager. JAXA will supply the second instrument, the Dual frequency Precipitation Radar, which will provide three-dimensional observation of rain and an accurate estimation of rainfall rate. The Core Observatory will leverage passive microwave measurements from other operating and planned "satellites of opportunity" by calibrating their measurements to its own. Given the prevalence of passive microwave instruments on operational and research satellite systems, the global sampling from this constellation of satellites will be robust providing frequent global mapping of precipitation. The spacecraft will launch from Tanegashima Space Center, Japan on a JAXA-provided H-IIA launch vehicle.

### ACHIEVEMENTS IN FY 2013

The completion of the observatory environmental testing occurred and final testing and preparations for shipment to Japan for launch began.

### WORK IN PROGRESS IN FY 2014

The project completed the observatory pre-ship testing and shipped the observatory to Japan for launch. JAXA launched the observatory successfully on February 27, 2014, and it has started operational commissioning.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

GPM will be fully operational and in its baseline mission.

## GLOBAL PRECIPITATION MEASUREMENT (GPM)

Formulation	Development	Operations
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### SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2015 PB Request
Key Decision Point (KDP-C)	Dec 2009	Dec 2009
Launch	Jul 2013	Feb 2014
End of Prime Mission	Sep 2016	May 2017

### Development Cost and Schedule

GPM successfully launched on February 27, 2014.

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2010	555.2	70	2014	519.3	-6.5	LRD	Jul 2013	Feb 2014	8

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

### Development Cost Details

Reductions in the Ground Systems and Other Direct Project Costs lines are due to the elimination of the Low-Inclination Observatory GMI-2 instrument, associated TDRSS communications subsystem, payload accommodation, ground system and operations costs in 2012. Increases in the Aircraft/Spacecraft and Systems Integration and Test (I&T) lines are due to spacecraft development issues and the extension of integration and testing activities supporting the replanned launch readiness date.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>555.2</b>	<b>519.3</b>	<b>-35.9</b>
Aircraft/Spacecraft	151.2	248.8	97.6
Payloads	91.2	93.5	2.3



## GLOBAL PRECIPITATION MEASUREMENT (GPM)

Formulation		Development	Operations
Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
Systems I&T	6.8	12.2	5.4
Launch Vehicle	1.5	.7	-0.8
Ground Systems	30.5	30.1	-0.4
Science/Technology	28.4	33.9	5.5
Other Direct Project Costs	245.6	100.2	-145.4

### Project Management & Commitments

GSFC has project management responsibility. GPM is a constellation mission that will incorporate data from other precipitation missions from a consortium of international space agencies, including CNES, Indian Space Research Organization, NOAA, European Organisation for the Exploitation of Meteorological Satellites, and others.

Element	Description	Provider Details	Change from Baseline
Core Observatory	Provides platform for the GMI and JAXA-supplied Dual frequency Precipitation Radar (DPR) instruments	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
GMI instrument	Provides 13 microwave channels ranging in frequency from 10 gigahertz (GHz) to 183 GHz; 4 high frequency, millimeter-wave, channels	Provider: Ball Aerospace Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
DPR instrument	Provides cross-track swath widths of 245 and 120 kilometers, for the Ku precipitation radar (KuPR) and Ka-band precipitation	Provider: JAXA Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s): JAXA	N/A
Low Inclination Observatory (LIO/GMI-2)	Provides platform for the second GMI instrument	Provider: Lead Center: Performing Center(s): Cost Share Partner(s):	Descoped

## GLOBAL PRECIPITATION MEASUREMENT (GPM)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Launch vehicle and services	H-IIA	Provider: JAXA Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s): JAXA	N/A
Ground System	Provides control of Core Observatory operations, science data processing, and distribution	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): JAXA	N/A

### Project Risks

Risk Statement	Mitigation
If: Delays occur in launch site processing, Then: The February 2014 launch could be delayed.	The Project will optimize the schedule of launch preparation activities to regain schedule reserve. The Project came up with a mitigation plan. Additional system administration personnel hiring is in progress.

### Acquisition Strategy

The selection of the GMI was through open competition in FY 2005.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
GMI	Ball Aerospace and Technologies Corp	Boulder, CO
GPM Core Spacecraft	GSFC	Greenbelt, MD

## GLOBAL PRECIPITATION MEASUREMENT (GPM)

Formulation	Development	Operations
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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Feb 2012	System integration review	Project approved to begin integration and test	Oct 2013
Performance	SRB	Jan 2014	Operations readiness review to determine project readiness to operate the flight and ground systems	Project approved to proceed to launch	Jun 2014

### CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT

On February 2, 2012, pursuant to Section 103(c) of P.L 109-155, NASA notified the Committee on Science, Space, and Technology of an anticipated schedule delay of more than six months, but that NASA did not expect this delay to cause the project to exceed its development cost baseline.

The NASA Associate Administrator approved a replan of the project with a new launch date of June 2014, an eight-month delay compared to the January 2010 MPAR baseline. Based on the analysis conducted and progress to date against the new plan, the GPM project, barring a major test failure or some other significant unplanned event, has a high likelihood of completing its development on the cost and schedule presented.

# ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

Formulation	Development	Operations
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## FY 2015 Budget

	Actual	Enacted	Request	Notional						
Budget Authority (in \$ millions)	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	BTC	Total
Formulation	249.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	249.1
Development/Implementation	5.8	165.9	150.7	109.5	TBD	TBD	TBD	0.0	0.0	TBD
Operations/Close-out	0.0	0.0	0.0	0.0	TBD	TBD	TBD	TBD	TBD	TBD
2015 MPAR LCC Estimate	254.9	165.9	150.7	109.5	TBD	TBD	TBD	TBD	TBD	TBD
Total Budget	254.9	165.9	140.7	109.5	118.4	27.1	14.1	10.9	6.4	847.8
Change from FY 2014				-31.2						
Percentage change from FY 2014				-22.2%						



ICESat-2 will use a multi-beam micropulse laser altimeter to measure the topography of the Greenland and Antarctic ice sheets as well as the thickness of Arctic and Antarctic sea ice. The satellite LIDAR also will measure vegetation canopy heights and support other NASA environmental monitoring missions. By discovering the anatomy of ice loss, researchers may be able to forecast how the ice sheets will melt in the future and what impact this will have on sea-levels.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*The 2014 MPAR LCC Estimate reflects a pending 2014 Operating Plan change that has been submitted to Congress. The LCC for ICESat-2 is under review.*

## PROJECT PURPOSE

The Ice, Cloud, and land Elevation Satellite-2 (ICESat-2) mission will serve as an ICESat follow-on satellite to continue the assessment of polar ice changes. ICESat-2 will also measure vegetation canopy heights, allowing estimates of biomass and carbon in above ground vegetation in conjunction with related missions, and allow measurements of solid earth properties.

ICESat-2 will continue to provide an important record of multi-year elevation data needed to determine ice sheet mass balance and cloud property information. It will also provide topography and vegetation data around the globe in addition to the polar-specific coverage over the Greenland and Antarctic ice sheets.

## ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

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Formulation	Development	Operations
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The ICESat-2 mission is a Tier 1 mission recommended by the National Academies. It entered formulation in FY 2010.

For more information, go to: <http://icesat.gsfc.nasa.gov/icesat2>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The development of the only ICESat-2 instrument, the Advanced Topographic Laser Altimeter System (ATLAS), made inadequate progress in design and development, attributed to the instrument optical design complexity. This will affect the instrument schedule, subsequent mission integration, verification, and testing.

NASA notified Congress on December 2, 2013 that it expects to exceed currently approved cost and schedule commitments. Pursuant to Section 103(d) (1) of P.L. 109-155 and Section 522, Title V, Division B of P.L. 113-6, NASA submitted a report to Congress on January 29, 2014 providing additional information regarding the anticipated increased development cost for ICESat-2, actions taken in response, and implications for other programs. NASA expects to rebaseline this project in FY 2014.

### PROJECT PARAMETERS

The ICESat-2 observatory employs a dedicated spacecraft with a multi-beam photon-counting surface elevation Lidar, which measures distance by illuminating the Earth's surface with a laser and analyzing the reflected light. ICESat-2 will continue the measurements begun with the first ICESat mission, which launched in 2003, and will improve upon ICESat by incorporating a micro-pulse multi-beam laser to provide dense cross-track sampling, improving elevation estimates over inclined surfaces and very rough (e.g., crevassed) areas and improving lead detection for above-water sea ice estimates.

### ACHIEVEMENTS IN FY 2013

The mission completed its KDP-C review in December 2012 and proceeded into the development phase. In February 2013, NASA awarded United Launch Alliance the contract to launch ICESat-2 aboard a dedicated Delta-II launch vehicle. Both the spacecraft and ground system successfully passed their critical design reviews (CDRs) during August and September 2013 respectively.

### WORK IN PROGRESS IN FY 2014

The Advanced Topographic Laser Altimeter System instrument and the overall mission will both undergo their CDRs early in FY 2014. Mission readiness testing for the ground system commences in June 2014. The complete mission design schedule is under review at this time, and NASA expects to rebaseline this project in FY 2014.

## ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

Formulation	Development	Operations
-------------	-------------	------------

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The Advanced Topographic Laser Altimeter System instrument will complete manufacturing and begin testing during FY 2015.

### SCHEDULE COMMITMENTS/KEY MILESTONES

The ICESat-2 launch date is currently under review.

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	Nov 2012	Dec 2012
CDR	Sep 2013	Under review
Launch	May 2017	Under review
End of Prime Mission	Jul 2020	Under review

### Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	558.9	70	2014	TBD	-	LRD	May 2017	TBD	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

## ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

Formulation	Development	Operations
-------------	-------------	------------

### Development Cost Details

The development cost for this project is currently under review.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>558.9</b>	<b>TBD</b>	<b>TBD</b>
Aircraft/Spacecraft	77.8	TBD	TBD
Payloads	88.6	TBD	TBD
Systems I&T	18.5	TBD	TBD
Launch Vehicle	123.8	TBD	TBD
Ground Systems	35.3	TBD	TBD
Science/Technology	22.9	TBD	TBD
Other Direct Project Costs	192.0	TBD	TBD

### Project Management & Commitments

GSFC has project management responsibility for ICESat-2.

Element	Description	Provider Details	Change from Baseline
ATLAS Instrument	Advanced Topographic Laser Altimeter System	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Spacecraft	Provides platform for the instrument	Provider: Orbital Sciences Corporation Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Ground System	Provides control of observatory operations, science data processing and distribution	Provider: Orbital Sciences Corporation Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A

## ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Launch Vehicle	Provides launch service and entry into proper Earth orbit	Provider: United Launch Alliance Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A

### Project Risks

Risk Statement	Mitigation
If: The launch vehicle development is delayed or mandates spacecraft changes for accommodation, Then: Mission cost will increase.	NASA completed the launch services procurement in February 2013. The launch vehicle vendor supports the NASA-established launch readiness date of May 2017
If: The instrument hardware experiences development problems, Then: The delay of Instrument completion increases the overall mission cost.	NASA replaced the instrument management and added new technical expertise and resources. New instrument management instituted more focused control measures including a more detailed monthly review of all instrument subsystems.

### Acquisition Strategy

GSFC is responsible for the design and testing of the ATLAS instrument. NASA competitively selected the spacecraft vendor, Orbital Sciences Corporation, which will provide the ground system element via a contract option. NASA competitively selected United Launch Alliance as the launch services vendor.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Ground System	Orbital Sciences Corporation	Dulles, VA
Spacecraft	Orbital Sciences Corporation	Gilbert, AZ
Launch Service	United Launch Alliance	Decatur, AL



## ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-II)

Formulation	Development	Operations
-------------	-------------	------------

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Dec 2012	KDP-C	Mission was approved to enter development	TBD
Performance	SRB	Feb 2014	Mission Critical Design Review	TBD	TBD
Performance	SRB	TBD	Flight Readiness Review	TBD	TBD
Performance	SRB	TBD	Operational Readiness Review (ORR)	TBD	N/A

### CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT

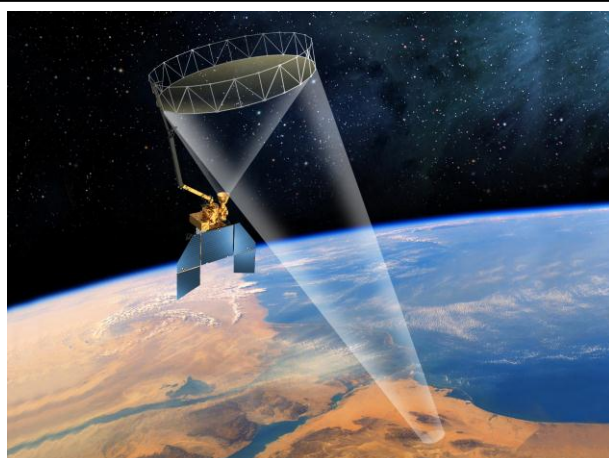
Under Review.

## SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations
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### FY 2015 Budget

	Actual	Enacted	Request	Notional						
Budget Authority (in \$ millions)	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	BTC	Total
Formulation	388.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	388.2
Development/Implementation	124.1	233.2	65.4	63.9	3.5	0.0	0.0	0.0	0.0	490.1
Operations/Close-out	0.0	0.0	0.0	11.0	12.4	11.3	1.7	0.0	0.0	36.4
2014 MPAR LCC Estimate	512.3	233.2	65.4	74.9	15.9	11.3	1.7	0.0	0.0	914.7
Total Budget	512.3	210.3	88.3	74.9	15.9	11.3	11.3	11.3	0.0	935.6
Change from FY 2014				-13.4						
Percentage change from FY 2014				-15.2%						



SMAP has the potential to enable a diverse range of applications involving drought and flood estimation, agricultural productivity estimation, weather forecasting, climate modeling, and other factors affecting human health and security. For example, SMAP can benefit the emerging field of landscape epidemiology where direct observations of soil moisture can provide valuable information on vector population dynamics, such as identifying and mapping habitats for mosquitoes that spread malaria.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

### PROJECT PURPOSE

The Soil Moisture Active and Passive (SMAP) mission will provide a capability for global mapping of soil moisture with unprecedented accuracy, resolution, and coverage.

Future water resources are a critical societal impact of climate change, and scientific understanding of how such change may affect water supply and food production is crucial for policy makers. Uncertainty in current climate models result in disagreement on whether there will be more or less water regionally compared to today. SMAP data will help enable climate

models to be brought into agreement on future trends in water resource availability.

SMAP science objectives are to acquire space-based measurements of surface soil moisture and freeze/thaw state, together termed the hydrosphere state, over a three-year period to:

## SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

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Formulation	Development	Operations
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- Understand processes that link the terrestrial water, energy and carbon cycles;
- Estimate global water and energy fluxes at the land surface;
- Quantify net carbon flux in boreal landscapes;
- Enhance weather and climate forecast skill; and
- Develop improved flood prediction and drought monitoring capabilities.

The SMAP mission is one of four first-tier missions recommended by the National Academies.

For more information, go to: <http://smap.jpl.nasa.gov>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PARAMETERS

The SMAP observatory employs a dedicated spacecraft that will launch into a near-polar, sun-synchronous orbit on an expendable launch vehicle. The SMAP baseline instrument suite includes a radiometer and non-imaging synthetic aperture radar (SAR). The design of the instruments is to make coincident measurements of surface emission and backscatter, with the ability to sense the soil conditions through moderate vegetation cover. The acquisition of data will occur for a period of three years and a comprehensive validation program will assess random errors and regional biases in the soil moisture and freeze/thaw estimates.

### ACHIEVEMENTS IN FY 2013

SMAP successfully passed its KDP-D review in May 2013, and is now integrating and testing the flight system.

### WORK IN PROGRESS IN FY 2014

In FY 2014, SMAP will continue development activities to include integration and testing of all flight systems and conduct the operational readiness review to verify the observatory's readiness for launch.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, SMAP will launch, perform an operational check, and enter into prime mission operations.

## SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations
-------------	-------------	------------

### SCHEDULE COMMITMENTS/KEY MILESTONES

SMAP will launch in March 2015 for a three-year prime mission.

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	Jun 2012	Jun 2012
CDR	Jul 2012	Jul 2012
KDP-D	May 2013	May 2013
Launch	Mar 2015	Mar 2015
End of Prime Mission	Aug 2018	Aug 2018

### Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	485.7	>70	2014	490	1	LRD	Mar 2015	Mar 2015	None

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

### Development Cost Details

In February 2013, the project performed an Estimate at Completion (EAC), which is a standard institutional schedule/cost estimating and project/line review practice. Baseline changes were limited to those areas requiring an update to scope, schedule, and/or cost. As a result, increases in the Aircraft/Spacecraft, Payloads, Ground Systems, and Science/Technology lines occurred to improve plan robustness, mainly for the Reflector Boom Assembly (RBA) and Spin Mechanism Assembly, and offsetting reductions in the Other Direct Project Costs and the Systems Integration and Test (I&T) lines occurred.

## SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation		Development		Operations
Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)	
<b>TOTAL:</b>	<b>485.7</b>	<b>490.0</b>	<b>4.3</b>	
Aircraft/Spacecraft	80.1	91.1	11.0	
Payloads	59.7	91.3	31.6	
Systems I&T	22.3	21.8	-0.5	
Launch Vehicle	123.6	123.6	None	
Ground Systems	24.2	27.7	3.5	
Science/Technology	8.9	10.4	1.5	
Other Direct Project Costs	166.9	124.0	-42.9	

## Project Management & Commitments

JPL has project management responsibility for SMAP.

Element	Description	Provider Details	Change from Baseline
Spacecraft	Provides platform for the instruments	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
L-Band SAR	Combined with Radiometer, provides soil moisture measurements in the top 5 centimeters of soil through moderate vegetation cover	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
L-Band Radiometer	Combined with SAR, provides soil moisture measurements in the top 5 centimeters of soil through moderate vegetation cover.	Provider: GSFC Lead Center: JPL Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Launch Vehicle	Delta II 7320-10C Launch System	Provider: Lead Center: Performing Center(s): Cost Share Partner(s):	N/A

## SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations
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### Project Risks

Risk Statement	Mitigation
If: The accelerated Reflector Boom Assembly development and test schedule cannot be maintained, Then: There is a possibility of a launch readiness date delay.	The relocation of RBA environmental testing to JPL occurred. This reduces the travel time between locations thus mitigating the developmental delays. The addition of resources to both the Reflector Boom Assembly vendor and JPL will help carry out this plan

### Acquisition Strategy

NASA directed the SMAP mission to JPL, with production of the radar and spacecraft as an in-house development, and the radiometer directed to GSFC for in-house development. Procurement of the key components, which are the deployable antenna/boom and instrument spin assemblies, were through open competition. Procurement of the launch service was under the NASA Launch Services II Contract.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Spin Mechanism Assembly	The Boeing Company	El Segundo, CA
Reflector Boom Assembly	Northrop Grumman Aerospace Systems	Carpinteria, CA

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Standing Review Board	Jun 2012	KDP-C Milestone Review	Project approved to enter development	May 2013
Performance	Standing Review Board	May 2013	KDP-D Milestone Review	Project approved to enter integration and test	Aug 2014
Performance	Standing Review Board	Aug 2014	Flight readiness review	TBD	N/A

## GRACE FOLLOW-ON

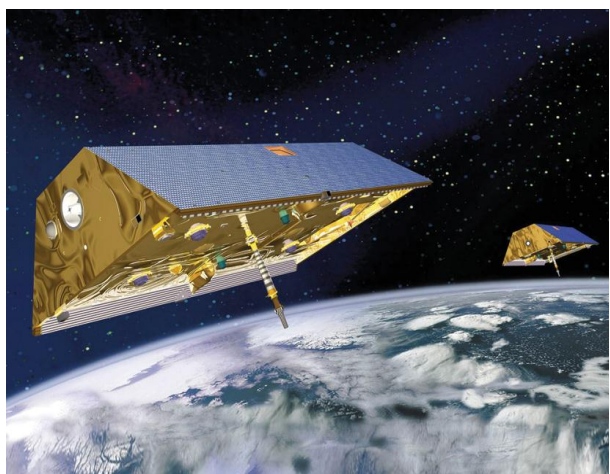
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	50.1	--	64.4	74.3	71.7	20.0	12.0

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Since 2002, the GRACE satellites have been making observations of changes in the Earth's gravity field to gain new insights into the dynamic processes in the planet's interior. The GRACE-Follow On mission will continue with extremely precise measurements taken by the satellite pair (artist's conception shown), which will be used to generate an updated model of the Earth's gravitational field every 30 days. Along with other climate and geo-research efforts, data from GRACE satellites will help scientists build an understanding of the Earth as an integral system.

### PROJECT PURPOSE

The Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) mission will allow scientists to gain new insights into the dynamic processes in Earth's interior, into currents in the oceans, and into variations in the extent of ice coverage. Data from the mission, combined with other existing sources of data, will greatly improve scientific understanding of glaciers, hydrology.

GRACE-FO will obtain the same extremely high-resolution global models of Earth's gravity field, including how it varies over time, as in the original GRACE mission (launched in 2002). The GRACE-FO data is vital to ensuring there is no gap in gravitational field measurements following the currently operating GRACE mission. GRACE-FO includes a partnership with Germany.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PRELIMINARY PARAMETERS

The GRACE-FO observatory employs two dedicated spacecraft that will be launched into a near-circular polar orbit. As the two spacecraft orbit Earth, slight variations in gravity will alter the spacecraft speed

## GRACE FOLLOW-ON

Formulation	Development	Operations
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and distance relative to each other. Scientists use the speed and distance changes to extrapolate and map Earth's gravitational field.

The GRACE-FO instrument suite includes the Microwave Instrument, which accurately measures changes in the speed and distance between the two spacecraft. The accelerometer instrument measures all non-gravitational accelerations (e.g., air drag, solar radiation pressure, attitude control, thruster operation) on each GRACE-FO satellite. The Laser Ranging Interferometer is a technology demonstration and is a partnership between the US and Germany. NASA will use the science data from the GRACE-FO mission to generate an updated model of Earth's gravitational field approximately every 30 days for the five-year lifetime of the mission.

### ACHIEVEMENTS IN FY 2013

During 2013, NASA completed the Interagency Coordination Process for the use of a contributed foreign launch vehicle; this process preceded NASA's concurrence on the selection of a Dnepr launch vehicle in June 2013 by the German Research Centre for Geosciences (GFZ). The GRACE-FO Project also successfully completed the preliminary design reviews for the Microwave Instrument and the Laser Ranging Interferometer in April 2013 and May 2013, respectively.

### WORK IN PROGRESS IN FY 2014

NASA and Germany signed a memorandum of understanding to codify international contributions (launch vehicle, operations, laser ranging instrument, ground data and science processing). The project conducted the preliminary design review for the accelerometer in November 2013, and conducted the spacecraft and mission preliminary design review in January 2014. The project completed its confirmation review, a major project gate review, in February 2014. The project will conduct critical design reviews for the Microwave Instrument, Laser Ranging Interferometer, and the accelerometer in 2014.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

GRACE-FO will undergo its critical design review in January 2015, followed by entry into the integration and test phase in February 2015.

### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	January 2012	January 2012
KDP-B	August 2012	August 2012
KDP-C	February 2014	February 2014



## GRACE FOLLOW-ON

Formulation	Development	Operations
Milestone	Formulation Authorization Document	FY 2015 PB Request
Mission CDR	January 2015	January 2015
Launch	August 2017	August 2017

### Formulation Estimated Life Cycle Cost Range and Schedule Range Summary

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Aug 2012	\$404-\$460	LRD	Aug 2017

### Project Management & Commitments

The Earth Systematic Missions Program at GSFC manages GRACE-FO. NASA has assigned responsibility for implementation to JPL.

Element	Description	Provider Details	Change from Formulation Agreement
Spacecraft	Provides platform for the instruments.	Provider: Astrium GmbH (Germany) Lead Center: N/A Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
Microwave Instrument	Measures the distance between the spacecraft as a function of time	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A

## GRACE FOLLOW-ON

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Accelerometers	Measures all non-gravitational accelerations of the satellite(s)	Provider: French Office National d'Etudes et Recherches Aéronautiques (ONERA) Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
Laser Ranging Interferometer	Heterodyne interferometric laser will measure the distance between the two spacecraft as a function of time	Provider: JPL and the German Research Centre for Geosciences (GFZ) Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): GFZ	N/A
Launch Vehicle	Delivers observatory into Earth orbit.	Provider: Germany Lead Center: JPL Performing Center(s): KSC Cost Share Partner(s): GFZ	N/A

## Project Risks

Risk Statement	Mitigation
If: The development of a MOU to establish international contributions is delayed, Then: It could have a negative impact on project deadlines.	NASA has submitted a draft memorandum of understanding to the U.S. Department of State. After receiving approval by the State Department, NASA will begin formal MOU negotiations with GFZ.

## Acquisition Strategy

The acquisition strategy for GRACE-FO leveraged GRACE heritage by using sole source procurement to the same vendors for major components. NASA has completed all major acquisitions.

## GRACE FOLLOW-ON

Formulation	Development	Operations
-------------	-------------	------------

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Spacecraft	Astrium	Germany
Microwave Instrument Ultra Stable Oscillator	Applied Physics Laboratory-Johns Hopkins University	Laurel, MD
Microwave Assemblies	Space Systems/Loral	Palo Alto, CA
Accelerometers	ONERA	France

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Standing Review Board	Aug 2012	KDP-B Milestone Review	Project approved to enter Phase B of formulation	Feb 2014
Performance	Standing Review Board	Feb 2014	KDP-C Milestone Review	To be determined (TBD)	Jul 2015
Performance	Standing Review Board	Jul 2015	KDP-D Milestone Review	TBD	Jul 2017
Performance	Standing Review Board	Jul 2017	Flight readiness review	TBD	N/A

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Earth Systematic Missions (ESM) Research	\$10.0	--	<b>\$15.8</b>	\$18.6	\$23.8	\$23.8	\$24.0
Ocean Surface Topography Science Team (OSTST)	\$5.8	--	<b>\$6.1</b>	\$6.2	\$5.8	\$5.8	\$5.8
Earth Observations Systems (EOS) Research	\$21.8	--	<b>\$23.1</b>	\$24.1	\$20.4	\$18.4	\$18.7
Deep Space Climate Observatory	\$3.4	--	<b>\$3.7</b>	\$3.2	\$0.0	\$0.0	\$0.0
Stratospheric Aerosol and Gas Experiment III (SAGE III)	\$24.4	--	<b>\$22.1</b>	\$14.1	\$4.8	\$3.9	\$0.0
Surface Water and Ocean Topography Mission	\$17.4	--	<b>\$66.0</b>	\$108.3	\$103.9	\$154.4	\$126.3
Land Imaging	\$0.0	30.0	<b>\$64.1</b>	\$66.1	\$116.7	\$116.7	\$120.0
Decadal Survey Missions	\$26.6	--	<b>\$116.5</b>	\$173.8	\$268.6	\$305.6	\$382.1
Radiation, Ozone, & Atmospheric Measurements (ROAM)	\$0.0	--	<b>\$40.0</b>	\$60.0	\$60.0	\$60.0	\$60.0
Earth Science Program Management	\$22.4	--	<b>\$28.5</b>	\$28.9	\$30.8	\$30.8	\$31.1
Precipitation Science Team	\$7.6	--	<b>\$7.3</b>	\$7.5	\$7.0	\$7.0	\$7.0
Ocean Winds Science Team	\$4.4	--	<b>\$4.5</b>	\$4.6	\$4.3	\$4.3	\$4.3
Land Cover Project Science Office (LCP SO)	\$1.5	--	<b>\$1.5</b>	\$1.6	\$1.5	\$1.5	\$2.8
Quick Scatterometer	\$3.7	--	<b>\$1.8</b>	\$0.0	\$0.0	\$0.0	\$0.0
Tropical Rainfall Measuring Mission (TRMM)	\$10.2	--	<b>\$10.0</b>	\$10.6	\$7.5	\$3.4	\$0.0
Landsat Data Continuity Mission (LDCM)	\$23.6	--	<b>\$2.2</b>	\$2.3	\$2.4	\$2.4	\$0.0
Ocean Surface Topography Mission	\$1.2	--	<b>\$2.1</b>	\$2.2	\$2.2	\$2.2	\$2.2
Suomi National Polar-Orbiting Partnership (Suomi NPP)	\$8.2	--	<b>\$7.3</b>	\$6.3	\$6.2	\$6.3	\$6.3
Terra	\$32.4	--	<b>\$30.8</b>	\$30.3	\$30.7	\$29.8	\$29.8
Aqua	\$33.0	--	<b>\$32.6</b>	\$32.6	\$33.1	\$32.1	\$32.1
Aura	\$27.1	--	<b>\$26.2</b>	\$26.1	\$26.4	\$25.4	\$25.4
Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT)	\$1.3	--	<b>\$0.7</b>	\$0.0	\$0.0	\$0.0	\$0.0
Solar Radiation and Climate Experiment (SORCE)	\$5.2	--	<b>\$3.4</b>	\$0.0	\$0.0	\$0.0	\$0.0
Jason	\$4.6	--	<b>\$0.0</b>	\$0.0	\$0.0	\$0.0	\$0.0
Earth Observing-1	\$2.5	--	<b>\$2.6</b>	\$1.3	\$0.0	\$0.0	\$0.0
<b>Total Budget</b>	<b>298.5</b>	<b>--</b>	<b>518.8</b>	<b>628.4</b>	<b>756.1</b>	<b>833.5</b>	<b>877.7</b>

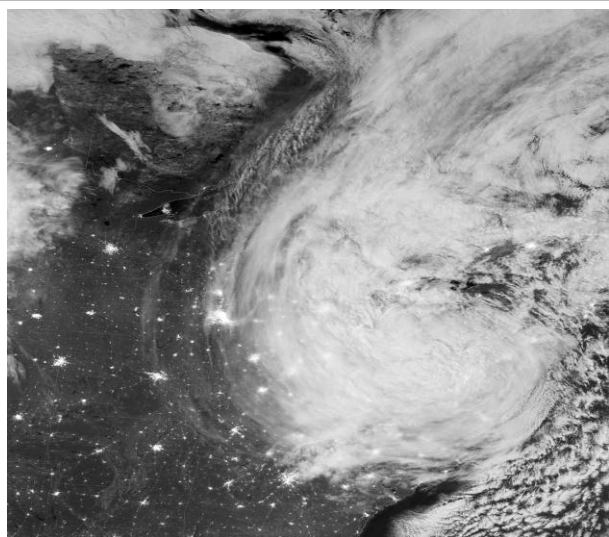
Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Earth Systematic Missions Other Missions and Data Analysis include operating missions and their science teams and competed research projects. Mission science teams define the scientific requirements for their missions and generate algorithms used to process the data into useful data products. The research projects execute competitively selected investigations related to specific mission measurements.



**The Visible Infrared Imaging Radiometer Suite (VIIRS) on NASA/NOAA's Suomi NPP satellite captured this nighttime view of Hurricane Sandy, taken 16 to 18 hours before the storm's landfall. The VIIRS instrument is one of five advanced instruments aboard Suomi NPP that provide observations to help us understand, monitor, and predict long-term climate change as well as short-term weather conditions.**

### Mission Planning and Other Projects

#### **EARTH SYSTEMATIC MISSIONS RESEARCH**

Earth Systematic Missions Research funds various science teams for the Earth Systematic missions. These science teams are composed of competitively selected individual investigators who analyze data from the missions to address the related science questions.

#### **Recent Achievements**

The Suomi National Polar-Orbiting Partnership (NPP) platform, launched in October 2011, carried the first flight models of a series of new environmental sensors. NASA developed these sensors to ensure the continued improvement and continuity of meteorological and other environmental prediction products. During FY 2013, the funded science teams completed their

assessment of the quality of the operational data products regarding their ability to provide continuity to these products.

NASA released initial measurements of the vertical distribution of ozone from the Suomi-NPP satellite Ozone Mapping and Profiler Suite (OMPS) in late 2012. A number of studies used the initial measurements during FY 2013. The OMPS measurements are able to capture the temporal evolution of the Antarctic ozone hole from its formation in early September to its dissolution in late October. In addition, OMPS was able to detect and track global transport of dust produced by the February 15, 2013, explosion of a meteor over Siberia.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### OCEAN SURFACE TOPOGRAPHY SCIENCE TEAM (OSTST)

OSTST uses scientific data from the Ocean Surface Topography Mission (OSTM) and Jason satellites to measure global sea surface height.

#### Recent Achievements

The combined 21-year record of precision altimetry data allowed the mission's science team to make extensive progress in the study of the evolution of seasonal to decadal variability such as El Niño, La Niña, and the Atlantic Meridional Overturning Circulation, as well as the causes for regional and global sea level changes. A 110-year time series of the spatial distribution of Pacific Ocean sea level was made possible by combining precision altimetry, tide gauges and sea surface temperature data with a novel mathematical technique. The global mean sea level curve completely recovered from the two-year dip (2011-12) caused by El Niño-Southern Oscillation and is now back to an upward trend. Altimetry allowed the study of fronts and mixing in the Southern Ocean, yielding a significant advance in the understanding of the dynamics and the fronts in the Antarctic Circumpolar Current. In addition to its many oceanographic applications, radar altimetry has also been instrumental in monitoring rivers and lakes, including a reservoir in southern Afghanistan.

### EARTH OBSERVATION SYSTEMS (EOS) RESEARCH

EOS Research funds science for the EOS missions, currently Terra, Aqua, Aura, Landsat, and ICESat missions. The project competitively selects individual investigators to undertake research projects that analyze data from specific missions. While overall the selected activities focus on science data analyses and the development of Earth system data records including climate data records relevant to NASA's research program, some funded activities continue algorithm improvement and validation for the EOS instrument data products.

#### Recent Achievements

A first measurement-based estimate of the intercontinental transport of minute particles suspended in the atmosphere (aerosols) to North America has been made using NASA mission and model data. Researchers estimate that about half of continental aerosol mass comes from overseas. Researchers use a variety of NASA data to understand the climatic impacts of aerosols and have made progress in quantifying the impact of absorbing aerosols on monsoon circulation and the role of aerosols in convective cloud development.

In the past year, there was an increasing trend in the use of multiple space-based observations at regional and local levels to address issues of societal relevance, like air quality and health. These studies addressed topics such as validating aerosol optical thickness measurements using ground-based instrumentation in Hong Kong for air quality applications, improving the accuracy of daily satellite-derived ground-level fine aerosol concentration estimates for North America, and measuring the range of outdoor fine particulate concentration in the India Subcontinent.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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Researchers compiled a comprehensive record of satellite observations from 2000 through 2011 of total column atmospheric carbon monoxide (CO) using the available measurements from multiple instruments. The researchers examined trends for CO in the Northern and Southern Hemispheres along with regional trends for Eastern China, Eastern USA, Europe, and India. They found that all the satellite observations are consistent with a modest decreasing trend of about -1 percent per year in total column CO over the Northern Hemisphere for this time period with a less significant, but still decreasing trend in the Southern Hemisphere.

### DEEP SPACE OBSERVATORY (DSCOVR)

The DSCOVR mission is a multi-agency (NOAA, U.S. Air Force (USAF), and NASA) mission planned for launch in January 2015 with the primary goal of making unique space weather measurements from the Lagrange point L1. Lagrange point L1 is on the direct line between Earth and the Sun and provides about a 45 minute early warning for adverse space weather events. NASA will deliver the two Earth-observing instruments, the Earth Poly-Chromatic Imaging Camera (EPIC) and the National Institute of Standards and Technology (NIST) Advanced Radiometer (NISTAR), to the DSCOVR satellite and support their integration. NASA will also develop and implement the necessary algorithms to enable the “Earth at noon” images from the satellite once on orbit. DSCOVR will fly aboard the USAF-provided SpaceX Falcon 9 launch vehicle out of Cape Canaveral.

#### Recent Achievements

NASA confirmed that the DSCOVR mission was ready to proceed into the development phase at a major lifecycle review in August 2013. The project is refurbishing the spacecraft and it is almost fully re-integrated, including EPIC and NISTAR instruments. NASA completed the refurbishment of the NISTAR instrument at the original manufacturer.

### STRATOSPHERIC AEROSOL AND GAS EXPERIMENT III- (SAGE III)

SAGE III will provide global, long-term measurements of key components of Earth's atmosphere. The most important of these are the vertical distribution of aerosols and ozone from the upper troposphere through the stratosphere. In addition, SAGE III also provides unique measurements of temperature in the stratosphere and mesosphere and profiles of trace gases such as water vapor and nitrogen dioxide that play significant roles in atmospheric radiative and chemical processes. These measurements are vital inputs to the global scientific community for improved understanding of climate, climate change, and human-induced ozone trends.

To take these measurements, SAGE III relies upon the flight-proven designs used in the Stratospheric Aerosol Measurement (SAM I) and SAGE I and II instruments. NASA is working to deliver SAGE III to the International Space Station (ISS) aboard one of NASA's first commercial SpaceX flights in 2015.

#### Recent Achievements

The SAGE III team completed post-test analysis of the updated instrument flight software in 2013.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### **SURFACE WATER OCEAN TOPOGRAPHY (SWOT)**

The Surface Water and Ocean Topography mission will improve our understanding of the world's oceans and terrestrial surface waters. The mission, through broad swath altimetry, will make high-resolution measurements of ocean circulation, its kinetic energy, and its dissipation. These measurements will improve ocean circulation models leading to better prediction of weather and climate. The mission will also revolutionize knowledge of the surface water inventory on the continents by precise measurement of water levels in millions of lakes and water bodies and the discharge of all major rivers. This will allow for deeper understanding of the natural water cycle and the informed control of this resource.

The 2007 National Academies' decadal survey of Earth Science and the NASA's 2010 Climate Plan endorsed SWOT. The mission will complement the Jason oceanography missions, as well as other NASA missions currently in development to measure the global water cycle (GPM, SMAP, and GRACE-FO). NASA will partner with CNES and CSA to accomplish this mission.

#### **Recent Achievements**

The Ka-band SAR interferometric instrument development progressed on schedule with no significant issues. The mission completed a peer review of science requirements in October 2013.

### **LAND IMAGING**

Unprecedented changes in land cover and land use have profound consequences for weather and climate change, crop monitoring and water management, carbon cycling and sequestration, and many other economic, health, and societal issues. The Landsat data series, begun in 1972, has provided the longest continuous record of changes in Earth's surface as seen from space, and is the only satellite system that is designed and operated to observe repeatedly the global land surface at moderate resolution. Landsat data are available at no cost to those who work in agriculture, geology, forestry, regional planning, education, mapping, and global climate change research.

The successful launch of the NASA-U.S. Geological Study (USGS) Landsat Data Continuity Mission (renamed Landsat-8) mission in February 2013 enables near-term continuation of the 41-year Landsat record. In FY 2014, NASA will meet Congressional and Administration directives to devise an aerospace architecture designed to ensure 20 years of sustained land imaging that will provide data compatible with the past 41 years of Landsat data. As a major part of this effort, a NASA/USGS Sustainable Land Imaging Architecture Team (AST) is examining numerous long-term operational alternatives, in consultation with the Landsat Science Team. Under the architecture plan, NASA will develop Landsat-compatible land-imaging capabilities, while the USGS will continue to fund ground system development, post-launch operations, and data processing, archiving and distribution.

Near-term activities will focus on studies to define the scope, measurement approaches, cost, and risk of a viable long-term land imaging system that will achieve national objectives. Evaluations and design activities will include consideration of stand-alone new instruments and satellites, as well as potential international partnerships. Based on the results of the AST study, the Administration will propose and



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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execute a capable, affordable, sustained system to provide land imaging information for the science and user communities, as a component of the nation's overall spaceborne Earth observation programs.

### Recent Achievements

NASA and the USGS have sponsored industry, research, and user-focused community meetings, as well as a NASA Request for Information (RFI) to support the ongoing Sustainable Land Imaging Architecture Study. A joint-agency AST, including government and external members, is examining a range of realistically cost-constrained measurement approaches and system designs that support near-term continuation of the Landsat data stream as called for in the FY 2014 omnibus appropriation bill, as well as for longer-term solutions.

### DECADAL SURVEY MISSIONS

The Decadal Survey Missions project contains missions recommended by the National Academies' Earth Science decadal study, as well as a variety of climate change missions. All the missions within this project are presently in a pre-formulation phase conducting mission concept studies. The current portfolio of missions under study includes:

- Pre-Aerosol, Clouds, and ocean Ecosystem (PACE), an ocean color/aerosol continuity mission and a bridge to the Decadal Survey's ACE mission);
- NASA- Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR; a derivative of the Decadal Survey's Deformation, Ecosystem Structure and Dynamics of Ice [DESDynI] mission);
- Climate Absolute Radiance and Refractivity Observatory (CLARREO);,
- Active Sensing of CO<sub>2</sub> Emissions over Nights, Days, and Seasons (ASCENDS);
- GEOstationary Coastal and Air Pollution Events (GEO-CAPE);
- Aerosol Cloud Ecosystems (ACE); and
- Hyperspectral Infrared Imager (HypIRI).

### Recent Achievements

The L-Band SAR mission study conducted substantial partnership discussions with ISRO, resulting in an exchange between the NASA and ISRO Administrators of letters of intent to examine a joint NASA-ISRO SAR mission. The dual L-band and S-band NI-SAR mission is expected to pass into formulation in mid-FY 2014.

A competitive ROSES solicitation for the PACE Science Definition Team (SDT) was released in December 2013. The SDT will be selected in 2014. Consistent with the congressional direction in the FY 2014 omnibus appropriations bill, PACE risk reduction and acquisition strategy activities are being carried out in FY 2014 to enable an accelerated launch for the PACE mission, with possible announcements of opportunity for selected mission hardware to be released in FY 2014.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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An additional \$50M investment is proposed under the Opportunity, Growth, and Security Initiative for the PACE mission. Please refer to the OGSi section for more information.

### RADIATION, OZONE, & ATMOSPHERIC MEASUREMENTS (ROAM)

Starting in FY 2014, NASA assumed responsibility for a suite of climate-relevant observations, intended to continue the 30 plus-year data record in ozone profiling, Earth radiation budget, and total solar irradiance. These measurements previously were to be implemented by NOAA with the Radiation Budget Instrument (RBI) and the limb soundings from the Ozone Mapping and Profiler Suite Limb profiler (OMPS-L), on NOAA's Joint Polar Satellite System 2 (JPSS-2) series, as well as the Total Solar Irradiance Sensor 2 (TSIS-2) instrument, flown separately.

NASA began to study options and approaches for economically acquiring these Earth observations, which are crucial to monitor and study the Earth's climate system. During FY 2015, NASA will mature plans for the next suite of instruments. These plans will leverage on-going activities initiated by NOAA for the procurement of OMPS-Limb. NASA will support the procurement of an OMPS-L profiler instrument to be flown as part of the overall OMPS instrument on JPSS-2. NASA will also support the procurement of the RBI, the follow on instrument to the successful Clouds and Earth's Radiant Energy System (CERES) series of instruments. Present plans call for the RBI to fly on the JPSS-2 satellite, with accommodations provided by NOAA through the JPSS program. NASA will also leverage, insofar as possible, previous investments in TSIS-2 instrument development.

### EARTH SCIENCE PROGRAM MANAGEMENT

The Earth Science Program Management budget supports the ESM Program Office at GSFC, the Earth System Science Pathfinder Program Office at LaRC and the Earth Science Flight Project Office at JPL. This budget also supports:

- The GSFC conjunction assessment risk analysis function, which determines maneuvers required to avoid potential collisions between spacecraft and to avoid debris;
- The technical and management support for the international Committee on Earth Observation Satellites, which coordinates civil space-borne observations of Earth. Participating agencies strive to enhance international coordination and data exchange and to optimize societal benefit;
- SRB teams, who conduct independent reviews of the various flight projects in Earth Science; and Earth observing instruments on the ISS, including the Hyperspectral Imager for the Coastal Ocean (HICO), the ISS SERVIR Environmental Research and Visualization System (ISERV), the Cloud-Aerosol Transport System (CATS), the Rapid Scatterometer (Rapid-SCAT), and the Lightning Imaging Sensor (LIS). The support includes some algorithm development and maintenance, data processing, and instrument and observations management.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### PRECIPITATION SCIENCE TEAM

The Precipitation Science Team uses scientific data received from the TRMM satellite to study weather and climate processes. This science team also supports improvements to the TRMM retrieval algorithms and the development of algorithms for the GPM mission. NASA competitively selected the Precipitation Science team in December 2012 with 56 principal investigators and 22 international principal investigators from 14 nations.

#### Recent Achievements

During FY 2013, the team completed the development of the final at-launch algorithms for GPM precipitation products. GPM algorithm production is on schedule for the early 2014 launch of the spacecraft.

In addition, the team performed the Iowa Flood Study field campaign during May to June 2013. The experiment was a ground validation activity to improve retrievals of rainfall that impact flood prediction. Spacecraft, aircraft, and ground-based instruments observed the more than 10 inches of rain that fell during the six-week field campaign. Analysis is underway.

### OCEAN VECTOR WINDS SCIENCE TEAM (OVWST)

OVWST uses scientific data received from the Quick Scatterometer (QuikSCAT) satellite, which measures ocean surface wind vectors by sensing ripples caused by winds near the ocean's surface. From this data, scientists can compute wind speed and direction thus acquiring hundreds of times more observations of surface wind velocity each day than is possible from ships or buoys.

#### Recent Achievements

The OVWST continued to advance the study of the annual variability of the global surface wind field by using QuikSCAT data. The OVWST made progress in characterizing archived scatterometer winds in tropical cyclone (high wind) conditions. The primary use of near-real time QuikSCAT data continues to be calibration of OSCAT (Indian scatterometer data) to extend the Ku-band wind climate record.

### LAND COVER PROJECT SCIENCE OFFICE (LCPSO)

The Land Cover Project Science Office maintains over 40 years of calibration records for the Landsat-1 through Landsat-7 series of satellites. The office also provides community software tools to make it easier for users to work with this data. In collaboration with USGS, LCPSO supports improvements in the Landsat-7 long-term acquisition plan and provision of preprocessed data sets for land-cover change analysis.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

During FY 2013, the Land Cover Project Science Office focused on several activities geared toward improving the quality and quantity of remote sensing data available to the scientific community. These activities included:

- The expanded provision of Commercial Imagery from the National Geospatial-Intelligence Agency archives to approved NASA investigators to support land science;
- The development of methods to merge data from Landsat and the upcoming ESA Sentinel-2 missions. The initial focus is on radiometric correction approaches in collaboration with CNES and University of Maryland; and
- Continued testing and development of a new, operational surface temperature product for Landsat (jointly with USGS, JPL, and Rochester Institute of Technology).

The office maintains science communication on the status of Landsat data and results, including Landsat-8, through the Landsat Science web site: <http://landsat.gsfc.nasa.gov>.

## Operating Missions

### QUICK SCATTEROMETER (QUIKSCAT)

The QuikSCAT mission carries the SeaWinds instrument, originally designed for measuring ocean surface wind speed and direction under nearly all-weather conditions. Since the antenna stopped rotating in 2009, more than seven years past its design life, the sensor became the standard for cross-calibration with other ocean wind scatterometers, enabling the continuation of the high quality, multi-mission ocean winds dataset and their support for accurate operational forecasts. In FY 2015, QuikSCAT extended operations will end and the mission will complete close-out, reprocessing, and documentation of the archival dataset.

### TROPICAL RAINFALL MEASURING MISSION (TRMM)

TRMM measures precipitation, clouds, and lightning over tropical and subtropical regions and extends our knowledge about how the energy associated with rainfall interacts with other aspects of the global climate. The TRMM sensor suite provides a three-dimensional map of storm structure, yielding information on rain intensity and distribution. TRMM launched in 1997. It is a joint mission with Japan. The 2013 Earth Science senior review endorsed the TRMM mission for continued operations through 2015 and preliminarily through 2017. The TRMM satellite fuel supply is running low and, depending on the effects of atmospheric drag on the satellite in the coming years, the satellite may end operations early. The next senior review will occur in 2015, and will re-evaluate the TRMM mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

TRMM completed its 16th year of operations, extending its long-term record of rainfall in the tropics. TRMM continues to provide data on tropical cyclones and heavy rainfall events, including such major storm events as Hurricane Sandy in the Atlantic, Super typhoon Usagi and Typhoon Utor in the Philippines and China, Tropical Storm Manuel and Hurricane Ingrid in Mexico, and monsoon flooding in India.

### LANDSAT DATA CONTINUITY MISSION (LDCM)

The LDCM is the eighth in the Landsat series of satellites that have been continuously observing Earth's land surfaces by recording data since 1972. This data is a key tool for monitoring climate change and led to the improvement of human and biodiversity health, energy and water management, urban planning, disaster recovery, and agriculture monitoring. These improvements offer incalculable benefits to the U.S. and global economies. NASA will continue to provide science activities in support of the USGS and the Landsat Science Team.

### Recent Achievements

Normal operations for this satellite began on May 30, 2013, when the leadership for satellite operations transferred from NASA to USGS. With the hand-off, the name of the satellite changed from the LDCM to Landsat 8. The USGS now manages the satellite flight operations team within the Mission Operations Center, which remains located at NASA's Goddard Space Flight Center in Greenbelt, Md.

Comparison of data from both the Operational Land Imager and Thermal infrared Sensor aboard the Landsat 8 satellite demonstrated the advantage of having sensors using complementary techniques to study the Earth. In FY 2013, having both sensors has been instrumental in the detection of cirrus clouds over Asia near the Aral Sea region, providing information useful to water managers relating to irrigation in California, and discriminating between ash clouds and areas from which lava is oozing from a volcano in Indonesia.

### OCEAN SURFACE TOPOGRAPHY MISSION (OSTM)

OSTM, or Jason-2, measures sea surface height and enables scientists to assess climate variability and change, and water and energy cycles. This mission is a follow-on mission to Jason, which launched in 2008 and recently completed its prime operations phase. OSTM is a joint mission with NOAA, CNES, and European Organisation for the Exploitation of Meteorological Satellites. The 2013 Earth Science senior review endorsed the OSTM mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the OSTM mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

In FY 2013, the full impacts of ocean surface topography information in making the U.S. a “weather-ready” nation have been widely publicized. The data are critical in hurricane intensity forecasting and major environmental catastrophes such as Deep-Water Horizon in the Gulf of Mexico.

### SUOMI NATIONAL POLAR-ORBITING PARTNERSHIP (SUOMI NPP)

Suomi NPP successfully launched in 2011, completed the commissioning and checkout phase in 2012, and successfully transitioned to routine operations under NOAA management on January 28, 2013. NASA and NOAA continue to collaborate during the mission’s five-year prime operations phase (Phase E) to ensure meeting the shared objectives of both agencies. The five instruments on Suomi NPP provide visible and infrared multi-spectral global imagery, atmospheric temperature and moisture profiles, total ozone and stratospheric ozone profiles, and measurements of Earth’s radiation balance. In addition to a wide range of applications studies, the NASA science focus areas served by Suomi NPP include atmospheric composition, climate variability and change, carbon cycle, ecosystems, water and energy cycles, and weather. The first joint annual review of the mission during Phase E is set for early 2014.

### Recent Achievements

Suomi NPP data is publicly available from NOAA, and it is already being used by the National Weather Service in support of the operational weather forecast system. Experimental data products produced by NASA’s Suomi NPP Science Team are also publicly available. To date, the work of the NASA Suomi NPP Science Team focused primarily on evaluation of the sensor data records and environmental data records produced by the NOAA Program as to their suitability for Earth system science. There is ongoing evaluation of these data products, especially for the time series data produced to date. These findings indicate that for most Earth observations, the Suomi NPP instruments are making quality measurements that have the potential to create data products suitable for Earth system science and applications, but that the current operational data products vary greatly in their quality and suitability for Earth system science. The future work of the NASA Suomi Science Team will focus on addressing these data product needs.

### TERRA

Terra is one of the Earth Observing System flagship missions. It enables a wide range of interdisciplinary studies of atmospheric composition, carbon cycle, ecosystems, biogeochemistry, climate variability and change, water and energy cycles, and weather. Terra, launched in 1999, is a joint mission with Japan and Canada. The 2013 Earth Science senior review endorsed the Terra mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the Terra mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

Terra continues its 13-year record from its five instruments. The demand for Terra data is evidenced by the nearly 155 million files delivered and the more than 1,100 peer-reviewed publications in 2012 alone, bringing the total publications for the lifetime of the mission to over 7,600.

### AQUA

Aqua, another of the Earth Observing System flagship missions, also operates in the afternoon constellation of satellites, known as the A-Train. Aqua improves our understanding of Earth's water cycle and the intricacies of the climate system by monitoring atmospheric, land, ocean, and ice variables. Aqua, launched in 2002, is a joint mission with Brazil and Japan. The 2013 Earth Science senior review endorsed the Aqua mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the Aqua mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

### Recent Achievements

The Aqua mission has been extremely successful and its products are widely used by scientists, government agencies, and operational groups. The impressive list of core science products is very mature and stable. Scientific citations of Aqua data now exceed 20,000. The Atmospheric Infrared Sounder (AIRS), Moderate Resolution Imaging Spectroradiometer (MODIS), and Clouds and the Earth's Radiant Energy System (CERES) sensors on Aqua continue to collect valuable science data. This data is used by hundreds of scientists around the world and for a variety of practical applications, including imaging such recent hurricanes as Typhoon Francisco and Hurricane Sandy.

### AURA

The Aura mission enables study of atmospheric composition, climate variability, and weather by measuring atmospheric chemical composition, tropospheric/stratospheric exchange of energy and chemicals, chemistry-climate interactions, and air quality. Aura is also part of the A-Train. Aura launched in 2004. It is a joint mission with the Netherlands, Finland, and the United Kingdom. The 2013 Earth Science senior review endorsed the Aura mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the Aura mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

### Recent Achievements

In FY 2013, a team of scientists from the Microwave Limb Sounder Instrument on NASA's Aura satellite used Microwave Limb Sounder data to investigate a provocative study published in *Science* that convection over North America contributes significant water vapor into the lower stratosphere, and can contribute to the conversion of chlorine into forms that significantly destroy ozone over much of North America in the summer months. This study indeed found significant enhancements of water over North

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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America at this time of year, but found no evidence of the conversion of chlorine or any depletion of ozone associated with the high levels of water. The lower stratospheric temperatures are too warm to drive the conversion, and the available chlorine for conversion are not at the levels required to drive the ozone loss conjectured in the Science paper.

### ACTIVE CAVITY RADIOMETER IRRADIANCE MONITOR SATELLITE (ACRIMSAT)

The ACRIMSAT launched in December 1999 to monitor total solar irradiance, which contributes to assessments of climate variability. Scientists correlate ACRIMSAT data with possible global warming data, ice cap shrinkage data, and ozone layer depletion data. By measuring incoming solar radiation and correlating the radiation with measurements of ocean and atmosphere currents and temperatures, as well as surface temperatures, climatologists improve their predictions of climate and global warming over the next century.

In December 2013, contact with ACRIMSAT was lost owing to degradations in its aging batteries and long eclipse durations in the satellite's orbit. Although ACRIMSAT returned to full sun orbits in early February, 2014, attempts to contact the 14-year old mission have been unsuccessful. In FY 2015, ACRIMSAT extended operations will end and the mission will begin final close-out, reprocessing, and documentation of the archival dataset.

### SOLAR RADIATION AND CLIMATE EXPERIMENT (SORCE)

The SORCE mission measures the total and spectral solar irradiance incident at the top of Earth's atmosphere. SORCE measurements of incoming X-ray, ultraviolet, visible, near-infrared, and total solar radiation help researchers to address long-term climate change, natural variability and enhanced climate prediction, and atmospheric ozone and Ultraviolet-B radiation. These measurements are critical to studies of the Sun, its effect on the Earth system, and its influence on humankind. SORCE, launched in 2003, is in extended operations. The 2013 Earth Science senior review endorsed the SORCE mission for continued operations through 2015, but it recognized that the satellite's aging batteries were highly degraded and that it was unlikely that the mission would be able to survive to 2015. Following final calibration analyses with Total solar irradiance Calibration Transfer Experiment (TCTE) (see "Recent Achievements" below) that will be completed in FY 2014, NASA will re-evaluate continued operation of SORCE.

#### Recent Achievements

In January 2013, SORCE completed 10 years of continuous operation measuring both total solar irradiance (TSI) and solar spectral irradiance (SSI). In 2013, SORCE measured what is apparently the Sun's solar maximum, during what is considered the weakest solar cycle in the past century. In late December 2013, accurate SORCE solar measurements were acquired in conjunction with those of the recently launched NOAA/NASA/USAF TCTE mission. Comparisons between the SORCE and TCTE data allow the precision calibration of the SORCE mission to carry over to TCTE, which will become the nation's primary source of accurate solar irradiance information.



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### JASON

The Jason mission makes precise measurements of ocean height to support the study of ocean circulation and sea level rise. Jason enables oceanographers to monitor global ocean circulation, improve global climate predictions, and monitor events such as El Niño conditions and ocean eddies. Jason, launched in 2001, is a collaboration between NASA and CNES. The 2011 Earth Science senior review endorsed the Jason mission for continued operations through 2013 and preliminarily through 2015; however, the satellite failed in early 2013.

#### Recent Achievements

The remaining transmitter on the Jason satellite stopped operating on June 21, 2013 due to a non-recoverable failure. Jason-1 was decommissioned in July 2013 after almost 12 years in orbit – 4 times the nominal lifetime. The mission closeout and final dataset delivery is scheduled for Oct 1, 2014.

From 2001 to 2013, Jason-1 provided an essential contribution to the monitoring of sea level rise. This was due to its excellent measurement accuracy, long-term stability, and continuous effort toward calibration and validation performed on the ground. The major accomplishment of FY 2013 was the completion of a 406-day full global mapping leading to improved ocean bottom topography maps and discovery of some new seamounts.

### EARTH OBSERVING-1 (EO-1)

The EO-1 satellite is an advanced land-imaging mission with relevance to various areas of Earth Science, including carbon cycle, ecosystems, biogeochemistry, and Earth surface and interior. EO-1, launched in 2000, is in extended operations. The 2013 Earth Science senior review endorsed the EO-1 mission for continued operations through 2015 and preliminarily through 2017. The EO-1 satellite fuel is running very low, and it is likely the satellite will run out of fuel before the end of FY 2015. The next senior review will occur in 2015, and will re-evaluate the EO-1 mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

#### Recent Achievements

The EO-1 mission continues to make numerous valuable contributions to the Earth Science community. Data from instruments and sensors aboard EO-1 enabled scientists and the international research community to observe evolving trends in Earth's physical phenomena. EO-1 identified, located, and imaged phenomena, such as wildfires, volcanoes, floods, and ice breakup with high-resolution instruments.

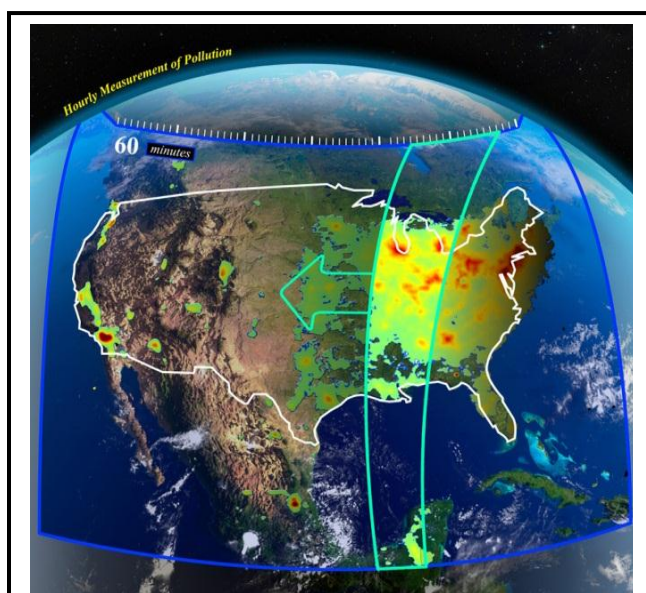
## EARTH SYSTEM SCIENCE PATHFINDER

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
OCO-2	80.3	81.2	21.0	12.5	7.9	12.0	12.0
Venture Class Missions	51.5	--	206.6	163.6	185.1	200.0	189.7
Other Missions and Data Analysis	44.8	--	38.5	33.5	34.0	31.2	30.2
<b>Total Budget</b>	<b>176.7</b>	<b>--</b>	<b>266.1</b>	<b>209.5</b>	<b>227.0</b>	<b>243.2</b>	<b>231.9</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA's newly selected Earth Venture Class project, the Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission, will be led by a team that includes partnerships with NASA Centers, the Environmental Protection Agency, industry, academia and research organizations. TEMPO will track ozone, aerosols and other trace gases over North America to gauge how pollution affects climate change and air quality.

The Earth System Science Pathfinder (ESSP) program provides an innovative approach to Earth science research by providing frequent, regular, competitively selected opportunities that accommodate new and emerging scientific priorities and measurement capabilities. This results in a series of relatively low-cost, small-sized investigations and missions. Principal investigators whose scientific objectives support a variety of studies lead these missions, including studies of the atmosphere, oceans, land surface, polar ice regions, or solid Earth.

ESSP projects include space missions and remote sensing instruments for space-based missions of opportunity or extended duration airborne science missions. The ESSP program also supports the conduct of science research utilizing data from these missions. ESSP projects often involve partnerships with other U.S. agencies and/or international organizations. This portfolio of missions and investigations provides opportunity for investment in innovative Earth science that enhances NASA's capability for better understanding the current state of the Earth system.

## **EARTH SYSTEM SCIENCE PATHFINDER**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

NASA provided additional extended mission funding to GRACE and CloudSat, per recommendations from the 2013 Senior Review. Work on the Orbiting Carbon Observatory 3 (OCO-3) instrument will cease in FY 2014.

**OCO-2**

Formulation	Development		Operations	
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**FY 2015 Budget**

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	60.9	0.0	0.0	<b>0.0</b>	0.0	0.0	0.0	0.0	0.0	60.9
Development/Implementation	212.6	80.3	74.1	<b>4.6</b>	0.0	0.0	0.0	0.0	0.0	371.6
Operations/Close-out	0.0	0.0	7.1	<b>16.4</b>	11.3	0.2	0.0	0.0	0.0	35.0
<b>2014 MPAR LCC Estimate</b>	<b>273.5</b>	<b>80.3</b>	<b>81.2</b>	<b>21.0</b>	<b>11.3</b>	<b>0.2</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>467.5</b>
<b>Total Budget</b>	<b>273.5</b>	<b>80.3</b>	<b>81.2</b>	<b>21.0</b>	<b>12.5</b>	<b>7.9</b>	<b>12.0</b>	<b>12.0</b>	<b>0.0</b>	<b>500.4</b>
Change from FY 2014				<b>-60.2</b>						
Percentage change from FY 2014				<b>-74.1%</b>						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Orbiting Carbon Observatory-2 (OCO-2) is comprised of a single instrument that flies on a dedicated spacecraft. The instrument, consisting of three high resolution grating spectrometers, will acquire precise measurements of atmospheric carbon dioxide. This image shows OCO-2 Observatory going into thermal vacuum testing.

**PROJECT PURPOSE**

Since the beginning of the industrial age, the concentration of carbon dioxide (CO<sub>2</sub>) in the Earth's atmosphere increased more than 38 percent. Scientific studies indicate that CO<sub>2</sub> is one of several greenhouse gases that trap heat near the Earth's surface. Most scientists have concluded that substantial increases in CO<sub>2</sub> in the atmosphere will increase the Earth's surface temperature, referred to as global warming.

From its vantage point in Earth orbit, OCO-2 will measure the CO<sub>2</sub> levels across the globe, collecting data on how CO<sub>2</sub> is distributed. With this data, scientists will have better insight into how much of the Earth's CO<sub>2</sub> is from natural sources and how much is man-made. This information may help decision makers determine the best ways to reduce man's impact on the environment.

**OCO-2**

Formulation	Development	Operations
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**EXPLANATION OF MAJOR CHANGES IN FY 2015**

None

**PROJECT PARAMETERS**

The OCO-2 spacecraft will carry three high-resolution grating spectrometers and fly in the A-train of Earth-observing satellites. The Observatory will acquire data in three different measurement modes. In "nadir mode," the instrument views the ground directly below the spacecraft. In "glint mode," the instrument tracks near the location where sunlight is directly reflected on Earth's surface. Glint mode enhances the instrument's ability to acquire highly accurate measurements, particularly over the ocean. In "target mode," the instrument views a specified surface target continuously as the satellite passes overhead. Target mode provides the capability to collect a large number of measurements over sites where ground based and airborne instruments measure atmospheric CO<sub>2</sub>. The Observatory has a planned operational life of two years.

**ACHIEVEMENTS IN FY 2013**

NASA completed spacecraft development and integrated the instrument with the spacecraft. The project began the series of environmental tests needed to ensure the spacecraft will operate successfully in space.

**WORK IN PROGRESS IN FY 2014**

The project continues to conduct a series of environmental tests on the spacecraft and instrument in preparation for launch.

**KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The project will launch and begin prime mission operations.

**SCHEDULE COMMITMENTS/KEY MILESTONES**

Milestone	Confirmation Baseline Date	FY 2015 PB Request
CDR	Aug 2010	Aug 2010
KDP-C	Sep 2010	Sep 2010
SIR	May 2012	May 2012
KDP-D	Jun 2012	Jun 2012
Re-baseline	N/A	Nov 2012
Launch	Feb 2015	Feb 2015

**OCO-2**

Formulation	Development	Operations
Milestone	Confirmation Baseline Date	FY 2015 PB Request
End of Prime Mission	May 2017	May 2017

**Development Cost and Schedule**

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	371.6	70	2014	371.6	0	LRD	Feb 2015	Feb 2015	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

**Development Cost Details**

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>371.6</b>	<b>371.6</b>	<b>0</b>
Aircraft/Spacecraft	68.3	70.8	2.5
Payloads	51.7	56.9	5.2
Systems I&T	5.6	5.5	-0.1
Launch Vehicle	136.8	136.8	0
Ground Systems	8.8	11.5	2.7
Science/Technology	17.0	18.3	1.3
Other Direct Project Costs	83.4	71.8	-11.4

**OCO-2**

<b>Formulation</b>	<b>Development</b>	<b>Operations</b>
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**Project Management & Commitments**

JPL has project management responsibility for OCO-2.

<b>Element</b>	<b>Description</b>	<b>Provider Details</b>	<b>Change from Baseline</b>
OCO-2 instrument	Three high-resolution grating spectrometers will acquire precise measurements of atmospheric CO <sub>2</sub> .	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
Spacecraft	Provides platform for the instrument.	Provider: Orbital Sciences Corporation Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
Ground System	Provides mission operations for satellite.	Provider: Orbital Sciences Corporation Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
Launch Vehicle	Delta II launches observatory into low Earth orbit.	Provider: United Launch Alliance Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A	Original launch vehicle was Taurus XL

**Project Risks**

<b>Risk Statement</b>	<b>Mitigation</b>
If: The launch vehicle development is delayed or mandates spacecraft changes for accommodation, Then: Mission cost will increase.	Program reserves are budgeted by NASA to accommodate cost increases and launch delays to the extent that the current JCL is at 70 percent.
If: A single-string component fails Then: Potential loss of mission.	The project designed OCO-2 (based on the original competed OCO design) to have some single-string components. Thorough analyses and testing are being performed to mitigate this risk as much as possible.

**OCO-2**

Formulation	Development	Operations
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**Acquisition Strategy**

NASA procured OCO-2 as a single source selection from JPL in order to maintain the same configuration as the previous OCO mission.

**MAJOR CONTRACTS/AWARDS**

Element	Vendor	Location (of work performance)
Spacecraft	Orbital Sciences Corporation	Gilbert, AZ
Launch Vehicle	United Launch Alliance	Vandenberg Air Force Base, CA

**INDEPENDENT REVIEWS**

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	May 2012	To determine readiness to proceed to observatory-level integration and test.	Project was approved to proceed into integration and test phase.	Nov 2012
Performance	SRB	Nov 2012	Rebaseline review of project plans to accommodate cost and schedule impacts of new launch vehicle	New plan approved; project will continue development	Apr 2014
Performance	SRB	Apr 2014	Flight readiness review to determine project readiness to launch	TBD	N/A

**CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT**

Pursuant to Section 103(c) of the NASA Authorization Act of 2005, NASA notified the Committees of an anticipated schedule delay of more than six months and development cost exceeding 15 percent of the baseline on July 25, 2012, as a result of replacing the planned launch vehicle, the Taurus XL. NASA terminated the Taurus XL contract due to the failure of an identical launch vehicle carrying the Glory mission. NASA has since awarded a launch services contract to United Launch Alliance for a Delta II launch vehicle.



## OCO-2

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Formulation	Development	Operations
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NASA completed an independent replan review in November 2012 of the OCO-2 Project to incorporate losses from the terminated Taurus-XL launch vehicle contract, new costs for the Delta-II launch vehicle, modifications to adapt the spacecraft and other systems to the new launch vehicle, and the associated delays for this launch service vendor change. The proposed replanned cost and schedule commitment are compliant with the 70 percent confidence level consistent with NASA policies. The proposed new mission plan was presented to and approved by the NASA Science Mission Directorate Associate Administrator (AA) and Directorate Program Management Council (DPMC) on January 16, 2013, and the final mission cost and schedule was included in the FY 2014 President's Budget Request.

The current projected OCO-2 launch readiness date is February 2015. The development cost estimate is \$371.6 million and the lifecycle cost estimate (excluding extended operations) is \$467.5 million. These cost and schedule commitments are unchanged from the FY 2014 President's Budget Request.

## VENTURE CLASS MISSIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>51.5</b>	<b>--</b>	<b>206.6</b>	<b>163.6</b>	<b>185.1</b>	<b>200.0</b>	<b>189.7</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE)** is one of five Earth Venture Suborbital missions utilizing airborne observations integrated with data from ground-based sites to fill a critical gap in Earth science knowledge. CARVE works to understand the fundamental elements of the complex Arctic biological-climatologic-hydrologic system. During 2013, CARVE flew over 260 science flight hours on the C-23 aircraft (shown above). The flights collected approximately 1.5 Terrabytes of data on important greenhouse gases such as carbon dioxide and methane.

NASA's Earth Venture Class project provides frequent flight opportunities for high-quality Earth science investigations that are low cost and that can be developed and flown in five years or less. NASA will select the investigations through open competitions to ensure broad community involvement and encourage innovative approaches. Successful investigations will enhance our capability to understand the current state of the Earth system and to enable continual improvement in the prediction of future changes. Solicitations will alternate between space-borne and airborne/suborbital opportunities.

NASA established the Venture Class project in response to recommendations in the National Academies' report, "Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond."

The Earth Venture Class project consists of three different types of activities:

- Earth Venture Suborbital (EVS) are sustained suborbital science investigations. Each solicitation is capped at \$150 million in FY 2014 dollars, and NASA will select multiple investigations within each call, individually cost capped at \$30 million. The EVS solicitations will be made at four-year intervals;
- Earth Venture small Missions (EVM) are small space-based missions. Each solicitation is cost capped at \$150 million in FY 2014 dollars. The EVM solicitations will be made at four-year intervals; and
- Earth Venture Instruments (EVI) are to be flown on space-borne platforms, which NASA will select. Each solicitation is cost capped at \$90 million in FY 2014 dollars. The EVI solicitations will be made at no more than 18-month intervals.

## **VENTURE CLASS MISSIONS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

Cyclone Global Navigation Satellite System (CYGNSS) successfully completed its mission design review and NASA approved the project for entry into Phase B of formulation in July 2013. NASA selected the first EVI instrument (TEMPO) in November 2012. All five EVS-1 missions collected critical data for their investigations. These data span from below the surface of the earth to 65,000 feet and were collected using seven different aircraft spread across North and Central America as well as the Atlantic and Pacific Oceans.

NASA released the EVI-2 and EVS-2 Announcements of Opportunity, with the proposals due in November 2013 and January 2014, respectively.

### **WORK IN PROGRESS IN FY 2014**

CYGNSS is currently working toward PDR with the associated confirmation review planned for the second quarter of FY 2014. The EVS-1 investigations continue in FY 2014, with the aircraft deployed to the same locations as 2013. Additionally, a NASA Global Hawk aircraft deployment to Guam will support the ATTREX mission. Each investigation will collect approximately 200 hours of science data over the course of a campaign year. NASA will assess the readiness of the TEMPO mission to proceed into Phase B of formulation. NASA will evaluate and select the winning proposals from the EVI-2 and EVS-2 calls.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

CYGNSS is planning to complete its CDR in the second quarter of FY 2015. In 2015, the focus for the EVS-1 missions will shift to analyzing the data collected by investigations during the prior several years. Both CARVE and AirMOSS will continue data collection into FY 2015. The TEMPO mission will make the transition from formulation into implementation and the host platform will be selected for the mission. The winning proposal from the EVI-2 call will continue in formulation and likely transition into Phase B, and the winning selections from the EVS-2 call will prepare for their initial field campaigns.

## **VENTURE CLASS MISSIONS**

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### **Program Elements**

#### **EARTH VENTURE SUBORBITAL -1 (EVS-1, SELECTED IN 2010) INVESTIGATIONS INCLUDE:**

- Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) addresses the uncertainties in existing estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems;
- Airborne Tropical Tropopause Experiment (ATTREX) studies chemical and physical processes at different times of year from bases in California, Guam, Hawaii, and Australia;
- Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) collects an integrated set of data that will provide experimental insights into Arctic carbon cycling, especially the release of the important greenhouse gases such as carbon dioxide and methane;
- Deriving Information on Surface Conditions from Column and VERTically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) improves the interpretation of satellite observations to diagnose near-surface conditions relating to air quality; and
- Hurricane and Severe Storm Sentinel (HS3) studies hurricanes in the Atlantic Ocean basin using two NASA Global Hawks flying high above the storms for up to 30 hours.

#### **EARTH VENTURE MISSION -1 (EVM-1, SELECTED IN 2012)**

CYGNSS will make accurate measurements of ocean surface winds throughout the life cycle of tropical storms and hurricanes, which could lead to better weather forecasting. CYGNSS data will enable scientists to probe from space key air-sea interaction processes that take place near the inner core of the storms, which are rapidly changing and play large roles in the genesis and intensification of hurricanes. The CYGNSS measurements also will provide information to the hurricane forecast community, potentially enabling better modeling to predict the strength of hurricanes as they develop. CYGNSS is currently in formulation and will launch in 2017.

CYGNSS's eight micro-satellite observatories will receive both direct and reflected signals from Global Positioning System (GPS) satellites. The direct GPS signals pinpoint CYGNSS observatory positions, while the reflected signals are indicative of ocean surface roughness; scientists will use both measurements to derive the critical measurement of wind speed.

#### **EARTH VENTURE INSTRUMENT-1 (EVI-1, SELECTED IN 2012)**

The Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument will measure atmospheric pollution covering most of North America. The instrument will be mounted on a commercial communications satellite launching in 2017. On an hourly basis, TEMPO will measure atmospheric pollution from Mexico City to the Canadian tar/oil sands and from the Atlantic to the Pacific. TEMPO will provide measurements that include the key elements of air pollution chemistry, such as ozone, nitrogen dioxide, and sulfur dioxide, in the lowest part of the atmosphere. Measurements will be from geostationary (GEO) orbit, to capture the inherent high variability in the daily cycle of emissions and chemistry. Measuring across both time and space will create a revolutionary dataset that provides understanding and improves prediction of air quality and climate forcing. The project will procure the

## VENTURE CLASS MISSIONS

commercial host spacecraft through a competitive procurement process that NASA is developing in coordination with the USAF Space and Mission Command (SMC).

### Program Schedule

Date	Significant Event
2013	EVI-2 (instrument) solicitation released
2013	EVS-2 (suborbital) solicitation released
Feb 2014	CYGNSS Confirmation Review
2014	EVI-3 (instrument) solicitation released
2015	EVI-4 (instrument) solicitation released
2015	EVM-2 (mission) solicitation released
Aug 2014	TEMPO Confirmation Review
2016	EVI-5 (instrument) solicitation released
May 2017	CYGNSS launch readiness
2017	EVI-6 (instrument) solicitation released
2017	EVS-3 (suborbital) solicitation released

### Program Management & Commitments

The ESSP program manages Venture Class missions and investigations, and assigned responsibility for implementation to the ESSP Program Manager at LaRC.

Program Element	Provider
EVS-1: AirMOSS	Provider: University of Michigan, JPL Lead Center: LaRC Performing Center(s): LaRC Cost Share Partner(s): N/A
EVS-1: ATTREX	Provider: ARC Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A

## VENTURE CLASS MISSIONS

Program Element	Provider
EVS-1: CARVE	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A
EVS-1: DISCOVER-AQ	Provider: LaRC Lead Center: LaRC Performing Center(s): LaRC Cost Share Partner(s): N/A
EVS-1: H3	Provider: GSFC, ARC Lead Center: GSFC, ARC Performing Center(s): GSFC, ARC Cost Share Partner(s): N/A
EVM-1: CYGNSS	Provider: University of Michigan Lead Center: LaRC Performing Center(s): LaRC Cost Share Partner(s): N/A
EVI-1: TEMPO	Provider: Smithsonian Astrophysical Observatory Lead Center: LaRC Performing Center(s): LaRC, GSFC Cost Share Partner(s): N/A

## Acquisition Strategy

NASA anticipates issuing a solicitation for a Venture Class element at least once a year. NASA will award all Venture Class funds through full and open competition.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
CYGNSS: project management, development, integration and mission operations	Southwest Research Institute	San Antonio, TX
TEMPO: development of instrument (ultraviolet-visible spectrometer)	Ball Aerospace & Technologies Corp.	Boulder, CO

## VENTURE CLASS MISSIONS

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Jul 2013	CYGNSS Mission Design Review	Project approved to enter Phase B of formulation	Jan 2014
Performance	SRB	Jan 2014	CYGNSS PDR	TBD	2016
Performance	SRB	Jan 2015	CYGNSS CDR	TBD	N/A
Performance	SRB	Q4 FY 2016	CYGNSS ORR	TBD	N/A
Performance	SRB	Dec 2013	Determine readiness of TEMPO to enter Phase B	TBD	Oct 2014
Performance	SRB	Oct 2014	TEMPO PDR	TBD	Jun 2017
Performance	SRB	Jun 2017	TEMPO CDR	TBD	Q3 FY 2018
Performance	SRB	Q3 FY 2018	TEMPO ORR	TBD	N/A

## OTHER MISSIONS AND DATA ANALYSIS

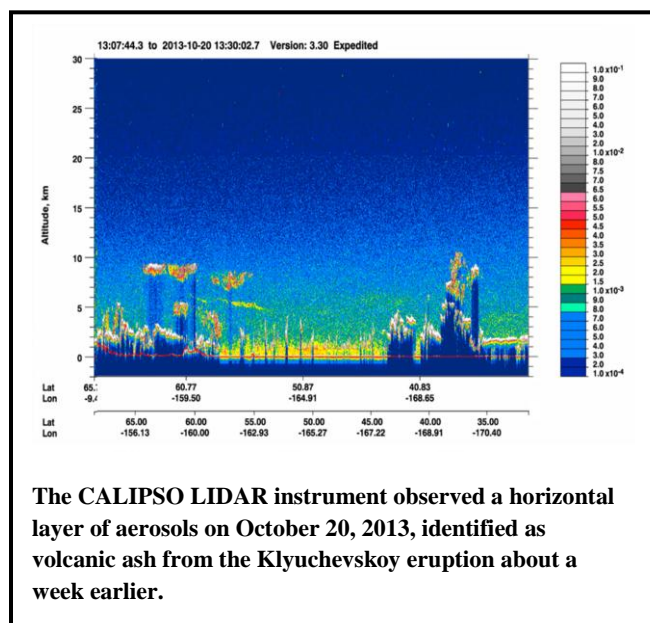
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Orbiting Carbon Observatory-3	7.4	--	0.0	0.0	0.0	0.0	0.0
ESSP Missions Research	12.6	--	13.4	13.9	15.6	17.6	17.8
Aquarius	4.7	--	5.1	5.3	5.3	5.3	5.3
Gravity Recovery and Climate Experiment (GRACE)	5.4	--	5.1	3.1	2.0	1.2	0.0
Cloudsat	8.1	--	8.0	4.2	3.9	0.0	0.0
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)	6.6	--	6.9	7.0	7.1	7.1	7.1
<b>Total Budget</b>	<b>44.8</b>	<b>--</b>	<b>38.5</b>	<b>33.5</b>	<b>34.0</b>	<b>31.2</b>	<b>30.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Earth System Science Pathfinder (ESSP) Other Missions and Data Analysis projects include operating missions and mission-specific research. These innovative missions will enhance understanding of the current state of the Earth system and enable continual improvement in the prediction of future changes.

### Mission Planning and Other Projects

#### OCO-3

OCO-3 was to be a space instrument designed to measure atmospheric concentrations of carbon dioxide. OCO-3 was to be assembled from

OCO-2 flight spare parts and flown on the ISS as an attached payload. In light of other planned spaceborne carbon dioxide measurement missions, the development of OCO-3 will cease, and no funds are requested for OCO-3 in FY 2015. The current designs and OCO-2 spare hardware will be stored and



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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held in reserve for potential future application as the measurements from the OCO-2 satellite are made and analyzed.

A \$29M investment is proposed under the Opportunity, Growth, and Security Initiative for OCO-3. Please refer to the OGSi section for more information.

### ESSP MISSIONS RESEARCH

ESSP Missions Research provides funds for the science teams supporting ESSP operating missions. The science teams are comprised of competitively selected individual investigators who analyze data from the missions to address relevant science questions.

#### Recent Achievements

During FY 2013, scientists used the observations from the GRACE satellite mission to evaluate freshwater storage trends in the north-central Middle East, including portions of the Tigris and Euphrates River Basins and western Iran, from January 2003 to December 2009. GRACE data show an alarming rate of decrease in total water storage over the course of the study period.

Significant improvements have been made in our ability to quantify mass losses from glaciers distinct from the Greenland and Antarctic ice sheets. For the first time, scientists combined conventional ground observations with data from the GRACE and ICESat satellites to obtain a single consensus estimate of their contribution to sea level rise. Estimates of mass loss from these glaciers, extrapolated from ground data along center flowlines, exceed the losses determined from satellites, suggesting pre-satellite era estimates need to be revised toward smaller magnitudes of mass loss.

### Operating Missions

#### AQUARIUS

The Aquarius spacecraft observes and models seasonal and year-to-year variations of sea-surface salinity and how these variations relate to changes in the water cycle and ocean circulation. The mission provides the first global observations of sea surface salinity, scanning the surface of Earth once every seven days. In its three-year mission life, Aquarius will collect as many sea surface salinity measurements as the entire 125-year historical record obtained from ships and buoys. The NASA-provided Aquarius instrument is flying on the Satellite for Scientific Applications-D (SAC-D) spacecraft, which is operated by the Argentine space agency, Comisión Nacional de Actividades Espaciales (CONAE). Aquarius launched in June 2011 and is currently in prime mission operations.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

In 2013, Aquarius salinity measurements contributed to the ocean climate assessment of 2012. Monthly salinity maps from Aquarius data show detailed and robust seasonal variations in the tropics, providing new insights on air-sea freshwater fluxes seasonal cycle

### GRAVITY RECOVERY AND CLIMATE EXPERIMENT (GRACE)

GRACE measures minute changes in Earth's gravity field by measuring micron-scale variations in the separation between the two spacecraft that fly in formation 220 kilometers apart in low Earth orbit. Local changes in Earth's mass cause the variations in gravitational pull. GRACE demonstrated a new paradigm of observations that utilizes ultra-small variations of Earth's gravity field, as small as one-billionth the surface force of gravity. With this capability, GRACE was the first mission to provide a comprehensive measurement of the monthly change in the ice sheets and major glaciers. GRACE provided significant new information on changes in water resources within river basins and aquifers worldwide, and measured the effects of major earthquakes around the world. NASA developed the twin GRACE satellites in collaboration with German Aero-Space Center (DLR), and launched in 2002.

The 2013 Earth Science senior review endorsed the GRACE mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the GRACE mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

### Recent Achievements

NASA scientists and university collaborators analyzed observations from the GRACE mission to evaluate freshwater storage trends in the north-central Middle East, including portions of the Tigris and Euphrates river basins and western Iran, from January 2003 to December 2009.

### CLOUDSAT

CloudSat measures cloud characteristics to increase understanding of the role of clouds in Earth's radiation budget. This mission specifically provides estimates of the percentage of Earth's clouds that produce rain, provides vertically-resolved estimates of how much water and ice are in Earth's clouds, and estimates how efficiently the atmosphere produces rain from condensates. CloudSat is collecting information about the vertical structure of clouds and aerosols that other Earth-observing satellites do not collect. This data is improving models and providing a better understanding of the human impact on the atmosphere. CloudSat launched in 2006. It is currently in extended operations.

The 2013 Earth Science senior review endorsed the CloudSat mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the CloudSat mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

The CloudSat data are increasingly being used not only to evaluate model performance in representing storms in weather forecasts and in representing cloud processes in climate models, but more specifically CloudSat data are instrumental in improving the representation of rainfall and snowfall in models. The measurement of snowfall is a unique capability of CloudSat, and this information has revealed important changes to ice mass distributions in the Antarctic. The CloudSat observations of snowfall linked to observations of gravity field changes observed by the NASA GRACE mission reveal that major increases in ice mass over the Eastern portion of Antarctica from 2009-2010 is a result of increased storminess that brought heavy snowfall into the region.

### CLOUD-AEROSOL LIDAR AND INFRARED PATHFINDER SATELLITE OBSERVATION (CALIPSO)

CALIPSO provides data on the vertical structure of clouds, the geographic and vertical distribution of aerosols and detects sub visible clouds in the upper troposphere. CALIPSO also provides an indirect estimate of how much clouds and aerosols contribute to atmospheric warming. CALIPSO launched in 2006. It is in extended operations.

The 2013 Earth Science senior review endorsed the CALIPSO mission for continued operations through 2015 and preliminarily through 2017. The next senior review will occur in 2015, and will re-evaluate the CALIPSO mission extension in terms of scientific value, national interest, technical performance, and proposed cost in relation to NASA Earth Science strategic plans.

### Recent Achievements

Atmospheric aerosols can affect Earth's radiation balance, the formation of clouds and precipitation, the chemical composition of the atmosphere, and pose a health risk when pollution levels rise. CALIPSO is providing the first comprehensive three-dimensional measurement record of aerosols, helping to better understand how aerosols form, evolve and are transported over the globe.

CALIPSO data contributed in recent studies assessing how Asian dust flows into North America each spring, how particles with black carbon from smoke from fires in Africa can warm the atmosphere, and how relatively modest volcanic eruptions can affect climate by reducing incoming solar radiation. These data are further aiding the development of air quality models used to assess health concerns and volcanic plume dispersion models used by flight planners to avoid hazardous flying conditions.

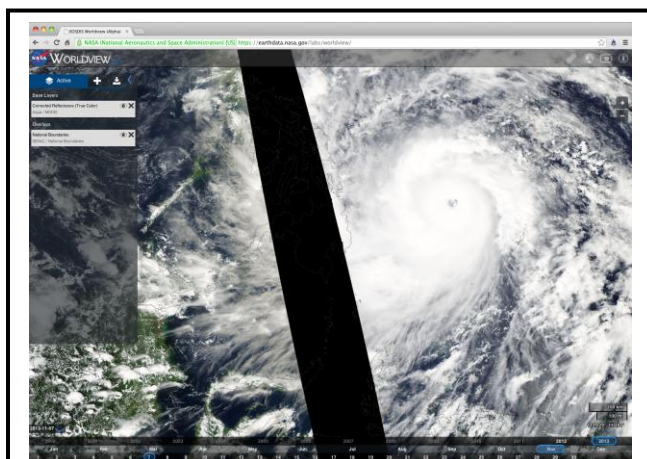
## EARTH SCIENCE MULTI-MISSION OPERATIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>162.2</b>	<b>--</b>	<b>176.1</b>	<b>179.6</b>	<b>181.0</b>	<b>183.2</b>	<b>183.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The NASA Worldview website shows users Super Typhoon Haiyan as it approaches the Philippines on November 7, 2013. This example shows the use of imagery acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument on NASA's Aqua satellite. This imagery shows the extent of the storm system and a clearly defined eyewall.

The Earth Science Multi-Mission Operations (MMO) program acquires, preserves, and distributes observational data from operating spacecraft to support Earth Science research focus areas. This is accomplished primarily by the Earth Observing System Data and Information System (EOSDIS), which has been in operations since 1994. EOSDIS acquires, processes, archives, and distributes Earth Science data and information products. The team creates these products from satellite data that arrives at the rate of more than four terabytes per day.

The archiving of NASA Earth Science information happens at eight Distributed Active Archive Centers (DAACs) and four disciplinary data centers located across the United States. The DAACs specialize by topic area, and make their data available to researchers around the world.

The MMO budget supports the science data Segment for Suomi NPP, and data archive and distribution for upcoming missions including OCO-2, SMAP, GPM, and ICESat-2. EOSDIS data centers also support Earth Science suborbital campaigns. A system plan for 2015 and beyond will take into account evolutionary needs for new missions in development, in response to the National Academies decadal survey. These investments will enable the system to keep technologically current, and incorporate new research data and services.

For more information, go to: <http://www.science.nasa.gov/earth-science/earth-science-data/>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

## **EARTH SCIENCE MULTI-MISSION OPERATIONS**

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### **ACHIEVEMENTS IN FY 2013**

NASA EOSDIS expanded its capabilities to support the increasing suborbital campaign data, including IceBridge and the EV-1 campaigns. Previous plans had been insufficient to cover these campaigns, which have the challenges of a large variety of instruments and the tailoring of discovery and access services to the unique nature of aircraft missions. EOSDIS enabled provision of data from the Moderate Resolution Imaging Spectroradiometer, Atmospheric Infrared Sounder, Microwave Limb Sounder, and Ozone Monitoring Instrument instruments in near real time (less than 3 hours from observation) to various applications users.

### **WORK IN PROGRESS IN FY 2014**

In response to the decadal survey, EOSDIS managers continue to build more capabilities focused on the societal benefit and use of our research data and information. EOSDIS accommodated increased support for SMAP to include new applied science requirements. NASA Earth Science Data Systems is a key partner in the Big Earth Data Initiative to promote open, interoperable, and machine-readable environmental data. Additionally, NASA leads the Climate Data Initiative portion of the President's Climate Action Plan. Together, these activities will greatly improve the tools and techniques needed to access, organize, and glean discoveries from huge volumes of digital data. NASA will also ensure interoperability with other national and international Earth science data systems. In addition, NASA will recover historical data records from past missions to extend the availability of key Earth science measurements.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA will continue to operate and maintain the EOSDIS, and all the accompanying infrastructure and functions. NASA also anticipates providing support for new Suomi NPP activities motivated by a new NASA NPP Science Team, as well as ICESat-2.

## **Program Elements**

### **EARTH SCIENCE MULTI-MISSION OPERATIONS**

This project funds the Elements of EOSDIS Evolution, aimed at improving the efficiency and effectiveness of EOSDIS while reducing the cost. It also supports the twelve nationwide DAAC installations that collect, disseminate, and archive Earth science data. Each DAAC focuses on a specific Earth system science discipline and provides users with data products, services, and data-handling tools unique to that specialty.

- The Alaska Synthetic Aperture Radar Facility, which collects data and information on sea ice, polar processes, and geophysics;
- The GSFC Earth Sciences Data and Information Services Center, which collects information on atmospheric composition, atmospheric dynamics, global precipitation, ocean biology, ocean dynamics, and solar irradiance;

## **EARTH SCIENCE MULTI-MISSION OPERATIONS**

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- The LaRC DAAC collects data on Earth's radiation budget, clouds, aerosols, and tropospheric chemistry;
- The Land Processes DAAC collects land processes data;
- The National Snow and Ice Data Center collects snow and ice data, as well as information about the cryosphere and climate;
- The Oak Ridge National Laboratory DAAC collects data on biogeochemical dynamics and ecological data for studying environmental processes;
- The Physical Oceanography DAAC collects information on oceanic processes and air-sea interactions;
- The Socioeconomic Data and Applications Center collects information on population, sustainability, multilateral environmental agreements, natural hazards, and poverty;
- The Crustal Dynamics Data Center collects information focused on Solid Earth data;
- The Ocean Biology Progressing Group produces and distributes ocean biology and biogeochemistry products;
- The Global Hydrology Research Center provides hydrological cycle and severe weather research data and information; and
- The Land and Atmosphere Data Center provides a large suite of MODIS atmospheric products.

### **EARTH OBSERVING SYSTEM DATA AND INFORMATION SYSTEM (EOSDIS)**

The EOSDIS project provides science data to a wide community of users, including NASA, Federal agencies, international partners, academia, and the public. EOSDIS provides users with the services and tools they need in order to use NASA's Earth science data in research and creation of models. EOSDIS archives and distributes data through standardized science data products, using algorithms and software developed by Earth Science investigators.

The EOSDIS project also funds research opportunities related to EOSDIS. Current programs include Advanced Collaborative Connections for Earth System Science (ACCESS) and Making Earth System data records for Use in Research Environments (MEaSUREs).

ACCESS projects increase the interconnectedness and reuse of key information-technology software and services in use across the spectrum of Earth science investigations. ACCESS also supports the deployment of data and information systems and services that enable the freer movement of data and information. ACCESS researchers develop needed tools and services to aid in measurable improvements to Earth science data access and usability.

Through the MEaSUREs activity, researchers investigate new types of sensors to provide three-dimensional profiles of Earth's atmosphere and surface. There is an emphasis on linking data from multiple satellites, and then facilitating the use of this data in the development of comprehensive Earth system models.

### **Program Schedule**

MMO solicits research opportunities every two years for ACCESS and every five years for MEaSUREs. In FY 2013, MMO released a new Sea-Level Rise Portal solicitation in coordination with Earth Science

## EARTH SCIENCE MULTI-MISSION OPERATIONS

Research Program elements on sea-level rise research, products, and modeling efforts. The Sea-Level Rise Portal will begin development in FY 2014, with the portal hosted into the EOSDIS architecture.

Date	Significant Event
Q1 FY 2014	ROSES ACCESS Peer Review Panel
Q1 FY 2014	ROSES Sea-Level Rise Peer Review Panel
Q2 FY 2015	ROSES ACCESS Solicitation Released
Q2 FY 2017	ROSES MEaSUREs Solicitation Released
Q2 FY 2017	OSSES ACCESS Solicitation Released

### Program Management & Commitments

The EOSDIS Project Office at GSFC has primary responsibility for day-to-day operations. DAACs are also co-located with other agencies [USGS-EDC Earth Resources Observation and Science (EROS) EDCEROS Data Center (EDC), DOE-Oak Ridge National Laboratory (ORNL)] and at the following universities: University of Alaska at Fairbanks, University of Colorado, and Columbia University.

Program Element	Provider
EOSDIS core system, and Evolution of EOSDIS upgrades	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A
DAACs	Provider: Various Lead Center: GSFC Performing Center(s): GSFC, LaRC, MSFC, JPL Cost Share Partner(s): N/A

### Acquisition Strategy

Research opportunities related to EOSDIS are available through NASA's ROSES announcements.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
EOSDIS Evolution & Development	Raytheon	Riverdale, MD

## EARTH SCIENCE MULTI-MISSION OPERATIONS

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	American Customer Satisfaction Index	2013	Survey current EOSDIS users to assess current status and improve future services	EOSDIS scored 77 out of 100, and improved in all areas of usability and user satisfaction. As recommended by the 2012 report, the top priority drivers (product search, selection and order, and documentation) were the most improved.	2014, annually thereafter



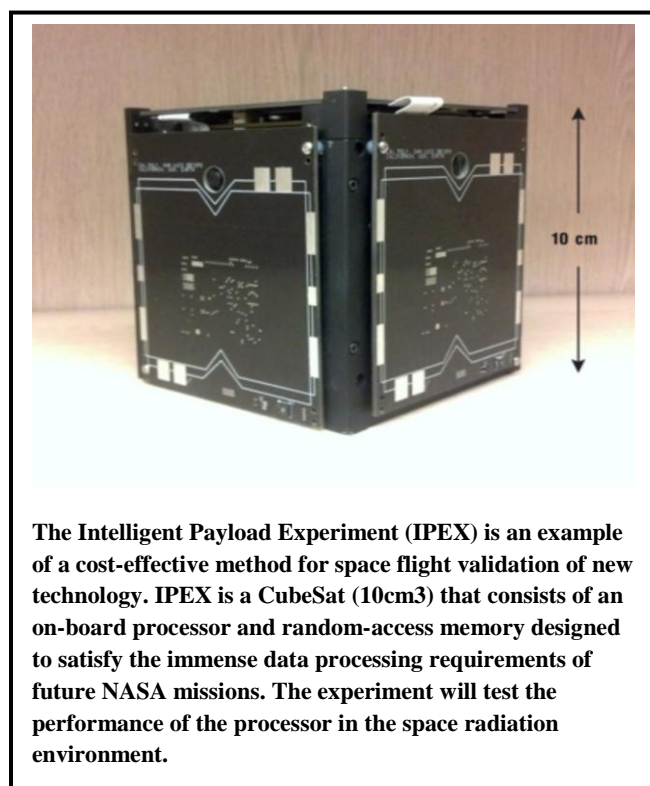
## EARTH SCIENCE TECHNOLOGY

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>48.9</b>	<b>--</b>	<b>55.6</b>	<b>54.5</b>	<b>55.6</b>	<b>55.6</b>	<b>55.6</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Advanced technology plays a major role in enabling Earth research and applications. The Earth Science Technology Program (ESTP) enables previously infeasible science investigations; improves existing measurement capabilities; and reduces the cost, risk, and/or development times for Earth science instruments.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

In FY 2013, NASA implemented the In-space Validation of Earth Science Technologies (InVEST) program, an advanced strategy for validating new instrument and component technologies in space. Recognizing that non-validated technology is a primary cause of cost overruns and mission delays, ESTP leveraged

recent advances in low-cost access to space and produced a competitive solicitation to help retire risk and validate key technologies well in advance of their use in Earth Science missions.

NASA selected four proposals, which will take advantage of the cost-effective CubeSat platform for in-space validation of various instrument technologies. During FY 2013, 27 percent of active technology projects advanced at least one technology readiness level and the incorporation of many technologies into science measurements, system demonstrations, or other applications. Overall, of the more than 600 activities completed in the portfolio, NASA incorporated 37 percent into various missions and identified a path for future incorporation for an additional 43 percent.

## **EARTH SCIENCE TECHNOLOGY**

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### **WORK IN PROGRESS IN FY 2014**

In FY 2014, ESTP will develop new remote-sensing and information systems technologies for infusion into future science missions and airborne campaigns. These technologies will enable or enhance measurements and data system capabilities. Instrument, component, and information technology activities awarded in prior solicitations will advance toward incorporation into decadal survey missions and NASA Earth science deployments. Technology space flight validation awards made in FY 2013 will be in their second year of development. The program anticipates the release of both ACT and AIST solicitations during FY 2014. An Instrument Incubator solicitation issued in FY 2013 sought innovative proposals to meet the climate measurement needs of the Earth Science Division while emphasizing the need to constrain cost and risk. The announcement of selections will occur in early FY 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA will make awards from the ACT and AIST FY 2014 solicitations, which will focus on technologies to enable future missions and help improve science data analysis.

## **Program Elements**

### **ADVANCED TECHNOLOGY INITIATIVES (ATI)**

This project enables development of critical component and subsystem technologies for instruments and platforms, mostly in support of the Earth science decadal survey. Current awards focus on areas such as space-qualified laser transmitters, passive optical technologies, and microwave and calibration technologies. Other awards support measurements of solar radiance, ozone, aerosols, and atmospheric gas columns for air quality and ocean color for coastal ecosystem health and climate emissions.

### **INSTRUMENT INCUBATOR**

This project develops instrument and measurement techniques at the system level, including laboratory breadboards and operational prototypes for airborne validation. NASA currently funds 17 Instrument Incubator efforts. These instrument prototypes support several measurements such as carbon dioxide, carbon monoxide, ocean color, and solar spectrum from ultraviolet to infrared for climate science. Instrument Incubator supports the development of instrument design, prototype through laboratory and/or airborne demonstrations for innovative measurement techniques that have the highest potential to meet the measurement capability requirements of the NASA Earth science community in both the optical and the microwave spectrum.

### **ADVANCED INFORMATION SYSTEMS TECHNOLOGY (AIST)**

This project develops end-to-end information technologies that enable new Earth observation measurements and information products. The technologies help process, archive, access, visualize, communicate, and understand science data. Currently, AIST activities focus on three areas needed to support future Earth science measurements:

## EARTH SCIENCE TECHNOLOGY

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- Sensor System Support, which nurtures autonomy and rapid response in the sensing process to improve the science value of data;
- Advanced Data Processing, designed to enhance the information extracted from the data stream; and
- Data Services Management, whose investments manage the growing body of Earth science data.

### **Program Schedule**

Date	Significant Event
Q2 2014	ROSES-2014 solicitation
	ROSES-2014 selection no earlier than 6 months of receipt of proposals

### **Program Management & Commitments**

The Earth Science Technology Office (ESTO), located at GSFC, implements the Earth Science Technology Program.

Program Element	Provider
Instrument Incubator	Provider: Various Lead Center: HQ Performing Center(s): GSFC, JPL, LaRC, ARC, GRC, AFRC Cost Share Partner(s): N/A
Advanced Information Systems	Provider: Various Lead Center: HQ Performing Center(s): GSFC, JPL, LaRC, ARC, GRC Cost Share Partner(s): N/A
Advanced Technology Initiatives	Provider: Various Lead Center: HQ Performing Center(s): GSFC, JPL, LaRC Cost Share Partner(s): N/A

### **Acquisition Strategy**

NASA procures tasks primarily through full and open competition, such as through the ROSES announcements. The solicitation of technology investments is competitive and selected from NASA Centers, industry, and academia.

## EARTH SCIENCE TECHNOLOGY

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### MAJOR CONTRACTS/AWARDS

None.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	NASA Advisory Council Earth Science Subcommittee	2012	Review for success in infusion of new technologies and participation of universities in developing the new generation of technologists.	The committee was pleased with the technology program; it recommended focusing on reducing cost in missions and enabling specific measurements. Reports are available at <a href="http://esto.nasa.gov">esto.nasa.gov</a>	2014, 2016, 2018

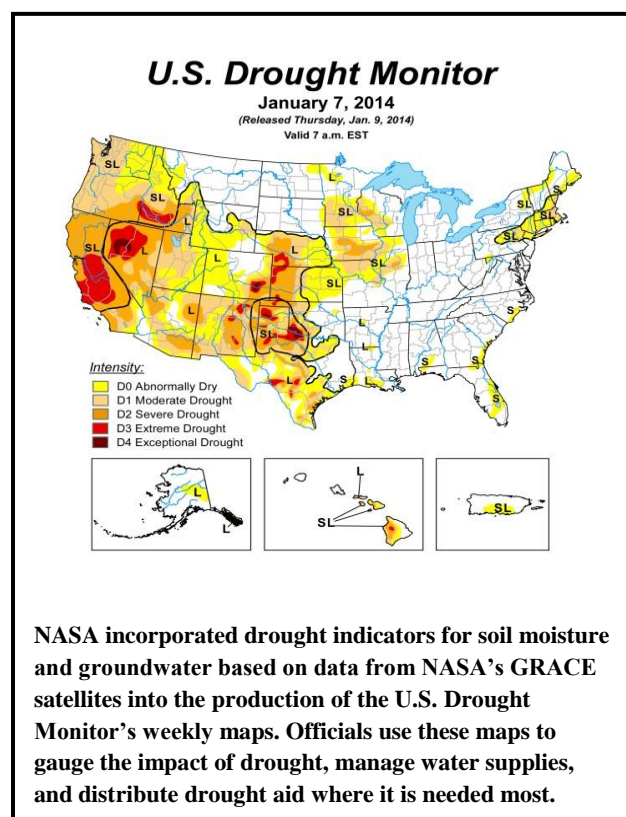
## APPLIED SCIENCES

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>32.5</b>	<b>--</b>	<b>36.3</b>	<b>38.0</b>	<b>39.7</b>	<b>39.7</b>	<b>39.7</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The NASA Applied Sciences program leverages NASA Earth Science satellite measurements and new scientific knowledge to provide innovative and practical uses for public and private sector organizations. It also enables near-term uses of Earth science knowledge, discovers and demonstrates new applications, and facilitates adoption of applications by non-NASA stakeholder organizations.

Applied Sciences projects improve decision-making activities to help the Nation better manage its resources, improve quality of life, and strengthen the economy. NASA develops Earth science applications in collaboration with end-users in public, private, and academic organizations.

Examples of these applications include:

- Improved assessment of flooding and landslide conditions with the International Red Cross to plan mitigation and response activities;
- Improved wildfire smoke predictions with the U.S. Forest Service to reduce downwind public exposure; and
- Advances in accuracy of volcanic ash advisories for airplane pilots with the National Weather Service and the FAA.

The program ensures sustained use of these products in the decision-making process of user organizations. The program also encourages potential users to envision and anticipate possible applications from upcoming satellite missions and to provide input to mission development teams to increase the societal benefits of NASA missions.

## **APPLIED SCIENCES**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

An effort with the California Department of Water Resources delivered improved methods to forecast water supply from snow cover data obtained by NASA satellites. A project with the Inter-American Tropical Tuna Commission delivered a satellite-based tool to map habitats of tuna and other marine resources for effective stock assessments and management actions. NASA supported disaster relief in FY 2013, providing data to respond to Hurricane Sandy, Typhoon Bopha, and wildfires, among others. The program completed dozens of applications projects focused on the Gulf of Mexico region, including ones focused on water management, disasters, and public health. The program selected nine (of 13) drought related feasibility studies for in-depth development under a new, phased approach to developing applications projects. NASA completed the transfer of a NASA airborne research sensor to the U.S. Forest Service for operational use in wildfire management. Involving over 350 young professionals from U.S. and abroad, the program supported 75 targeted applications projects with state and local governments. NASA expanded novel uses of TRMM data with the U.S. Agency for International Development to help ministries in East Africa assess stream flow, better anticipate flooding, support farming practices, and have early warnings of agricultural production shortages.

### **WORK IN PROGRESS IN FY 2014**

In FY 2014, the program will select a sub-set of feasibility studies in wildfires and disasters to pursue as full, in-depth applications development projects with the partners. NASA will hold applications symposia for the GPM and SMAP missions, scheduled for launch in 2014, to prepare the applications community to use data products soon after launch and validation. ICESat-2 will initiate an Earth Adopters program to encourage applications users' involvement in the mission. NASA and USAID will select a new SERVIR hub in Southeast Asia to increase use of Earth observations and geospatial information in that region. The program will support targeted projects with state and local governments in at least 30 U.S. states. The program will solicit and competitively select projects in the areas of disasters, health, and water management. The program will initiate projects in ecological forecasting, including innovative uses of crowdsourcing to collect data in support of resources management decisions.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The program will deliver results from projects in an interagency applied research effort to apply Earth observations to improve U.S. land-management strategies. The program will deliver results from U.S.-sponsored applications projects to apply Earth observations on health, water, air quality, and disasters by developing countries in East Africa, Mesoamerica, and Hindu Kush-Himalayan region. The program will deliver initial results in projects focused on use of Earth observations to improve drought forecasts and management practices. NASA will deliver results from feasibility studies in the areas of ecological forecasting and will select a sub-set of high-reward projects to pursue as full, in-depth applications development projects. Initial results from decision-support projects in the areas of disasters, health and air quality, long-term water availability forecasts, and wildfire management will become available. The program will deliver initial indications on applicability of GPM and SMAP data to support and improve

## APPLIED SCIENCES

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management and decision making activities. NASA and USAID will likely open a new SERVIR hub in West Africa to increase use of Earth observations and geospatial information in that region.

### **Program Elements**

#### **PATHWAYS**

The Pathways project has two primary lines of business: Applications and Capacity Building. The Applications themes are Health and Air Quality, Disasters, Ecological Forecasting, and Water Resources. The Capacity Building elements focus on foreign and domestic activities to build skills and capabilities in uses of Earth observations, including international and economic development.

### **Program Schedule**

Date	Significant Event
Q2 2014	ROSES-2014 solicitation
	ROSES-2014 selection no earlier than 6 months of receipt of proposals

### **Program Management & Commitments**

NASA Headquarters manages the Applied Sciences Program.

Program Element	Provider
Pathways	Provider: Various Lead Center: HQ Performing Center(s): GSFC, LaRC, SSC, JPL, MSFC, ARC Cost Share Partner(s): EPA, NOAA, U.S. Department of Agriculture, USGS, National Park Service, U.S. Fish and Wildlife Service, Centers for Disease Control, USAID, U.S. Forest Service

### **Acquisition Strategy**

NASA bases the Earth Science Applied Science acquisitions on full and open competition. Grants are peer reviewed and selected based on NASA research announcements and other related announcements.

## APPLIED SCIENCES

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### MAJOR CONTRACTS/AWARDS

None.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Relevance	Applied Sciences Analysis Committee	Jun 2013	Review strategy and implementation. Semi-annual reports to NASA SMD/Earth Science Division Director.	Meeting report released Summer 2013	Jan 2014; semi-annual thereafter



# PLANETARY SCIENCE

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	Notional			
				FY 2016	FY 2017	FY 2018	FY 2019
Planetary Science Research	195.8	--	<b>255.8</b>	280.5	284.4	283.3	278.4
Discovery	215.5	285.0	<b>230.8</b>	163.0	174.2	280.2	377.8
New Frontiers	158.8	258.0	<b>281.5</b>	254.7	110.0	51.1	45.9
Mars Exploration	369.5	288.0	<b>279.3</b>	381.7	547.8	573.1	518.8
Outer Planets	147.8	159.0	<b>95.7</b>	82.2	84.5	27.8	9.1
Technology	123.4	146.0	<b>137.2</b>	142.9	136.3	140.1	144.1
Lunar Quest Program	63.8	--	<b>0.0</b>	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>1274.6</b>	<b>1345.0</b>	<b>1280.3</b>	<b>1304.9</b>	<b>1337.1</b>	<b>1355.7</b>	<b>1374.1</b>

## Planetary Science

PLANETARY SCIENCE RESEARCH .....	PS-2
Other Missions and Data Analysis .....	PS-7
DISCOVERY .....	PS-10
InSight.....	PS-14
Other Missions and Data Analysis .....	PS-20
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MARS EXPLORATION.....	PS-36
Other Missions and Data Analysis .....	PS-39
OUTER PLANETS.....	PS-47
TECHNOLOGY .....	PS-52

## PLANETARY SCIENCE RESEARCH

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Planetary Science Research and Analysis	128.6	130.0	<b>165.4</b>	165.5	165.5	165.4	165.4
Directorate Management	3.9	--	<b>4.0</b>	7.1	7.4	7.4	7.4
Near Earth Object Observations	20.5	40.5	<b>40.0</b>	40.0	40.0	40.0	40.0
Other Missions and Data Analysis	42.8	--	<b>46.4</b>	67.9	71.5	70.6	65.6
<b>Total Budget</b>	<b>195.8</b>	<b>--</b>	<b>255.8</b>	<b>280.5</b>	<b>284.4</b>	<b>283.3</b>	<b>278.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

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**This solar-system montage of the eight planets and four large moons of Jupiter in our solar system are set against a false-color view of the Rosette Nebula.  
Credit: NASA Planetary Photo Collection**

The Planetary Science Research program provides the scientific foundation for unique data sets returned from NASA missions exploring the solar system. It is also NASA's primary interface with university faculty and graduate students in this field and the research community in general. The program develops analytical and theoretical tools, as well as laboratory data to support analysis of flight mission data. These capabilities allow Planetary Science to answer specific questions about, and increase the understanding of, the origin and evolution of the solar system. The research program achieves this by supporting research grants solicited annually and subjected to a competitive peer review before selection and award. The Planetary Science Research program focuses on five key research goals:

- Explore and observe the objects in the solar system to understand how they formed and evolve.
- Advance the understanding of how the chemical and physical processes in our solar system operate, interact, and evolve.
- Explore and find locations where life could have existed or could exist today.
- Improve our understanding of the origin and evolution of life on Earth to guide our search for life elsewhere.
- Identify and characterize objects in the solar system that pose threats to Earth or offer resources for human exploration.

## **PLANETARY SCIENCE RESEARCH**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The Planetary Research & Analysis program in FY 2015 combines the Mars Fundamental Research Program (MFRP) budget, portions of the Discovery Research program, and the Outer Planets Research Program (OPRP) budget into the Planetary R&A budget. Additionally, with the termination of the Lunar Quest Program, the Lunar Science R&A begins moving existing and new awards to Planetary R&A in FY 2014 and completes the transition in FY 2015. The apparent budget increase for Planetary R&A thus reflects the transferred Mars, Outer Planets, Discovery, and Lunar Science requirements, with no significant change in total budget.

### **ACHIEVEMENTS IN FY 2013**

The research program continued to curate and distribute solar system samples (astromaterials) returned by NASA planetary missions such as Stardust and Genesis, and the Japanese Space Agency Hayabusa mission. The program also provided continued support for the Rosetta mission's arrival at Comet Churyumov-Gerasimenko in 2014. The Robotics Alliance Project (RAP) selected 241 teams for receipt of the For Inspiration and Recognition of Science and Technology (FIRST) Robotics Student Competition 2012 Grant award.

In 2013, the Near Earth Object Observations (NEOO) project catalogued the 10,000th object discovered. Asteroid 2013 MZ was found on June 18, 2013, by the Pan-STARRS-1 search team. This approximately 300 meter sized object was determined to be the 10,000th small body in the solar system to be found by astronomers, in the long history of the science, that approaches Earth orbit close enough to be designated a near Earth object (NEO). There were only 497 known NEOs before the inception of this project in 1998, and NASA supported search teams have found over 97 percent of these objects since then. In FY 2013, 1047 more near-Earth asteroids were found, of which 98 are considered potentially hazardous to Earth and warrant future monitoring.

The NEOO project has now found about 96 percent of the estimated population of 1-kilometer and larger objects and in FY 2013 increased efforts for finding and characterizing smaller asteroids down to 140 meters in size. At this time only about 10 percent of the 100 meter sized asteroids have been found.

### **WORK IN PROGRESS IN FY 2014**

The NEOO project supports a network of search and characterization observatories and the data processing and analysis required to understand the near-Earth population of small bodies. In accordance with the findings and recommendations of the January 2010 National Academies study on the NEO hazard, NASA continues to:

- Analyze the small body data collected by the newly reactivated Wide-field Infrared Survey Explorer (WISE) mission, and support increased follow-up and analysis of this data;
- Increase collection of NEO detection and characterization data by the United States Air Force's (USAF) Panoramic Survey Telescope and Rapid Reporting System (Pan-STARRS) and the newly commissioned Space Surveillance Telescope;
- Complete the prototype of a wider field survey telescope system called ATLAS, the Asteroid Terrestrial-impact Last Alert System, designed to detect smaller asteroids as they approach the Earth;

## **PLANETARY SCIENCE RESEARCH**

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- Support the continued and enhanced operation of planetary radar capabilities at the National Science Foundation's Arecibo and NASA's Goldstone facilities; and
- Investigate both ground and space-based concepts for increasing capacity to detect, track, and characterize NEOs of all sizes.
- The European Space Agency's (ESA) Rosetta mission, with NASA participation, will arrive and orbit the Comet Churyumov-Gerasimenko.
- Samples of asteroid Itokawa, collected by the Japanese Space Agency's Hayabusa mission, were allocated to researchers in the spring of 2012. The first samples were delivered to NASA in late 2011, and were available for research starting in spring 2012. The first results of their analysis, including study of space weathering and the search for organic matter, are expected in FY 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015 NASA will aggressively continue an expanded NEO observation effort that will increase the detection of NEOs of all sizes by increasing the observing time on ground-based telescopes such as Pan-STARRs and the Space Surveillance Telescope, and improve their characterization using assets such as the Infra-Red Telescope Facility. The program will also support the study of the composition of NEOs through the collection and analyses of meteorites, as well the analyses of samples returned by spacecraft missions.

## **Program Elements**

### **NEAR EARTH OBJECT OBSERVATIONS (NEOO)**

The goal of the NEOO project is detecting and tracking at least 90 percent of the NEOs, asteroids, and comets that come within 1.3 astronomical units of the Sun, which is within about 30 million miles of Earth's orbit. The NEOO project looks for NEOs that have any potential to collide with Earth and do significant damage to the planet. The project will also discover and characterize NEOs that could be viable targets for robotic and crewed exploration where possible. This is part of NASA's response to the Asteroid Grand Challenge: to find all asteroid threats to human population and know what to do about them.

For more information on the NEOO project, go to <http://neo.jpl.nasa.gov>.

### **DIRECTORATE MANAGEMENT**

The Directorate Management project supports Science Mission Directorate (SMD)-wide administrative and programmatic requirements.

## PLANETARY SCIENCE RESEARCH

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### ROBOTICS ALLIANCE

The Robotics Alliance Project is dedicated to increasing interest in science, technology, engineering, and mathematics disciplines among youth in the United States. Annual activities and events expose students to challenging applications of engineering and science. The Robotics Alliance Project supports national robotic competitions in which high school students team with engineering and technical professionals from government, industry, and universities to gain hands-on experience and mentoring.

### RESEARCH AND ANALYSIS (R&A)

Planetary Science Research & Analysis enhances the scientific return from on-going and completed spaceflight missions and provides the foundation for the formulation of new scientific questions and strategies for answering those questions. R&A develops new theories and instrumentation concepts that enable the next generation of flight missions. R&A funds research tasks in areas such as astrobiology and cosmochemistry; the origins and evolution of planetary systems; and the atmospheres, geology, and chemistry of the solar system's planets other than Earth.

### Program Schedule

The Planetary Science Research Program will conduct its next call for research proposals as part of the Science Mission Directorate's annual Research Opportunities in Space and Earth Sciences (ROSES) research calls in 2014.

### Program Management & Commitments

Program Element	Provider
R&A	Provider: NASA Lead Center: HQ Performing Center(s): ARC, GRC, GSFC, JPL, JSC, LaRC, MSFC, HQ Cost Share Partner(s): N/A
NEOO	Provider: NASA Lead Center: HQ Performing Center(s): HQ, GSFC, JPL, ARC Cost Share Partner(s): NSF, USAF, Smithsonian Astrophysical Observatory (SAO)

## PLANETARY SCIENCE RESEARCH

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### **Acquisition Strategy**

The Research and Analysis budget will fund competitively selected activities from the ROSES omnibus research announcement.

### **INDEPENDENT REVIEWS**

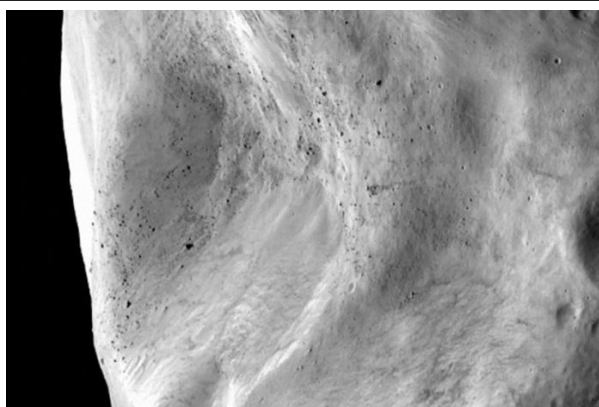
<b>Review Type</b>	<b>Performer</b>	<b>Date of Review</b>	<b>Purpose</b>	<b>Outcome</b>	<b>Next Review</b>
Quality	Planetary Science Subcommittee	2011	Review to assess goals and objectives of program.	Recommendation was to maintain a strong program consistent with the decadal survey.	To be determined (TBD)

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Joint Robotics Program for Exploration	10.0	--	10.0	10.0	10.0	10.0	10.0
Planetary Science Directed R&T	0.0	--	0.0	23.8	30.9	33.0	33.0
Science Innovation Fund	4.0	--	0.0	0.0	0.0	0.0	0.0
Planetary Data System	10.9	--	13.7	13.8	13.7	13.9	14.0
Astromaterial Curation	5.7	--	6.4	6.1	6.3	6.4	6.6
Science Data & Computing	3.1	--	2.0	2.0	2.0	2.0	2.0
Rosetta	9.1	--	14.3	12.2	8.6	5.3	0.0
<b>Total Budget</b>	<b>42.8</b>	<b>--</b>	<b>46.4</b>	<b>67.9</b>	<b>71.5</b>	<b>70.6</b>	<b>65.6</b>



U.S. scientists participating in the Rosetta mission investigated Asteroid Lutetia, an ancient, cratered relic from the dawn of the solar system. Lutetia, also known as a planetesimal, shows landslides in this image, possibly caused by the vibrations from impacts elsewhere on the asteroid that dislodged pulverised rocks. This data provides new insights into the origin and history of asteroids and about the evolution of the solar system. Rosetta is continuing on to a 2014 rendezvous with its primary target, comet Churyumov-Gerasimenko.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Other Missions and Data Analysis includes supporting mission functions such as the Planetary Data Systems and the Astromaterials Curation as well as supporting the NASA portion of the European Space Agency (ESA) Rosetta mission.

### Mission Planning and Other Projects

### JOINT ROBOTICS PROGRAM FOR EXPLORATION

This activity funds research and analysis in support of human spaceflight planning and robotic systems development. These activities will characterize exploration environments, identify hazards, and assess resources, which will inform the selection of future destinations, support the development of exploration systems, and reduce the risk associated with human exploration. NASA's Science Mission Directorate will jointly conduct many of these research and analysis activities with the Human Exploration and

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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Operations Mission Directorate to maximize the benefit to both science and exploration objectives, as was done successfully with the Lunar Reconnaissance Orbiter (LRO) mission.

### Recent Achievements

In 2013, the Joint Robotics Program for Exploration (JRPE) established the Solar System Exploration Research Virtual Institute (SSERVI) and research teams, which will address scientific questions about the Moon, near-Earth asteroids, the Martian moons Phobos and Deimos, and their near space environments, in cooperation with international partners. SSERVI members include academic institutions, non-profit research institutes, private companies, NASA centers, and other government laboratories. NASA selected the nine winning research teams, which SSERVI will support for five years, from a pool of 32 proposals based on competitive peer-review evaluation.

Also in 2013, JRPE supported the reactivation of the WISE spacecraft to resume the search for and characterization of the asteroid and comet population, including NEOs that would be good destinations for either robotic or human spaceflight. NASA expects this “NEOWISE” project to discover a few hundred NEOs and provide infrared characterization data on a few thousand more already known asteroids during the estimated 3-year remainder of its useful life.

## PLANETARY SCIENCE DIRECTED RESEARCH AND TECHNOLOGY

This project funds the civil service staff that will work on emerging Planetary Science flight projects, instruments, and research. The workforce and funding will transfer to projects by the beginning of FY 2016.

## PLANETARY DATA SYSTEM

The Planetary Data System is the active data archive for NASA’s Planetary Science missions. The Planetary Data System furthers NASA’s Planetary Science goals by efficiently collecting, archiving, and making accessible digital data produced by, or relevant to, NASA’s planetary missions, research programs, and data analysis. The archives include imaging experiments, magnetic and gravity field measurements, orbit data, and various spectroscopic observations. All space-borne data from over 50 years of NASA-funded exploration of comets, asteroids, moons, and planets is publically available through the Planetary Data Systems archive.

## ASTROMATERIAL CURATION

The Astromaterials Curation Facility at JSC curates all extraterrestrial material and space-exposed flight hardware under NASA control. Curation is an integral part of any sample return mission. It comprises initial characterization of new samples, preparation and allocation of samples for research and clean and secure storage for the benefit of current and future generations. Samples currently include Apollo lunar samples, Antarctic meteorites, and solar wind, comet, asteroid, and interplanetary dust samples.



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### SCIENCE DATA AND COMPUTING

This project, through the National Space Science Data Center (NSSDC), preserves NASA's science data assets by working with all space science data archives, missions, and investigators. The NSSDC serves as the deep archive for the Planetary Data System (PDS). In addition to being a depository that makes unique data and metadata available, the NSSDC provides the space science community with stewardship, guidance, and support so that data made available to the research community is well documented to provide independent usability.

### Operating Missions

#### ROSETTA

Rosetta is an ESA-led comet rendezvous mission, with NASA participation, in its operations phase. It launched in March 2004, and will enable scientists to look at some of the most primitive material from the formation of the solar system 4,600 million years ago. Rosetta will enable study of the nature and origin of comets, the relationship between cometary and interstellar material, and the implications of comets with regard to the origin of the solar system. The Rosetta spacecraft will be the first to undertake long-term exploration of a comet at close quarters. It comprises a large orbiter designed to operate for a decade at large distances from the Sun, and a small lander. Each of these elements carries a large number of scientific experiments and examinations designed to complete the most detailed study of a comet ever attempted. Rosetta will arrive at Comet Churyumov-Gerasimenko (Comet C-S) in FY 2014.

Science observation and operations planning are gearing up for Comet C-S orbit insertion and mapping during the August to September 2014 timeframe with the lander touching down on Comet C-S in November 2014.

## DISCOVERY

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
InSight	122.7	193.3	170.0	92.1	13.3	8.7	0.0
Other Missions and Data Analysis	92.8	--	60.8	70.9	160.9	271.5	377.8
<b>Total Budget</b>	<b>215.5</b>	<b>285.0</b>	<b>230.8</b>	<b>163.0</b>	<b>174.2</b>	<b>280.2</b>	<b>377.8</b>
Change from FY 2014			-54.2				
Percentage change from FY 2014			19.0%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**All completed Discovery missions have achieved ground-breaking science, each taking a unique approach to space exploration, doing what's never been done before, and driving new technology innovations.**

NASA's Discovery program supports innovative, relatively low-cost, competitively selected Planetary Science missions. Discovery provides scientists the opportunity to dig deep into their imaginations and find innovative ways to unlock the mysteries of the solar system through missions to explore the planets, their moons, and small bodies such as comets and asteroids.

The Discovery program currently has two operational spacecraft: MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) and Dawn. The program also has one instrument in operations: the Analyzer of Space Plasma and Energetic Atoms (ASPERA-3) on the ESA Mars Express mission; one flight mission in development: the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport

(InSight); and one instrument in spacecraft integration: Strofio on the ESA BepiColombo mission to Mercury.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

InSight was confirmed and entered its development phase after completing a successful Preliminary Design Review (PDR). NASA competitively selected a launch vehicle, and the InSight team is working toward a March 2016 launch date.

## DISCOVERY

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The Discovery program has initiated the process for a new Announcement of Opportunity (AO) and plans to select new mission candidates by the end of FY 2015.

### ACHIEVEMENTS IN FY 2013

GRAIL completed its highly successfully prime and extended missions to create a detailed gravity map of the moon. Following fuel depletion, both spacecraft ended their mission by colliding with the surface, at a site now officially known as the Sally Ride Memorial site. Dawn continued using its unique electric propulsion system to thrust along its trajectory between the asteroid Vesta and the dwarf planet Ceres. MESSENGER entered a third year of science data collection during its extended mission orbiting Mercury. The Strofio instrument was completed and delivered to the Italian SERENA instrument suite for launch in 2016. InSight successfully completed its PDR, a key step for confirmation.

NASA issued a request for information to gather lessons learned from the last three Planetary Science Division announcements of opportunity (New Frontiers 2009, Discovery 2010, and Jupiter ICy moons Explorer (JUICE) in preparation for releasing the next Discovery AO in FY 2014.

### WORK IN PROGRESS IN FY 2014

NASA confirmed the InSight mission for development, leading to launch in March of 2016.

NASA will release a new AO for Discovery, with preliminary selection of new mission candidates expected in 2015.

A Senior Review of potential Planetary mission extensions is being held. The missions to be reviewed include LRO. An additional investment for Planetary extended missions is proposed under the Opportunity, Growth, and Security Initiative. Please refer to the OGSi section for more information.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Upon fuel depletion, MESSENGER will complete its orbital mission at Mercury, with impact on the surface. Dawn will arrive at Ceres to begin science operations orbiting the largest main belt asteroid. InSight will complete design activities and begin assembly and test. Plans for FY 2015 include selection of missions to enter concept studies for the next Discovery Mission.

### Program Schedule

Discovery plans to initiate its 13th AO in FY 2014, allowing for preliminary selection of new mission candidates by the end of FY 2015.

Date	Significant Event
2014	Release of AO for 13th mission

**DISCOVERY**

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**Program Management & Commitments**

<b>Program Element</b>	<b>Provider</b>
InSight	Provider: Lockheed Martin Lead Center: JPL Performing Center(s):NA Cost Share Partner(s): Centre National d'Etudes Spatiales (CNES), German Aerospace Center (DLR)
MESSENGER	Provider: Johns Hopkins University Applied Physics Laboratory Lead Center: NA Performing Center(s):NA Cost Share Partner(s):NA
Dawn	Provider: NA Lead Center: JPL Performing Center(s): NA Cost Share Partner(s): German Aerospace Center (DLR), Agenzia Spaziale Italiana (ASI)
ASPERA-3	Provider: Southwest Research Institute Lead Center: NA Performing Center(s):NA Cost Share Partner(s):NA
Strofio	Provider: Southwest Research Institute Lead Center: NA Performing Center(s): NA Cost Share Partner(s): NA

**Acquisition Strategy**

All acquisitions for current projects are complete. The AO for Discovery 2014 will be competed, open to all interested parties.

**MAJOR CONTRACTS/AWARDS**

Discovery Program has no major contracts. The individual projects manage all contracts.

## DISCOVERY

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### INDEPENDENT REVIEWS

The Discovery Program's next review is the Program Integration review in 2016.

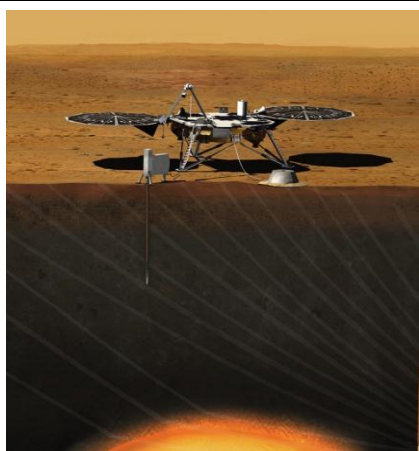
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Implementation Review (PIR)	Standing Review Board (SRB)	2010	Review implementation of Program	Passed	FY 2016

# INSIGHT

Formulation	Development	Operations
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## FY 2015 Budget

	Actual	Enacted	Request	Notional						
Budget Authority (in \$ millions)	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	BTC	Total
Formulation	65.1	33.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98.9
Development/Implementation	0.0	88.9	203.3	170.0	79.6	0.0	0.0	0.0	0.0	541.8
Operations/Close-out	0.0	0.0	0.0	0.0	12.4	13.3	8.7	0.0	0.0	34.4
2014 MPAR LCC Estimate	65.1	122.7	203.3	170.0	92.0	13.3	8.7	0.0	0.0	675.1
Total Budget	65.1	122.7	193.3	170.0	92.1	13.3	8.7	0.0	0.0	665.1
Change from FY 2014				-23.3						
Percentage change from FY 2014				-12.1%						



Scientists have determined the deep structure of only one planet — Earth. To obtain vital clues to how Mars formed, InSight will deploy a German-built drill nicknamed “The Mole” to pound 16 feet into the Martian crust for thermal measurements, and a sensitive French-built seismometer to detect “Marsquakes.” Through these and other instruments, scientists will be able to deduce the deep structure of Mars, which currently is a mystery.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

## PROJECT PURPOSE

InSight is a Mars lander mission planned for launch in spring 2016. InSight is an investigation of the terrestrial planets that will address fundamental issues of planet formation and evolution with a study of the deep interior of Mars. This mission will seek to understand the evolutionary formation of rocky planets, including Earth, by investigating the crust and core of Mars. InSight will also investigate the dynamics of any Martian tectonic activity and meteorite impacts and compare this with like phenomena on Earth.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

The project will complete the System Integration Review (SIR) and start spacecraft assembly and testing in FY 2015.

## PROJECT PARAMETERS

NASA plans to launch InSight in March 2016, landing on Mars in September 2016. The InSight lander will be equipped with two science instruments that will conduct the first “check-up” of Mars in its more

## INSIGHT

Formulation	Development	Operations
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than 4.5 billion years, measuring its “pulse,” or internal activity; its temperature; and its “reflexes” (the way the planet wobbles when it is pulled by the Sun and its moons). The science payload comprises two major instruments: the Seismic Experiment for Interior Structure (SEIS) and the Heat Flow and Physical Properties Package (HP3). SEIS will take precise measurements of quakes and other internal activity on Mars to help understand the planet’s history and structure. HP3 is a self-penetrating heat flow probe that burrows up to five meters below the surface to measure how much heat is coming from Mars’ core. In addition, the Rotation and Interior Structure Experiment will use the spacecraft communication system to provide precise measurements of planetary rotation. InSight will spend roughly two years (720 Earth days or 700 “sols” Martian days) investigating the deep interior of Mars. The first science return is expected in October 2016. The prime mission ends in December 2018.

### ACHIEVEMENTS IN FY 2013

In August 2013, the InSight project held its PDR.

### WORK IN PROGRESS IN FY 2014

On December 6, 2013, the mission transitioned from formulation to development, beginning its final design and fabrication phase (Phase C). In May 2014, the project will complete the Critical Design Review (CDR).

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

InSight will complete its final design and fabrication phase (Phase C) and hold an SIR in October 2014. The Project will start Phase D in November 2014.

### SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2015 PB Request
Formulation Authorization	Discovery 2010 Announcement of Opportunity	N/A
Mission Selection	Sep 2012	Sep 2012
KDP-C	Dec, 2013	Dec 2013
SIR	Oct 2014	Oct 2015
KDP-D	Nov 2014	Nov 2015
Operational Readiness Review (ORR)	Dec 2015	Dec 2015
Launch	Mar 2016	Mar 2016
KDP-E	Apr 2016	Apr 2016

**INSIGHT**

Formulation	Development	Operations
Milestone	Confirmation Baseline Date	FY 2015 PB Request
Mars Landing	Sep 2016	Sep 2016
End of Prime Mission	Dec 2018	Dec 2018

**Development Cost and Schedule**

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	541.8	70	2014	541.8	0	LRD	03/2016	03/2016	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

**Development Cost Details**

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>541.8</b>	<b>541.8</b>	<b>0</b>
Aircraft/Spacecraft	196.9	196.9	0
Payloads	18.1	18.1	0
Systems I&T	0	0	0
Launch Vehicle	159.9	159.9	0
Ground Systems	7.4	7.4	0
Science/Technology	7.1	7.1	0
Other Direct Project Costs	152.4	152.4	0



**INSIGHT**

Formulation	Development	Operations
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**Project Management & Commitments**

NASA selected the InSight project through the competitive Discovery 2010 Announcement of Opportunity (AO). The principal investigator for InSight is from JPL. JPL will manage the InSight mission and will provide systems engineering, safety and mission assurance, project scientists, flight dynamics, payload management, and mission system management.

Element	Description	Provider Details	Change from Baseline
Spacecraft	Similar in design to the Mars lander that the Phoenix mission used successfully in 2007	Provider: Lockheed Martin Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
SEIS	Will take precise measurements of quakes and other internal activity on Mars	Provider: CNES Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
HP3	A heat flow probe that will hammer 5m into the Martian subsurface (deeper than all previous arms, scoops, drills and probes) to measure heat emanating from the core	Provider: DLR Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
Rotation and Interior Structure Experiment (RISE)	Uses the spacecraft's communication system to provide precise measurements of planetary rotation	Provider: JPL Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
Launch Vehicle	Atlas V launch vehicle and related launch services	Provider: United Launch Alliance (ULA) Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A	N/A

**INSIGHT**

Formulation	Development	Operations
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**Project Risks**

Risk Statement	Mitigation
<p>If: Growth of lander avionics and payload electronics continues to strain volume of thermal enclosure,</p> <p>Then: The heritage design of the thermal enclosure and aeroshell is at risk. The project cannot grow the size of the thermal enclosure.</p>	<p>Instrument teams are working to close trade studies that will establish the baseline for payload electronics configuration, and spacecraft team members are working closely with instrument teams to identify and analyze overall configuration options.</p>
<p>If: If Mars environment, entry conditions, or spacecraft behavior is not as anticipated,</p> <p>Then: Landing may not be successful.</p>	<p>Project will build comprehensive simulations of landing scenarios and test entry descent and landing systems, including independent verification of analysis. The project will be staffed with personnel who conducted previous successful Mars landings. Potential landing ellipses will be certified for elevation, slopes, and rock abundance. The project will use validated environmental models informed by atmospheric measurements from the previous three decades of observations at Mars.</p>
<p>If: Deployment of SEIS is not successful,</p> <p>Then: The science objectives will be compromised.</p>	<p>Extensive testing of deployments will be conducted in testbeds, including fault scenarios. Testbeds will also be available during mission operations to verify actual deployment moves, and ground verification will be deployed at each step during operations. Potential landing ellipses will be certified for elevation, slopes, and rock abundance.</p>

**Acquisition Strategy**

NASA selected the InSight mission through a competitive Discovery Program 2010 AO and a down selection in September 2012. All major acquisitions are in place.

**MAJOR CONTRACTS/AWARDS**

A contract with Lockheed Martin is in place for the flight system.

Element	Vendor	Location (of work performance)
Spacecraft	Lockheed Martin	Denver, Colorado

# INSIGHT

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Formulation	Development	Operations
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## INDEPENDENT REVIEWS

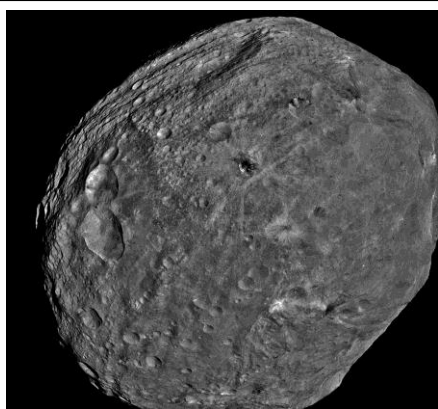
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Aug 2013	PDR	InSight passed PDR and was approved to continue to the next phase	May 2014
Performance	SRB	May 2014	CDR		Oct 2014
Performance	SRB	Oct 2014	SIR		Dec 2015
Performance	SRB	Dec 2015	ORR		Feb 2016
Performance	JPL System Review Team and SRB	Feb 2016	FRR		

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Strofió	1.9	--	0.7	0.8	0.8	0.6	0.4
Discovery Future	1.5	--	14.3	27.8	126.0	248.9	358.5
Discovery Management	14.6	--	14.7	14.8	13.4	15.0	11.8
Discovery Research	15.1	--	4.1	5.2	5.6	5.6	5.6
Gravity Recovery and Interior Laboratory	7.0	--	2.9	0.0	0.0	0.0	0.0
Dawn	23.3	--	17.2	20.9	13.8	0.0	0.0
MESSENGER	16.6	--	5.0	0.0	0.0	0.0	0.0
ASPERA-3	1.7	--	0.8	0.2	0.0	0.0	0.0
Deep Impact	3.0	--	0.0	0.0	0.0	0.0	0.0
International Mission Contributions (IMC)	0.0	--	1.1	1.2	1.3	1.4	1.5
Lunar Reconnaissance Orbiter Science Mission	8.1	--	0.0	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>92.8</b>	<b>--</b>	<b>60.8</b>	<b>70.9</b>	<b>160.9</b>	<b>271.5</b>	<b>377.8</b>



Dawn mission data has revealed the rugged topography and complex textures of the asteroid Vesta's surface. Soon, other pieces of data such as the chemical composition, interior structure, and geologic age will help scientists understand the history of this remnant protoplanet and its place in the early solar system. After a year orbiting Vesta, the Dawn spacecraft departed in August 2012 for the dwarf planet Ceres, where it will arrive in 2015.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Other Missions and Data Analysis funds research and analysis, management activities, operations of active missions, small projects, and international collaborations. It includes missions of opportunity (e.g., the instruments Strofió and ASPERA-3); operating missions (Dawn, MESSENGER); missions whose operations have ceased but data analysis continues (GRAIL); competed research; funding for future mission selections; and program management activities.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Mission Planning and Other Projects

#### STROFIO

Strofio is a unique mass spectrometer, part of the SERENA (Search for Esospheric Refilling and Emitted Natural Abundances) suite of instruments that will fly onboard the ESA BepiColombo spacecraft, scheduled for launch in 2016. Strofio will determine the chemical composition of Mercury's surface, providing a powerful tool to study the planet's geologic history.

#### Recent Achievements

NASA delivered the Strofio Proto-Flight Model for integration into the SERENA instrument suite on November 8, in Milan, Italy. The SERENA suite completed integration and testing in December and ESA held the SERENA Pre-Ship Review December 9 to 11. Delivery of the Proto- Flight Model to ESA took place on January 7, 2014.

#### DISCOVERY FUTURE

Discovery Future Missions supports the selection of future Discovery flight missions. In 2012, NASA selected InSight, the 12th mission of the Discovery program, as a result of the Discovery 2010 AO. NASA issued a Request for Information seeking community comment on the previous Discovery AO, which it is using as input to the planning for the next Discovery AO in late FY 2014.

#### DISCOVERY MANAGEMENT

Discovery Management fully funds Planetary Science's integrated program office at the MSFC, which manages all of the flight projects that are not part of the Mars Exploration Program. This currently includes four development projects and five operating projects. Discovery Management includes support for the day-to-day efforts of the Mission Managers and business office, as well as standing review boards and external technical support as needed for the projects. It also funds work at the LaRC's office for Mission Assessments to support the mission selection process including the development of AO and the formation and operations of independent panel reviews to evaluate mission proposals.

#### DISCOVERY RESEARCH

Discovery Research funds analysis of archived data from Discovery missions, and supports participating scientists for the MESSENGER, Dawn, and GRAIL missions. Discovery Research gives the research community access to samples and data and allows research to continue for many years after mission completion. Scientists in the US planetary science community submit research proposals that NASA selects through competitive peer review.

Discovery Research also funds the analysis of samples returned to the Earth by the Stardust and Genesis missions as well as the development of new analysis techniques for future sample return missions.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

The measurement of oxygen isotope concentration was a key goal of the Genesis mission, and now researchers have experimentally verified a mechanism that explains the observed pattern. Advances also continue on methods to clean Genesis collectors, contaminated upon the hard landing of the spacecraft. This will allow the determination of solar wind composition for a variety of elements previously beyond our technical reach.

Over the last year, the Planetary Mission Data Analysis Program has enabled researchers to produce new geologic maps of several regions on Venus, which provide new understanding of the geophysical structures, volcanic processes, and geologic history of that planet. The PMDAP also supports efforts to recalibrate, reanalyze, and archive data from older spacecraft missions, including Voyager, IRAS and Galileo, using newer methodologies and improved software tools. This in turn is producing new insights into the physical characteristics, chemical compositions, and collisional histories of comets and asteroids. The Planetary Data System recently added datasets from the Dawn and MESSENGER missions, and the Planetary Mission Data Analysis Program is facilitating efforts to better understand the interiors of asteroid Vesta and the planet Mercury through image processing, geological mapping, and spectroscopic analyses.

## Operating Missions

### GRAVITY RECOVERY AND INTERIOR LABORATORY

Launched in September 2011, the GRAIL mission was composed of two functionally identical spacecraft, called Ebb and Flow, that flew in tandem around the Moon to precisely measure and map variations in the Moon's gravitational field. The mission provided the most accurate global gravity field to date for any planet, including Earth. This detailed information will reveal differences in the density of the Moon's crust and mantle and will help answer fundamental questions about the Moon's internal structure, thermal evolution, and history of collisions with asteroids. This mission terminated in December 2012.

### Recent Achievements

The GRAIL mission satisfied all measurement requirements and science objectives from its primary mission. Continued refinement of science data collected during the extended mission and the calculation of a high-order lunar gravity model are part of a one-year extension for data analysis.

### DAWN

Dawn is on a journey to the two oldest and most massive bodies in the main asteroid belt between Mars and Jupiter. By closely orbiting asteroid Vesta and the dwarf planet Ceres with the same set of instruments, Dawn has the unique capability to compare and contrast these bodies, enabling scientists to answer questions about the formation and evolution of the solar system. Their surfaces are believed to

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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preserve clues to the solar system's first 10 million years, along with alterations since that time, allowing Dawn to investigate both the origin and the current state of the main asteroid belt. Launched in September 2007, Dawn reached Vesta in July 2011, left in August 2012, and will arrive at Ceres in February 2015.

Dawn mission data revealed the rugged topography and complex textures of the asteroid Vesta's surface. Soon other pieces of data, such as the chemical composition, interior structure, and geologic age, will help scientists understand the history of this remnant protoplanet and its place in the early solar system.

### Recent Achievements

The Dawn spacecraft is en-route to Ceres and scheduled for arrival in the spring of 2015. The spacecraft remains healthy, other than two failed reaction wheels, and is preparing to accomplish all mission objectives at Ceres without the use of reaction wheels.

## MERCURY SURFACE, SPACE ENVIRONMENT, GEOCHEMISTRY, AND RANGING (MESSENGER)

The MESSENGER mission is a scientific investigation of the planet Mercury, the smallest and least explored of the terrestrial planets. It is the only rocky planet, besides Earth, to possess a global magnetic field. Understanding Mercury and the forces that have shaped it is fundamental to understanding the origin and evolution of the four rocky inner planets in our solar system. Launched in August 2004, MESSENGER entered Mercury's orbit in March 2011 for a one-year prime mission. NASA approved two mission extensions since completion of its primary mission.

### Recent Achievements

The MESSENGER spacecraft successfully finished the primary and first extended mission accomplishing all the science objectives planned. The spacecraft is the first to orbit the planet Mercury. Through careful management of resources, MESSENGER started the second mission extension in March of 2013, and will continue the scientific study of the planet, including a more detailed study of the surface features, such as pyroclastic hollows recently discovered. MESSENGER is expected to complete its mission in December 2014, when it will deplete its fuel, and impact the surface of Mercury.

## ANALYZER OF SPACE PLASMA AND ENERGETIC ATOMS (ASPERA-3)

Launched in June 2003, ASPERA-3 is one of seven scientific instruments aboard the European Space Agency's Mars Express spacecraft that answer questions about the Martian atmosphere, structure, and geology. ASPERA-3 is measuring ions, electrons, and energetic neutral atoms in the outer atmosphere to reveal the number of oxygen and hydrogen atoms interacting with the solar wind, and the regions where such interaction occurs. Mars Express is now on its third mission extension.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### INTERNATIONAL MISSION CONTRIBUTIONS (IMC)

There are more scientifically interesting destinations across the solar system than any one country's program can quickly undertake. NASA works closely with the planetary science programs of other space agencies to find opportunities to participate in each other's missions. Under the International Mission Contributions, NASA funds instruments and scientific investigators, and will provide navigation and data relay services, in exchange for participation. International missions in FY 2015 include the Japanese Space Agency's Hayabusa-2 and Akatsuki (Venus Climate Orbiter) missions.

### LUNAR RECONNAISSANCE ORBITER (LRO)

LRO will be reviewed by the Senior Review Board in 2014 for a potential additional two years of operations as a Discovery mission. It is being moved to the Discovery Program because of the Lunar Quest Program ending. LRO is devoting the capabilities of the seven LRO instruments to five science investigations: the bombardment history of the Moon; the lunar geologic processes and their role in the evolution of the crust and lithosphere; the processes that have shaped the global lunar regolith; the types, sources, sinks, and transfer mechanisms associated with volatiles on the Moon; and how the space environment interacts with the lunar surface, in order to advance our understanding of the origin and evolution of the Moon. Extension of the LRO mission is not funded in the Budget. However, the Opportunity, Growth, and Security Initiative provides additional funding for extended missions, which could include LRO.



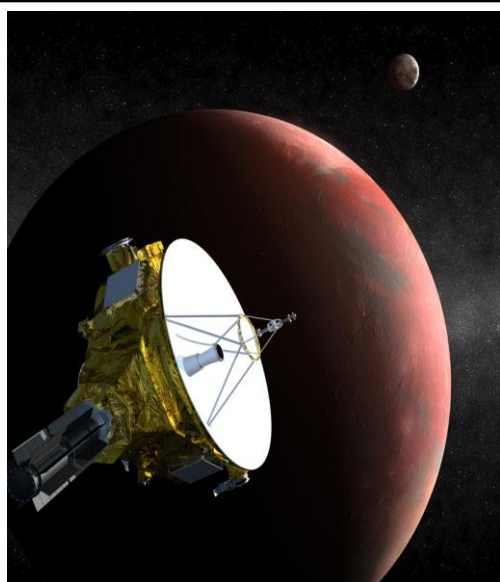
## NEW FRONTIERS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Origins Spectral Interpretation Resource	125.5	218.7	224.8	193.7	44.0	26.1	43.1
Other Missions and Data Analysis	33.3	--	56.6	61.0	66.0	25.0	2.8
<b>Total Budget</b>	<b>158.8</b>	<b>258.0</b>	<b>281.5</b>	<b>254.7</b>	<b>110.0</b>	<b>51.1</b>	<b>45.9</b>
Change from FY 2014			23.5				
Percentage change from FY 2014			9.0%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The New Frontiers Program seeks to contain total mission cost and development time and improve performance through the use of validated new technologies, efficient management, and control of design, development and operations costs while maintaining a strong commitment to flight safety. The program objective is to launch high-science-return planetary science investigations twice per decade.

The New Frontiers program explores our solar system with medium-class spacecraft missions. Within the New Frontiers program, possible mission destinations and the science goals for each competitive opportunity are limited to those identified by the National Academies as recommended science targets.

The New Horizons mission will help us understand worlds at the edge of the solar system by making the first reconnaissance of Pluto and Charon, then possibly visiting one or more Kuiper Belt Objects.

Juno is a mission to Jupiter that will significantly improve our understanding of the origin and evolution of the gas giant planet. Juno will help us better understand how planets are formed, and the origins of our solar system.

Origins Spectral Interpretation Resource Identification Security Regolith Explorer (OSIRIS-REx) will bring pristine samples from a carbon-rich asteroid to study and analyze on Earth. This will increase our understanding of planet formation and the origin of life. In addition to its science objectives OSIRIS-REx will improve our knowledge of:

- How to safely operate human and robotic missions in close proximity to a large NEO; and
- How the OSIRIS-REx spacecraft will alter the

## **NEW FRONTIERS**

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trajectory of a NEO through thruster exhaust impingement, gravitational attraction, and touch-and-go sample collection.

This knowledge will provide significant insight for both the future human mission to an asteroid, and for potential planetary defense strategies.

Potential future destinations identified by the National Academies include: Venus In Situ Explorer, Saturn Probe, Trojan Tour and Rendezvous, the Comet Surface Sample Return, and Lunar South Pole-Aitken Basin Sample Return.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

In May 2013, NASA confirmed OSIRIS-REx to enter its development phase after completing a successful preliminary design review. A launch vehicle has been competitively selected, and the OSIRIS-REx team is working toward a launch no later than October 2016.

There are no current plans for a New Frontiers 4 AO.

### **ACHIEVEMENTS IN FY 2013**

On October 9, 2013, the Juno solar powered spacecraft successfully flew by the Earth at an altitude of about 375 miles, the closest flyby since the Galileo mission, propelling it on a direct trajectory for arrival to Jupiter in 2016.

The New Horizons mission to Pluto completed a week-long live rehearsal with the spacecraft as part of its preparation for a July 14, 2015 arrival to the enigmatic Pluto system.

### **WORK IN PROGRESS IN FY 2014**

OSIRIS-REx continues critical design activities, culminating in its CDR, scheduled for April 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The New Horizons will start its preparation for encounter phase in January of 2015. The spacecraft will get as close as about 6,000 miles from Pluto and about 17,000 miles from its largest moon, Charon. During the half-hour when the spacecraft is closest to Pluto, it will take a variety of scientific observations, including close-up pictures in both visible and near-infrared wavelengths. These first images should depict surface features as small as 200 feet across and bring a plethora of new discoveries.

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

Formulation	Development	Operations
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## FY 2015 Budget

		Actual	Enacted	Request	Notional					
Budget Authority (in \$ millions)	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	BTC	Total
Formulation	108.1	36.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.3
Development/Implementation	0.0	89.3	207.3	224.8	187.0	13.3	0.0	0.0	0.0	721.7
Operations/Close-out	0.0	0.0	0.0	0.0	6.7	30.7	26.1	43.1	91.7	198.3
2014 MPAR LCC Estimate	108.1	125.5	207.3	224.8	193.7	44.0	26.1	43.1	91.7	1064.2
Total Budget	108.1	125.5	218.7	224.8	193.7	44.0	26.1	43.1	91.7	1075.7
Change from FY 2014				6.1						
Percentage change from FY 2014				2.8%						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Asteroids are leftovers formed from the cloud of gas and dust -- the solar nebula -- that collapsed to form our sun and the planets about 4.5 billion years ago. As such, they contain the original material from the solar nebula, which can tell us about the conditions of our solar system's birth. In sampling the near Earth asteroid designated 1999 RQ36 in 2019, OSIRIS-Rex will be opening a time capsule from the birth of our solar system.

## PROJECT PURPOSE

The OSIRIS-Rex spacecraft will travel to Bennu, a near-Earth carbonaceous asteroid formerly designated (101955) 1999 RQ36, study the asteroid in detail, and bring back a sample (at least 60 grams or 2.1 ounces) to Earth. This sample will yield insight into planet formation and the origin of life, and the data collected at the asteroid will aid in understanding asteroids that can collide with Earth. This mission will also measure the Yarkovsky effect on a potentially hazardous asteroid and measure the asteroid properties that contribute to this effect. By describing the integrated global properties of a primitive carbonaceous asteroid, this mission will allow for direct comparison with ground-based telescopic data of the entire asteroid population.

The Yarkovsky effect is a small force caused by the Sun on an asteroid, as it absorbs sunlight

## **ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER**

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Formulation	Development	Operations
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and re-emits that energy as heat. The small force adds up over time, but it is uneven due to an asteroid's shape, wobble, surface composition, and rotation. For scientists to predict an Earth-approaching asteroid's path, they must understand how the effect will change its orbit.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **PROJECT PARAMETERS**

OSIRIS-REx will launch in October 2016, encountering the primitive, near-Earth asteroid Bennu in 2018. The mission will study the asteroid for about one year, globally mapping the surface from distances of about three miles to less than half a mile, before acquiring the sample. The spacecraft cameras and instruments will photograph the asteroid and measure its surface topography, composition, and thermal emissions. Radio science will provide mass and gravity field maps. This information will help the mission team select the most promising sample site, from which it will collect and return to Earth at least 60 grams of pristine material from the target asteroid. The spacecraft will remain in the vicinity of the asteroid for almost another 2 years before beginning its return to Earth. The sample return will use a capsule similar to the one that returned the sample of Comet 81P/Wilt on the Stardust spacecraft. This will allow the sample to return and land at the Utah Test and Training Range in September 2023. The capsule will then travel to JSC for processing, analysis, and curation at a dedicated research facility. Subsamples will be made available for research to the worldwide science community.

### **ACHIEVEMENTS IN FY 2013**

In March 2013, OSIRIS-REx completed its PDR. In May, 2013, the mission transitioned from formulation to development, beginning its final design and fabrication phase (Phase C). NASA competitively selected a launch vehicle, and the OSIRIS-REx team is working toward launch no later than October 2016.

### **WORK IN PROGRESS IN FY 2014**

The project will complete its CDR in April 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

OSIRIS-REx will complete its SIR and transition from the final design and fabrication phase (Phase C) to the system assembly, integration and test, launch and checkout phase (Phase D).

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

Formulation	Development	Operations
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## SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	May 2013	May 2013
CDR	Apr 2014	Apr 2014
SIR	Feb 2015	Feb 2015
KDP-D	Mar 2015	Mar 2015
Launch	Oct 2016	Oct 2016
KPD-E	Oct 2016	Oct 2016
Earth flyby	Sep 2017	Sep 2017
Sample Return to Earth	Sep 2023	Sep 2023
KDP-F	Oct 2023	Oct 2023
End of Prime Mission (Completion of Project Sample Analysis)	Sep 2025	Sep 2025

## Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	721.7	70	2014	721.7	0	LRD	Oct 2016	Oct 2016	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

Formulation	Development	Operations
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## Development Cost Details

This is the first report of development costs for this mission.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>721.7</b>	<b>721.7</b>	<b>0</b>
Aircraft/Spacecraft	220.2	220.2	0
Payloads	32.2	32.2	0
Systems I&T	24.9	24.9	0
Launch Vehicle	177	177	0
Ground Systems	34.3	34.3	0
Science/Technology	17.8	17.8	0
Other Direct Project Costs	215.3	215.3	0

## Project Management & Commitments

NASA selected the OSIRIS-REx project through the New Frontiers 2009 AO. The principal investigator for OSIRIS-REx is from the University of Arizona and has delegated the day-to-day management of the OSIRIS-REx project to NASA's GSFC.

Element	Description	Provider Details	Change from Baseline
Spacecraft	MAVEN heritage spacecraft bus, Stardust heritage Sample Return Capsule (SRC), and innovative Touch and Go Sample Acquisition Mechanism (TAGSAM)	Provider: Lockheed Martin Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Launch Vehicle	Atlas V launch vehicle and related launch services	Provider: United Launch Alliance (ULA) Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A	N/A

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
OSIRIS-REx Camera Suite (OCAMS)	OCAMS is comprised of multiple cameras (PolyCam, MapCam, SamCam) with a common Camera Control Module (CCM)	Provider: University of Arizona Lead Center: Performing Center(s): Cost Share Partner(s):	N/A
OSIRIS-REx Thermal Emission Spectrometer (OTES)	Thermal Emission Spectrometer with significant flight heritage from Mars Exploration Rover Mini-TES and MO/MGS TES instruments	Provider: Arizona State University Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
OSIRIS-REx Visible and Infrared Spectrometer (OVIRS)	Visible and Infrared Spectrometer with flight heritage from Landsat TIRS (focal plane electronics), Juno (electronics box), OCO (detectors), and New Horizons LEISA (Linear Variable Filter) Instruments	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
OSIRIS-REx Laser Altimeter (OLA)	Dual laser altimeter with heritage from XSS-11 and Phoenix Mars Lander lidars	Provider: MacDonald, Dettwiler and Associates Ltd. (MDA) Lead Center: Canadian Space Agency (CSA) Performing Center(s): CSA Cost Share Partner(s): CSA	N/A
Regolith X-ray Imaging Spectrometer (REXIS)	Instrument to observe x-rays fluorescence induced by solar x-rays using a coded aperture for imaging with a spectrometer to determine elemental composition	Provider: Massachusetts Institute of Technology (MIT) Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A

# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

Formulation	Development	Operations
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## Project Risks

Risk Statement	Mitigation
If the Guidance, Navigation, and Control (GNC) is not ready for integration onto the spacecraft by 2015/02/12 Then the spacecraft costs will substantially increase in order to accommodate a late delivery, and ultimately the launch readiness could be missed	Careful management and monitoring of progress of GNC Lidar supplier
If baseline altimetry method does not work at the asteroid Then we do not get sample to meet mission success	Development of back-up capability using Natural Feature Tracking
If OSIRIS-REx Laser Altimeter (OLA) does not meet delivery date to Assembly, Test, Launch, and Operations (ATLO) Then the project will incur additional costs for integration	Careful monitoring of the technical progress of the OLA instrument and the programmatic approval by the Canadian government of OLA funding – the OLA instrument could be descope if it is not ready for integration onto the spacecraft

## Acquisition Strategy

All major acquisitions are in place. NASA competitively selected OSIRIS-REx on May 25, 2011 under the third New Frontiers Program Announcement of Opportunity.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Spacecraft, Integration and Test	Lockheed Martin Space Systems Company (LMSSC)	Denver, Colorado
Payload – OCAMS Instrument	University of Arizona	Tucson, Arizona
Payload – OTES Instrument	Arizona State University	Tempe, Arizona
Ground System – Science Processing and Operations Center (SPOC)	University of Arizona	Tucson, Arizona
Launch Vehicle and Services	United Launch Alliance	Cape Canaveral, Florida



# ORIGINS-SPECTRAL INTERPRETATION-RESOURCE IDENTIFICATION-SECURITY-REGOLITH EXPLORER

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Formulation	Development	Operations
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## INDEPENDENT REVIEWS

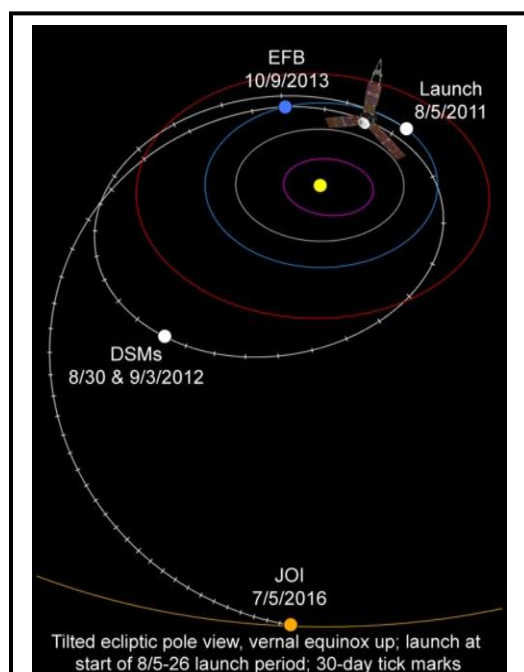
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Mar 2013	PDR	OSIRIS-REx passed PDR and was approve to continue to the next phase	Apr 2014
Performance	SRB	Apr 2014	CDR		Feb 2015
Performance	SRB	Feb 2015	SIR		Apr 2016
Performance	SRB	Apr 2016	ORR		Aug 2016
Performance	GSFC System Review Team (GSRT)	Aug 2016	FRR		

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
New Frontiers Management	5.9	--	0.0	0.0	0.0	0.0	0.0
New Horizons	9.6	--	28.8	21.5	27.6	0.0	0.0
Juno	17.8	--	27.8	39.5	38.4	25.0	2.8
<b>Total Budget</b>	<b>33.3</b>	<b>--</b>	<b>56.6</b>	<b>61.0</b>	<b>66.0</b>	<b>25.0</b>	<b>2.8</b>



Juno's principal goal is to understand the origin and evolution of Jupiter. The graphic shows Juno's path to Jupiter, from Launch on August 5, 2011; Deep Space maneuvers (DSM) to adjust the trajectory in 2012; an Earth Flyby (EFB) in 2013; and finally, Jupiter Orbit Insertion (JOI) in 2016.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

New Frontiers Other Missions and Data Analysis supports operating New Frontiers missions (New Horizons, Juno). No future missions are currently funded.

## Operating Missions

### NEW HORIZONS

New Horizons is the first scientific investigation to obtain a close look at Pluto and its moons Charon, Nix, Hydra, Kerberos and Styx (scientists discovered the last four moons after the spacecraft's launch in 2006). Scientists aim to find answers to basic questions about the surface properties, geology, interior makeup, and atmospheres on these bodies, the last in the solar system to be visited by a spacecraft.

New Horizons launched on January 19, 2006. It will reach Pluto in July 2015. As part of a potential extended mission, the spacecraft may then venture deeper into the Kuiper Belt to study one or more of the icy mini-worlds in this region approximately two billion miles beyond Pluto's orbit. The project continues to work to identify Kuiper Belt candidate targets for a post-Pluto mission phase.

To get to Pluto, which is three billion miles from Earth, in just 9.5 years, the spacecraft will fly by the dwarf planet and its five moons in 2015 at a velocity of about 27,000 miles per hour. The instruments on

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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New Horizons will start taking data on Pluto and Charon months before it arrives. About three months from the closest approach, when Pluto and its moons are about 65 million miles away, the instruments will begin taking measurements and begin to make the first maps of these intriguing bodies.

The New Horizons spacecraft will get as close as about 6,000 miles from Pluto and about 17,000 miles from Charon. When the spacecraft is closest to Pluto, it will take a variety of scientific observations, including close-up pictures in both visible and near-infrared wavelengths. These first images should depict surface features as small as 200 feet across and bring a plethora of new discoveries.

### Recent Achievements

The New Horizons spacecraft is rapidly approaching Pluto, covering an additional 280 million miles in the past year (three times the distance between the Earth and the Sun). The spacecraft is now approximately 466 million miles from Pluto and approaching at over nine miles each second.

The mission team completed a week-long live rehearsal with the spacecraft as part of its preparation for a 2015 arrival.

## JUNO

Juno will conduct an in-depth study of Jupiter, the most massive planet in the solar system. Juno's instruments will seek information from deep in Jupiter's atmosphere, enabling scientists to understand the fundamental processes of the formation and early evolution of the solar system. Juno successfully launched on August 5, 2011 as scheduled and within the budget allocated for development of this mission. Juno is the first solar panel power spacecraft to orbit the giant planet.

During its approximately one-year mission, Juno, with its first-ever polar orbit, will complete 33 eleven-day-long orbits and will sample Jupiter's full range of latitudes and longitudes. From its polar perspective, Juno combines remote sensing observations to explore the polar magnetosphere and determine what drives Jupiter's remarkable auroras. Juno has an onboard camera to produce images and it will provide unique opportunities to engage the next generation of scientists.

### Recent Achievements

In October 9, 2013, Juno successfully flew by the Earth to pick up speed, and currently is in a direct trajectory to the giant planet.


## MARS EXPLORATION

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Other Missions and Data Analysis	369.5	--	279.3	381.7	547.8	573.1	518.8
<b>Total Budget</b>	<b>369.5</b>	<b>288.0</b>	<b>279.3</b>	<b>381.7</b>	<b>547.8</b>	<b>573.1</b>	<b>518.8</b>
Change from FY 2014			-8.7				
Percentage change from FY 2014			-3.0%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Every time we feel close to understanding Mars, new discoveries send us straight back to the drawing board to revise existing theories. We've discovered that today's Martian wasteland hints at a formerly volatile world where volcanoes once raged, meteors plowed deep craters, and flash floods rushed over the land. Mars continues to throw out new enticements with each landing or orbital pass made by our spacecraft.

The Mars Exploration Program seeks to understand whether Mars was, is, or can be, a habitable world and whether it ever supported life. As the most Earth-like planet in the solar system, Mars has a landmass approximately equivalent to the Earth's as well as many of the same geological features, such as riverbeds, past river deltas, and volcanoes. Mars also has many of the same "systems" that characterize Earth, such as air, water, ice, and geology that all interact to produce the Martian environment.

The four broad, overarching goals for Mars Exploration are to:

- Determine whether life ever arose on Mars;
- Characterize the climate of Mars;
- Characterize the geology of Mars; and
- Prepare for human exploration.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

The Mars Rover 2020 Science Definition Team concluded its work. NASA released an instrument/payload AO, and the mission completed its initial Mission Concept Review.

## MARS EXPLORATION

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Curiosity found evidence of ancient habitable environments at Gale Crater and made atmospheric measurements confirming loss of more than 80 percent of Mars' atmosphere.

### WORK IN PROGRESS IN FY 2014

MAVEN launched in early FY 2014 and began its 10-month cruise to Mars.

The Mars Rover 2020 began Phase A/Formulation. NASA will select the payload in spring 2014.

Curiosity will explore several waypoints as it completes the trek to Mt. Sharp.

The missions to be reviewed include MSL, MRO Opportunity, Odyssey and Mars Express. An additional investment for Planetary extended missions is proposed under the Opportunity, Growth, and Security Initiative. Please refer to the OGSi section for more information.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY2015, the MAVEN spacecraft will complete Mars Orbit Insertion and begin science operations.

The Mars Rover 2020 will conduct the PDR and the Confirmation Review process.

### Program Management & Commitments

Program Element	Provider
Mars Rover 2020	Provider: JPL Lead Center: JPL Performing Center(s): JPL, GSFC Cost Share Partner(s): N/A
MOMA	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A
MSL	Provider: JPL Lead Center: JPL Performing Center(s): JPL, GSFC Cost Share Partner(s): Canadian Space Agency, Centro de Astrobiología, Federal Space Agency of Russia
MAVEN	Provider: GSFC Lead Center: GSFC Performing Center(s): JPL, GSFC Cost Share Partner(s): N/A

## MARS EXPLORATION

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Program Element	Provider
Mars Reconnaissance Orbiter (MRO)	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): Agenzia Spaziale Italiana
Mars Exploration Rover (MER)/Opportunity	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): Canadian Space Agency
Odyssey	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A

### Acquisition Strategy

NASA is acquiring the Mars Rover 2020 through JPL, taking advantage of the previous investment in the MSL to maximize heritage. By using contracts existing from the MSL project to procure copies of the as-flown hardware, JPL plans to maintain the lowest possible costs.

### MAJOR CONTRACTS/AWARDS

NASA released an AO for the Mars 2020 Rover instruments on September 24, 2013, with selections expected in June 2014.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
KDP-A for Mars Rover 2020	Agency Program Management Council (APMC)	Nov 2013	To determine if the Mars Rover 2020 project is ready to begin Phase A	The Mars Rover 2020 Mission is granted authority to begin Phase A	Sep 2014

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Mars Organic Molecule Analyzer (MOMA)	14.4	--	25.0	20.0	10.0	2.7	0.7
ExoMars	4.8	--	3.5	2.6	1.4	1.4	1.5
Mars Program Management	17.9	--	19.5	19.1	19.2	19.3	19.5
Mars Future Missions	108.5	--	0.0	0.0	0.0	0.0	0.0
Mars Rover 2020	0.0	65.0	92.0	202.7	388.6	416.6	370.2
Mars Mission Operations	1.8	--	1.8	1.8	1.9	1.9	1.9
Mars Research and Analysis	18.6	--	10.0	10.0	10.0	10.0	10.0
Mars Technology	4.0	--	4.0	4.0	6.5	11.0	4.8
2011 Mars Science Lab	63.8	--	59.4	58.0	58.0	58.0	58.0
Mars Reconnaissance Orbiter 2005 (MRO)	20.6	--	29.5	29.5	30.5	30.5	30.5
Mars Exploration Rover 2003	13.2	--	0.0	0.0	0.0	0.0	0.0
Mars Odyssey 2001	13.2	--	12.3	12.3	0.0	0.0	0.0
Mars Express	2.2	--	2.2	2.2	2.2	2.2	2.2
Mars Atmosphere & Volatile Evolution	86.5	--	20.1	19.5	19.5	19.5	19.5
<b>Total Budget</b>	<b>369.5</b>	<b>--</b>	<b>279.3</b>	<b>381.7</b>	<b>547.8</b>	<b>573.1</b>	<b>518.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Mars Exploration Other Missions and Data Analysis includes operating missions, Mars Research and Analysis, Mars Technology, and Mars Program Management. Also included are small projects in development, including the Mars Organics Molecule Analyzer-Mass Spectrometer (MOMA-MS) instrument to fly on ESA's 2018 ExoMars rover, and Electra communications radio to fly on ESA's 2016 ExoMars Trace Gas Orbiter.

## Mission Planning and Other Projects

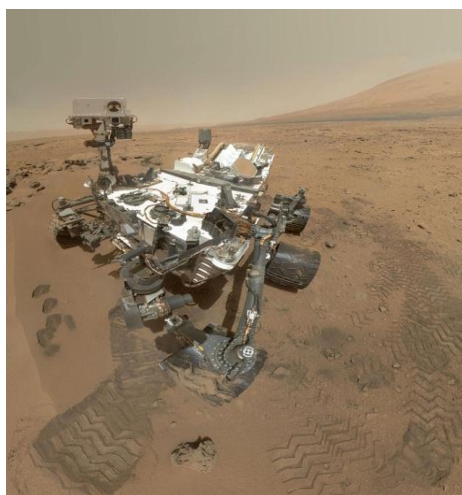
### MARS ORGANIC MOLECULE ANALYZER (MOMA)

MOMA is the core astrobiology instrument on the ESA ExoMars 2018 rover, and it addresses the top ExoMars science goal of seeking signs of past or present life on Mars. The MOMA-Mass Spectrometer (MOMA-MS) is the NASA-provided subsystem of MOMA composed of a dual-source mass

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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spectrometer to detect a wide range of organic molecules in Martian samples. Organic structure and distribution can be indicators of past or present life.



All of our future missions will be driven by rigorous scientific questions that will continuously evolve as we make new discoveries. Brand new technologies will enable us to explore Mars in ways we never have before, resulting in higher-resolution images, precision landings, longer-ranging surface mobility and the potential return of Martian soil and rock samples for studies in laboratories here on Earth.

### Recent Achievements

During FY 2013, the MOMA-MS project successfully completed the PDR and began production of the Engineering Test Unit. In FY 2014, MOMA-MS will conduct a Confirmation Review and enter Phase C, leading to a CDR. In FY 2015, MOMA-MS will begin production of the flight model in preparation for delivery to ESA.

### ExoMars

The ESA ExoMars program (Exobiology on Mars) is a series of missions designed to understand if life ever existed on Mars. The first mission in the ExoMars program is called the Trace Gas Orbiter. For this mission, NASA is contributing the Electra telecommunication radios, which have been successfully used on NASA's Mars Reconnaissance Orbiter. Electra acts as a communications relay and navigation aid for Mars spacecraft. Electra's UHF radios support navigation, command, and data-return needs.

### Recent Achievement

The mission completed the development, integration and test of both the Electra Engineering Model and the Electra Ground Support Equipment test racks. These were delivered and integrated to ESA in May and August,

2013 respectively. The overall NASA tasks are on schedule and budget.

## MARS PROGRAM MANAGEMENT

Mars Program Management provides for the broad-based implementation and programmatic management of the Mars Exploration program. Mars Program Management also supports independent panel reviews, studies regarding planetary protection, advanced mission studies and program architecture, program science, and telecommunications coordination and integration.

## MARS ROVER 2020

Building on the success of Curiosity's Mars landing, NASA initiated formulation of the next strategic mission in the Mars Exploration Program—a new science rover to be launched in 2020 to address the highest priority Mars science objectives recommended by the Planetary Science Decadal Survey, while



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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also providing opportunities for Human Exploration and Operations Mission Directorate and Space Technology Mission Directorate contributions and international collaboration. NASA will use the MSL architecture that successfully carried the Curiosity rover to the Martian surface, as the basis for the 2020 Mars rover design. A new 2020 Mars Pre-Project office at JPL conducted mission design work leading to a successful Mission Concept Review in August 2013. The mission concept leverages the MSL/Curiosity design, residual hardware, an experienced team, and existing industry partnerships in order to ensure mission costs and risks are as low as possible, while still delivering a highly capable rover with a proven landing system. Based on the results of the Science Definition Team effort from January to July 2013, NASA released a competitive AO on September 24, 2013, for scientific and exploration technology payloads to fly on the 2020 rover. The Mars Rover 2020 Project formally entered Phase A of formulation in November 2013.

During FY 2014, the Mars Rover 2020 Project will perform Phase A formulation activities, including: selecting the science and exploration technology payloads for flight; conducting inheritance reviews for heritage systems; maturing the potential sample handling and caching system architecture and design; and beginning launch vehicle procurement activities. Phase A will conclude with a Systems Requirements Review and Mission Definition Review.

The Mars Rover 2020 Project will perform Phase B formulation activities in FY 2015, including accommodation reviews of selected payloads; preliminary design efforts on new and modified hardware; continuing to build and integrate heritage system efforts that began in Phase A; completing the environmental impact statement; and launch vehicle selection. Phase B will conclude with a PDR and Confirmation to begin implementation phase of the mission.

### MARS MISSION OPERATIONS

Mars Mission Operations provides management and leadership for the development and operation of Mars multi-mission systems for operations. Mars Mission Operations supports and provides common operational systems and capabilities at a lower cost and risk than having each Mars project produce systems individually.

### MARS RESEARCH AND ANALYSIS

Mars R&A provides funding for research and analysis of Mars mission data in order to understand how geologic, climatic, and other processes have worked to shape Mars and its environment over time, as well as how they interact today. Specific investments include:

- Mars Data Analysis, which analyzes archived data collected on Mars missions;
- Critical Data Products, which provides data for the safe arrival, aero-maneuver, entry, descent, and landing at Mars; and
- MRO and MSL Participating Scientists programs for the MRO and MSL missions.

Data analysis through Mars R&A allows a much broader and objective analysis of the data and samples. It also allows research to continue for many years after the mission completion. Researchers make

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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fundamental measurements and discoveries and testable hypotheses about the Martian environment through these programs. This budget moves funding for Mars Fundamental Research to Planetary Science Research as part of a restructuring of the Planetary research program along fundamental science questions.

### Recent Achievements

The Mars R&A programs provided funding for more than 200 research projects, with 64 new awards in FY 2013 and five new graduate student research fellowships. These projects increase our scientific understanding of Mars' geology and environment, and the results are disseminated through publication in the scientific literature. Mars R&A funded work to identify potential hazards and landing sites for future missions, including human missions.

## MARS TECHNOLOGY

Mars Technology focuses on technological investments that lay the groundwork for successful future Mars missions, such as sample handling and processing technologies; entry, descent, and landing capabilities; Mars ascent vehicle component technology, and surface-to-orbit communications improvements.

### Recent Achievements

In FY 2013, the Mars Technology Development program matured a variety of technologies to enable and improve future landed missions on Mars. The Sample Acquisition, Handling and Caching technology achieved a maturity level adequate for potential inclusion on the Mars 2020 Rover mission. Two other technologies, Lander Vision System (LVS) and Fast Traverse (FT), also achieved their maturity goals and are candidates for infusion into future Mars missions. In FY 2014, the LVS and FT tasks will conclude, and several new tasks relating to Mars Sample Return focused technology and other technologies will be initiated.

## Operating Missions

### 2011 MARS SCIENCE LAB

MSL and its Curiosity rover, which successfully landed in August 2012, have initiated the prime mission exploration activities. MSL is exploring and quantitatively assessing regions around the landing site on Mars as potential past habitats for life. MSL is twice as long and three times as heavy as the Mars Exploration Rover Opportunity. The Curiosity rover is collecting Martian soil and rock samples and analyzing them for organic compounds and environmental conditions that could have supported microbial life. MSL is the first planetary mission to use precision landing techniques, steering itself toward the Martian surface. This landing method enabled the rover to land in an area less than 12 miles in diameter, about one-sixth the size of previous landing zones on Mars. In addition, Curiosity is the first planetary

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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rover to make use of a nuclear power source, which gives the rover the ability to travel up to 12 miles during her two-year primary mission. This international partnership mission uses components provided by the space agencies of Russia, Spain, and Canada.

### Recent Achievements

Curiosity's major activity is to complete the traverse from the landing site to the base of Mt. Sharp, approximately five miles away. The rover has already traveled more than 2.5 miles since landing. During the traverse to Mt. Sharp, the rover is continuing to examine the local surface along the way. One key finding from the data returned by Curiosity is the discovery that approximately two percent of the weight of the examined soil samples is composed of water ice. Analysis of the isotope ratio of argon in the atmosphere of Mars by Curiosity's Sample Analysis at Mars (SAM) instrument confirmed that some meteorites that have fallen to Earth originated on Mars. In addition, the isotope ratios point to the significant loss of the Martian atmosphere. The Radiation Assessment Detector instrument aboard the rover determined the radiation dose that a human crew might receive during a potential mission to Mars based on current propulsion technologies. During a six-month transit each way plus 18 months on the surface, a crew would receive a round-trip radiation dose of 0.6 Sievert, or 60 REM, which could affect mission design. Within the first year of the mission, Curiosity already determined that water flowed on the surface, was relatively neutral and low salinity, and contained the ingredients for life, demonstrating Mars could have supported microbial life.

### MARS RECONNAISSANCE ORBITER 2005 (MRO)

MRO, currently in its second extended operations phase, carries the most powerful camera ever flown on a planetary exploration mission. This capability provides a more detailed view of the geology and structure of Mars, and helps identify obstacles that could jeopardize the safety of future landers and rovers. MRO also carries a sounder to find subsurface water, an important consideration in selecting scientifically worthy landing sites for future exploration. Other science instruments on this spacecraft identify surface minerals and study how dust and water are transported in the Martian atmosphere. A second camera acquires medium-resolution images that provide a broader geological and meteorological context for more detailed observations from higher-resolution instruments. MRO will follow up on recent discoveries to determine the extent of ancient aqueous environments, reveal the three dimensional structure and content of the polar ice deposits, characterize the episodic nature of great dust storms, and detect seasonal flows of liquid water on Mars today.

MRO is capturing unique views of Mars with the most powerful telescopic camera ever to orbit another planet including continuing discoveries of warm-season flows of salty water. The camera also identified and characterized the landing site for the Curiosity rover and will identify landing sites for future landers in 2016, 2018, and 2020. MRO also serves as a major installment of an "interplanetary Internet," a crucial service for future spacecraft to communicate back to Earth.

### Recent Achievements

MRO data reveals a growing collection of evidence indicating that the present surface of Mars is still geologically active. One of the most exciting discoveries is dark markings or streaks, 0.5 to 5 meters in

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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width on steep slopes (greater than 25 degrees) that form and incrementally grow in late spring to summer, then fade or disappear in fall. They reform at nearly the same locations in multiple Mars years in the warm seasons, extending down-slope from bedrock outcrops or rocky areas, and are often associated with small channels on equator-facing slopes in the southern hemisphere. The streaks grow in size as temperatures increase to levels at which brines (waters that have high concentrations of dissolved minerals, largely salts) would be liquid.

### MARS EXPLORATION ROVER 2003

Mars Exploration Rover Opportunity, which is currently on its eighth extended operations phase, continues to explore geological settings on the surface of Mars. It continues to expand understanding of the history and the geological processes that shaped Mars, particularly those involving water. Opportunity has trekked for 24 miles across the Martian surface, conducting field geology, making atmospheric observations, finding evidence of ancient Martian environments where intermittently wet and habitable conditions existed, and sending back to Earth nearly 175,000 spectacular, high-resolution images.

#### Recent Achievements

In FY 2013, Mars Exploration Rover Opportunity explored the area around Endeavour Crater. In a location called Cape York on the rim of the crater, the rover analyzed rocks with compositions higher in aluminum and silicon and lower in calcium and iron than those previously encountered. The rock compositions are consistent with the presence of clay minerals, indicating that not only was water present in the past, but persistent enough to change rock compositions. Opportunity arrived at Solander Point to look for more clay minerals and maintain a tilt to the north to gather enough sunlight for power during the upcoming Mars winter.

Opportunity has traveled more than 24 miles across the Martian surface, setting a new record for U.S. driving distances away from Earth. In January 2014, Opportunity celebrated its tenth year on Mars.

### MARS ODYSSEY 2001

Mars Odyssey, currently in its fifth extended mission operations phase, is still in orbit around Mars. It continues to send information to Earth about Martian geology, climate, and mineralogy. Measurements by Odyssey enabled scientists to create maps of minerals and chemical elements and identify regions with buried water ice. Images that measure the surface temperature provided spectacular views of Martian topography. Mars Odyssey will continue critical long-term longitudinal studies of the Martian climate. Odyssey has served as the primary means of communications for NASA Mars surface explorers over the past decade and will continue that role for the Curiosity rover. The Odyssey orbiter continues to provide a communications relay for the Mars Exploration Rover Opportunity. Transmitting over 95 percent of the data from the rover to Earth, Odyssey will support the rover throughout its extended mission.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

2001 Mars Odyssey is the longest-lived Martian spacecraft in history (more than 12 years). Odyssey's longevity enables continued science, including the monitoring of seasonal changes on Mars from year to year and the most detailed global maps ever made of the planet, including infrared mapping. Odyssey served as the primary communication relay for the Mars Exploration Rover Opportunity transmitting from the rover to Earth 340 Mbits of data per week on average. In addition, it continues to be a key communications link for Mars Science Laboratory/Curiosity transmitting a total of 885Mbits of data per week.

### MARS EXPRESS

Mars Express, currently in its third extended mission operations phase, is an ESA mission that provides an understanding of Mars as a "coupled" system: from the ionosphere and atmosphere down to the surface and sub-surface. This mission addresses the climatic and geological evolution of Mars as well as the potential for life on the planet. NASA contributed components for the Mars Advanced Radar for Subsurface and Ionospheric Sounding and ASPERA instruments aboard Mars Express, and participates in the scientific analysis of mission data. Mars Express provides valuable context for the MAVEN mission by providing measurements of the upper Martian atmosphere and ionosphere during the solar maximum that occurs in FY 2013 to FY 2014.

### Recent Achievements

This past year, the MARSIS instrument successfully observed the Northern Polar cap. These observations provided improved estimates of the water inventory and history. Sounding observations also enhanced our understanding of the Martian ionosphere. This will provide valuable context for NASA's MAVEN mission, which NASA launched in November 2013 and will arrive at Mars in September 2014. These measurements provide more insights into how the Martian atmosphere and ionosphere interact with the solar wind and how Mars may have lost its atmosphere.

### MARS ATMOSPHERE & VOLATILE EVOLUTION (MAVEN)

MAVEN, successfully launched in 2013, will provide a comprehensive picture of the Mars upper atmosphere, ionosphere, solar energetic drivers, and atmospheric losses, to determine how the Mars atmosphere evolved through time. The mission will help answer long-standing questions regarding the loss of the Mars atmosphere, climate history, liquid water, and habitability. MAVEN will provide the first direct measurements ever taken to address key scientific questions about Mars' evolution. The MAVEN mission is the second mission of NASA's Mars Scout program. It will explore the upper atmosphere, ionosphere, and interactions with the Sun and solar wind. Scientists will use MAVEN data to determine the role that loss of volatile compounds (such as carbon dioxide and water) from the Mars atmosphere to space has played through time, giving insight into the history of Mars' atmosphere and climate, liquid water, and planetary habitability. As with all Mars Exploration Program orbiters, MAVEN also carries an Electra radio for communications with rovers and landers on the Mars surface. MAVEN will provide

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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contingency relay support during its primary science mission and eventually evolve into a more regular communications role.

### Recent Achievements

In FY 2013, MAVEN concluded a Development Phase highlighted by excellent cost and schedule performance. MAVEN launched in November 2013, and is in cruise to Mars. Mars Orbit Insertion will occur in September 2014, followed by a five-week commissioning and transition to science.

## OUTER PLANETS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Outer Planets Future Mission	69.7	80.0	15.0	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>147.8</b>	<b>159.0</b>	<b>95.7</b>	<b>82.2</b>	<b>84.5</b>	<b>27.8</b>	<b>9.1</b>
Change from FY 2014			-63.3				
Percentage change from FY 2014			39.8%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



While the Cassini spacecraft was in Saturn's shadow, the cameras were turned toward Saturn and the sun so that the planet and rings are backlit. In addition to the visual splendor, this special, very-high-phase viewing geometry lets scientists study ring and atmosphere phenomena not easily seen at a lower phase. Taken when Cassini was closer to Saturn than a similar image in 2006, it shows more detail in the rings.

The Outer Planets program enables science investigations spanning the diverse geography and disciplines of the outer solar system. The strategic missions in this portfolio investigate a broad array of science disciplines with more depth than is possible for smaller, tightly focused missions in the Discovery and New Frontiers programs. The science discoveries made by these strategic missions provide answers to long-held questions and theories about life beyond Earth and the origin and evolution of outer planets.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The budget includes \$15 million for pre-formulation work on the architecture for a potential Europa mission.

### ACHIEVEMENTS IN FY 2013

On February 21, 2013, NASA and ESA completed the competitive selection of the instrument payload

for the ESA JUICE mission. NASA will contribute approximately \$100 million of instruments, including a US-led instrument (the Ultraviolet Spectrograph) and two European-led instruments with significant US participation and hardware contributions (the Radar for Icy Moons Exploration and the Particle Environment Package). The selected teams are already beginning to work with ESA.

The Cassini mission continued generating new science discoveries at Saturn and completed an additional eight flybys of Titan, and one flyby of the small moon Rhea. The Cassini science team improved our knowledge of the temperature of Enceladus' striped ice, helping to resolve some of the mysteries

## OUTER PLANETS

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surrounding stripe formation. The team monitored the largest storm in the solar system on Saturn as well as a huge hurricane at the north pole; observed meteors colliding with Saturn's rings; and discovered a river on Titan similar to the Nile River on Earth as well as evidence of icebergs floating in Titan's lakes. Cassini also captured a new mosaic of a backlit Saturn with Earth, Mars, and Venus in the background. For the first time ever NASA provided advance notice to the world and encouraged people around the globe to wave at Saturn for the picture. Tens of thousands of people participated, the event generated over 200,000 hits on the Cassini website, and national and international news media covered the event.

NASA continued formulation activities for a Europa mission as directed by Congress in the FY 2013 budget. Most notably, the formulation team completed a more detailed assessment of orbiter and flyby mission concepts. Subsequently, NASA completed a series of trade studies, technology efforts, and independent reviews, including an assessment of using solar rather than nuclear power for the mission. NASA also addressed a long-standing risk for a Europa mission by competitively awarding 15 grants for instrument development and risk reduction under the Instrument Concepts for Europa Exploration program.

### WORK IN PROGRESS IN FY 2014

JUICE instrument development will continue based on the approved schedule negotiated with ESA. Payload Readiness Reviews, a critical step prior to formal ESA adoption of the mission, will be completed in mid FY 2014.

The Cassini mission will continue its high inclination orbit around Saturn in order to better investigate the planet's rings, north pole, and Titan's northern hemisphere as summer finally returns. Saturn's lengthy "year" measures 29 Earth years long, and Cassini is using its unique position to study Saturn over 13 years as it moves from winter to summer, an opportunity that is not likely to be repeated. During FY 2014 the spacecraft will flyby Titan an additional 11 times, allowing the team to also monitor the satellite as its long seasons change. The Cassini team will also continue to develop the proximal orbit mission.

The Europa flyby mission formulation team continues with limited technology developments and is conducting analysis to maximize science opportunities through Europa flybys while minimizing radiation exposure. In the interest of supporting a cost-effective Europa mission, NASA is exploring a variety of mission options, including ones that cost \$1 billion or less. In addition, the formulation team is working to assess the feasibility and potential benefits of utilizing alternative potential future launch vehicles, including the Space Launch System (SLS) and the Falcon Heavy, for a potential Europa mission. Grant recipients will continue their instrument development efforts and are expected to finish late in FY 2014.

A Senior Review of potential Planetary mission extensions is being held. The missions to be reviewed include Cassini. The Budget assumes continued support for Cassini in FY 2015.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

JUICE instruments development will continue based on the approved schedule. ESA scheduled formal adoption of the mission (equivalent to NASA's confirmation step for a mission) for November 2014.

Cassini will continue to observe seasonal and temporal change in the Saturn system to understand: (1) hemispherically asymmetric behavior on Titan, (2) the role of sunlight in Enceladus plume activity, and



## **OUTER PLANETS**

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(3) the origin of surprising asymmetry in Saturnian polar circulation. During FY 2015 Cassini will flyby Titan another eight times and begin lowering the inclination of its orbit to enable it to flyby Dione and Enceladus as well.

Following the analysis of options for a lower-cost Europa mission conducted in FY 2014, NASA will continue pre-formulation work developing the architecture for a Europa mission.

### **Mission Planning and Other Projects**

#### **JUPITER ICY MOONS EXPLORER (JUICE)**

NASA has partnered with ESA on an ESA-led mission to Ganymede and the Jupiter system. Planned for launch in 2022, the mission has a tentative model payload of 11 scientific instruments, and will arrive at Jupiter in 2030.

#### **OUTER PLANETS FUTURE MISSION**

Following the analysis of options for a lower-cost Europa mission conducted in FY 2014, NASA will continue developing the architecture for a potential Europa mission.

#### **OUTER PLANETS RESEARCH**

Outer Planets Research increases the scientific return of current and past NASA outer planets missions, guides current mission operations (e.g., selecting Cassini imaging targets), and paves the way for future missions (e.g., refining landing sites on Titan, reconsidering the ice shell thickness on Europa). The competitive programs within the Outer Planets Research effort increase understanding of the origin and evolution of the outer solar system and broaden the science community's participation in the analysis of data returned by Cassini, Galileo, New Horizons, and other missions. Part of Outer Planets Research moved to Planetary Science Research as part of a restructuring of the Planetary research program focused on fundamental science questions encompassing all planets and moons in the solar system.

### **Operating Missions**

#### **CASSINI**

Cassini, in its extended operations phase, is a flagship mission in orbit around Saturn that altered our understanding of the planet, its famous rings, magnetosphere, icy satellites, and particularly the moons Titan and Enceladus. It is exploring the Saturn system in detail, including its rings and moons. A major focus is Saturn's largest moon, Titan, with its dense atmosphere, methane-based meteorology, and geologically active surface. The Solstice mission is observing seasonal and temporal change in the Saturn system, especially at Titan, to understand underlying processes and prepare for future missions. The Solstice mission will continue to operate and conduct data analysis through 2017 (pending successful

## OUTER PLANETS

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Senior Review of its scientific merit). In 2017, an encounter with Titan will change its orbit in such a way that, at closest approach to Saturn, it will be only about 1,800 miles above the planet's cloud tops, and below the inner edge of the D ring. This sequence of approximately 15 "proximal orbits" will provide an opportunity for an entirely different mission for the Cassini spacecraft, investigating science questions never anticipated at the time Cassini launched. Cassini completed its prime mission in July 2008, completed its Equinox extended mission in July 2010, and began the Solstice extended mission in October 2010. The Cassini mission will end after the proximal orbits when a final encounter with Titan will send the Cassini probe into Saturn's atmosphere.

### **Program Management & Commitments**

Management responsibility for Cassini resides at JPL. Scientific mission priorities for the program and the research efforts reside within SMD's Planetary Science Division.

The Cassini mission is a cooperative project of NASA, the ESA, and the Italian Space Agency.

Cassini is committed to continue delivery of science data until 2018, contingent upon health and status of the spacecraft.

Program Element	Provider
Outer Planets Research	Provider: HQ Lead Center: Performing Center(s): Multiple Cost Share Partner(s): N/A
Cassini	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): The Italian Space Agency provided Cassini's high-gain communication antenna and the Huygens probe was built by ESA.
JUICE	Provider: JPL Lead Center: JPL Performing Center(s): JPL, APL, MSFC Cost Share Partner(s): ESA

### **Acquisition Strategy**

Outer Planets Research is included in the annual ROSES NASA Research Announcement. All major acquisitions and contracts for Cassini are in place.

## OUTER PLANETS

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Technical Feasibility	Independent Review Board	Aug 2013	To assess the feasibility of solar power for a potential Europa Mission	Solar power was preliminarily considered a feasible option for a Europa Mission	Sep 2014

## TECHNOLOGY

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>123.4</b>	<b>146.0</b>	<b>137.2</b>	<b>142.9</b>	<b>136.3</b>	<b>140.1</b>	<b>144.1</b>
Change from FY 2014			-8.8				
Percentage change from FY 2014			-6.0%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Mars Science Laboratory rover, Curiosity, took this self-portrait, which shows its Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG. This power source was selected for the rover's mission to provide greater flexibility in accessing difficult or remote terrain, to enable effective operation in the dusty Martian environment and throughout its winter season, and for providing heat to maintain effective operating temperatures for its instruments and systems.

Planetary Science missions demand advances in both power and propulsion systems to enable successful trips to harsh environments, far distances from the Sun that cannot be easily solar powered, and missions with highly challenging trajectories and operations. To meet these needs, Planetary Science supports multi-mission capabilities and technology developments in key spacecraft systems, and mission operations. The Planetary Science Technology program includes the Radioisotope Power Systems (RPS), Plutonium Production, RPS Production Operations infrastructure and Advanced Multi-Mission Operations System (AMMOS) projects.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

To sustain the necessary capacity to meet future missions' power needs, the FY 2015 NASA budget continues to support radioisotope power system production.

Due to shifting priorities in planetary science necessitated by budget realities, the Advanced Stirling Radioisotope Generator (ASRG) flight development is no longer affordable. In FY 2014, the RPS program restructured the ASRG project from a flight development effort to a technology maturation effort. Planetary Science has a sufficient amount of Pu-238 for its needs and will no longer fund the ASRG in FY 2015.

## **TECHNOLOGY**

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### **ACHIEVEMENTS IN FY 2013**

The Radioisotope Power Systems (RPS) program continued to advance the Stirling radioisotope generator technology, including solving key manufacturing issues.

### **WORK IN PROGRESS IN FY 2014**

The program is sustaining the Agency's investment in free-piston Stirling technology by advancing the maturity through in-house testing at GRC, and through targeted contracts with key suppliers. The program is also continuing investments in advanced thermoelectric technology, leading to eventual improvements in RPS performance, and in improving processes for supporting future RPS missions. The program will also build on FY 2013 successes in advancing transformational technologies to flight for the benefit of future planetary missions.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

RPS will continue the development of advanced radioisotope thermoelectric generator couples by validating lifetime and four-couple module power. RPS will also fund DOE safety testing to verify safety models for solid upper stages.

## **Program Elements**

### **PLUTONIUM**

NASA and DOE have begun implementing a Plutonium (Pu-238) Supply Project to restart domestic production under a DOE Pu-238 production program. NASA worked with DOE to assess the need and schedule for plutonium supplies to respond to the diminishing inventory of Pu-238 available to NASA missions from past US production and material purchased from Russia. Based on the studies of the Planetary decadal survey mission set, NASA revalidated the need for Pu-238 production to support future NASA missions. NASA is currently working with DOE to produce additional plutonium and radioisotope power systems.

### **RADIOISOTOPE POWER SYSTEM (RPS)**

NASA will continue technology investments in advanced thermal conversion technology, such as advanced thermocouples and Stirling converters, and will maintain and sustain current RPS system capabilities such as the Multi-Mission Radioisotope Thermal Generator. An additional \$15 million investment is proposed under the Opportunity, Growth, and Security Initiative to accelerate progress in Stirling convertor development and qualification, as a follow-on to the cancelled Advanced Stirling Radioisotope Generator project.

## TECHNOLOGY

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### DOE RADIOISOTOPE POWER SYSTEM INFRASTRUCTURE

The DOE Space and Defense Infrastructure subprogram has transitioned to a full cost recovery funding model. Funding to support this infrastructure is now included in NASA's budget request. NASA is currently the only user of radioisotope power systems.

### ADVANCED MULTI-MISSION OPERATION SYSTEM (AMMOS)

AMMOS provides multi-mission operations, navigation, design, and training tools for Planetary Science flight missions, as well as other Science Mission Directorate missions, and invests in improved communications and navigation technologies. The AMMOS project will continue to provide and develop multi-mission software tools for spacecraft navigation and mission planning throughout FY 2015. In addition, AMMOS will pursue complementary collaborations with the Agency's crosscutting Space Technology program. Utilizing the AMMOS common tools lowers individual mission cost and risk by providing a mature base for mission operations systems at significantly reduced development time.

### Program Management & Commitments

Program Element	Provider
RPS	Provider: GRC Lead Center: GRC Performing Center(s): GRC, JPL, KSC, DOE Cost Share Partner(s): N/A
Plutonium	Provider: DOE Lead Center: HQ Performing Center(s): GRC Cost Share Partner(s): N/A
DOE RPS Infrastructure	Provider: DOE Lead Center: HQ Performing Center(s): GRC Cost Share Partner(s): N/A
AMMOS	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A

## TECHNOLOGY

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### Acquisition Strategy

DOE provides radioisotope systems, production operations, and the Plutonium Restart project on a reimbursable basis.

### MAJOR CONTRACTS/AWARDS

None planned.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Relevance	National Academies	Dec 2010	Assessing the restart and sustainment of domestic production of radioisotope heat source material for deep space and other exploration missions. Assessing the development of and standards for flight certification of ASRG for flagship and other missions.		TBD
Performance	SRB/IPAO	Sep 2013	RPS Program Implementation Review.	SRB recommendations and Program responses will be presented to the Agency Program Management Council in early 2014	Sep 2015

# ASTROPHYSICS

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Astrophysics Research	155.8	--	<b>191.0</b>	216.2	221.2	234.6	261.2
Cosmic Origins	218.9	--	<b>120.3</b>	106.4	108.2	114.2	105.8
Physics of the Cosmos	124.5	--	<b>108.8</b>	100.9	86.6	89.4	142.4
Exoplanet Exploration	52.8	--	<b>47.5</b>	46.4	60.4	89.8	237.3
Astrophysics Explorer	65.1	--	<b>139.7</b>	163.7	174.9	168.7	186.4
<b>Total Budget</b>	<b>617.0</b>	<b>668.0</b>	<b>607.3</b>	<b>633.7</b>	<b>651.2</b>	<b>696.8</b>	<b>933.0</b>

## Astrophysics

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Other Missions and Data Analysis .....	ASTRO-8
COSMIC ORIGINS .....	ASTRO-11
Hubble Space Telescope Operations .....	ASTRO-13
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Other Missions and Data Analysis .....	ASTRO-24
PHYSICS OF THE COSMOS .....	ASTRO-28
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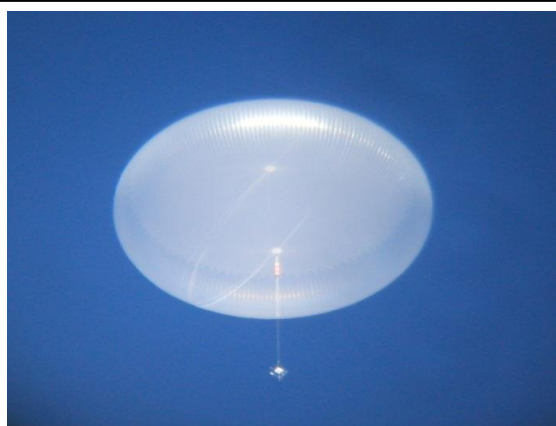
## ASTROPHYSICS RESEARCH

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Astrophysics Research and Analysis	65.0	--	<b>66.0</b>	70.2	71.5	71.5	71.5
Balloon Project	33.0	32.9	<b>38.3</b>	34.2	34.3	37.3	37.4
Other Missions and Data Analysis	57.8	--	<b>86.6</b>	111.8	115.3	125.8	152.2
<b>Total Budget</b>	<b>155.8</b>	<b>--</b>	<b>191.0</b>	<b>216.2</b>	<b>221.2</b>	<b>234.6</b>	<b>261.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Photograph of 7 MCF Super-Pressure balloon at float.**  
The SPB is a major technological advance that offers an order of magnitude increase in flight capability.

The Astrophysics Research program analyzes the data from NASA missions to understand astronomical events such as the explosion of a star, the birth of a distant galaxy, or the nature of planets circling other stars. The program also enables the early development of new technologies for future missions, and suborbital flights of experimental payloads on balloons and sounding rockets.

The program facilitates basic research for scientists to test their theories, and to understand how they can best use data from NASA missions to develop new knowledge about the cosmos.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The FY 2015 request includes funding to extend some operating Astrophysics missions, pending the recommendations of the next Astrophysics Senior Review in the spring of 2014. The Balloon project's budget increase supports two foreign campaigns. NASA expects an oversubscription of the Antarctic campaign because of the cancelled FY 2014 campaign. This request provides \$15.0 million to SMD to fund the best application of NASA Science education assets to meet the goals of the Nation's STEM education efforts. For more information on this education funding, please refer to the Other Missions and Data Analysis section

### ACHIEVEMENTS IN FY 2013

In 2013, NASA introduced a new competed research program, the Theory and Computational Astrophysics Networks, as a joint program with the Astronomical Sciences Division of the National Science Foundation. In response to a recommendation in the 2010 Astrophysics Decadal Survey, this new

## ASTROPHYSICS RESEARCH

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program offered three-year awards for networked teams distributed across multiple distinct institutions, to address key challenges in theoretical astrophysics that are of a scale and complexity that require sustained, multi-institutional collaborations. NASA and National Science Foundation funded six proposed networks, three each, from 29 proposals submitted. The networks will address key challenges, including: What were the first objects to light up the cosmos, and when did they do it? How do black holes grow? How do planets form? How does a star explode as a supernova?

NASA chose a second cohort of fellows of the Nancy Grace Roman Technology Fellowship. After which, in FY 2013, NASA chose two of the fellows from the first cohort to continue their projects for a further four years. NASA created this fellowship in 2011 within Astrophysics to develop early career researchers, who could lead future astrophysics flight instruments, projects, and missions.

Five groups launched experiments on sounding rockets in FY13. Interstellar Medium Absorption Gradient Experiment Rocket (IMAGER) made images of the Pinwheel Galaxy M101 in the ultraviolet light of the hottest young stars, to trace how the galaxy's dusty gas is disturbed. Sub-orbital Local Interstellar Cloud Experiment (SLICE) used ultraviolet spectra to study how starlight heats the interstellar gas in the Sun's neighborhood. The Far-ultraviolet Off Rowland-circle Telescope for Imaging and Spectroscopy (FORTIS) experiment tested a far-ultraviolet spectrometer to study the gas of comet ISON. The pattern of X-ray brightness seen by the DXL experiment confirmed a theory that fast-moving particles streaming outwards from the Sun produce some of the X-rays, as they collide with atoms of interstellar gas. Cosmic Infrared Background Experiment (CIBER) had its final flight, studying infrared light to measure the pace of star birth in the earliest galaxies.

The Balloon project conducted 12 balloon launches during three campaigns from the United States, Sweden, and Antarctica. The 2012 - 2013 Antarctic campaign was the most successful to date, in terms of both the total number of flight days (97) in a single campaign of three payloads and a record-breaking flight (55 days) for one of those payloads. Super Trans-Iron Galactic Element Recorder (Super-TIGER) broke flight duration records, with a 55-day flight measuring fast-moving nuclei of atoms heavier than iron. These atoms are produced as massive stars explode, and accelerated to near-light speeds. Two payloads tested technology to observe polarization in the background radiation, a relic of early cosmic history. Balloon-borne Large-Aperture Sub-millimeter Telescope (BLAST) measured magnetic fields in star-forming gas, while EBEX mapped the background radiation itself. At 8,000 pounds, E and B Experiment (EBEX) is the heaviest payload launched aboard a NASA scientific balloon. NASA studied the Sun for approximately 5 days during a mid-duration flight from Sweden to Canada. Furthermore, the Balloon project conducted the first science flight using the Wallops Arc-Second Pointing system as well as six other missions from Fort Sumner, New Mexico. This exceptional domestic campaign also included two static launches, counted as one launch, to test a new static-launch vehicle for the Space Technology Mission Directorate and the Jet Propulsion Laboratory (JPL).

### WORK IN PROGRESS IN FY 2014

Two science payloads and a SPB had each passed their mission readiness review and been shipped to New Zealand, to await subsequent shipment to Antarctica for onsite assembly and launch. The team planned to recover two payloads left on the ice from the previous year as part of the pending Antarctic balloon launch campaign. However, the Agency cancelled the launches due to the impact of the government shutdown on early launch site preparations that were underway on the ice. The two science payloads and the SPB are returning to their home base for recertification of flight readiness, while backup flight options are being considered. The project team plans to recover the two payloads forced to winter-

## **ASTROPHYSICS RESEARCH**

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over on the ice, although the recovery attempt for one of them will be pushed out to the end of the season, February 2014.

Contingency plans to fly the SPB and science payloads from other acceptable launch sites are under development. Currently under consideration is the possibility of launching the SPB from Wanaka, New Zealand and one of the science payloads from Hawaii. Neither of these options is certain at this time, so they conceivably could just go back to Antarctica in the coming year. A planned foreign campaign to Hawaii for the launch of a technology development mission for the Space Technology Mission Directorate and JPL will occur in spring 2014. The Balloon project also plans to support one domestic campaign, with perhaps six to eight conventional flights from Fort Sumner, New Mexico. On November 21, 2013, the FORTIS far-ultraviolet spectroscopic payload flew from the White Sands Missile Range, New Mexico, on a six-minute journey to study the gas streaming from Comet ISON as it approached the Sun.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA will continue a robust competed astrophysics research program, with emphasis on suborbital payloads and on development of key technologies for use in future missions. NASA will also pursue new work to confirm the nature of Kepler exoplanet candidates and explore the nature of planets circling other stars.

The Balloon project plans to support two foreign campaigns, including Hawaii and the annual Antarctic long-duration balloon flights, plus one domestic campaign with a significant number of conventional flights from Fort Sumner, New Mexico. The Hawaii campaign would again support technology flights for the Space Technology Mission Directorate and the Jet Propulsion Laboratory.

NASA is configuring its successful balloon-borne Cosmic Ray Energetics and Mass (CREAM) payload for a one-year exposure on the International Space Station, starting in FY 2015. From its vantage point above the Earth's atmosphere, this instrument, dubbed ISS-CREAM, will pursue the balloon payload discoveries with much greater statistical accuracy and lower background. The University of Maryland in College Park leads the ISS-CREAM mission and the NASA Goddard Space Flight Center (GSFC) Wallops Flight Facility (WFF) manages the mission. The international collaboration includes teams from the United States, South Korea, Mexico, and France.

## **Program Elements**

### **RESEARCH AND ANALYSIS**

This project supports basic research, solicited through NASA's annual Research Opportunities in Space and Earth Sciences (ROSES) announcements. NASA solicits investigations relevant to Astrophysics over the entire range of photon energies, gravitational waves, and particles of cosmic origin. Scientists and technologists from a mix of disciplines review proposals and provide findings that underlie NASA's merit-based selections.

## ASTROPHYSICS RESEARCH

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Astrophysics Research and Analysis solicits technology development for detectors and instruments for potential use on future space flight missions. Astrophysics Research and Analysis also solicits science and technology investigations using sounding rockets, high-altitude balloons, and similar platforms. A new type of scientific instrument is often flown first on a stratospheric balloon mission or on a sounding rocket flight that takes it briefly outside Earth's atmosphere. Instruments for balloons and sounding rockets are not as costly as those for an orbital mission, and experimenters can build them quickly to respond to unexpected opportunities. The experimenter usually retrieves the equipment after the flight, so that novel instruments can be tested, improved, and flown again. These suborbital flights are important for training the next generation of scientists and engineers to maintain US leadership in science, engineering, and technology. The project also supports small experiments to be flown on the ISS, laboratory astrophysics, and limited ground-based observations.

The Astrophysics Theory Program solicits basic theory investigations needed to interpret data from NASA's space astrophysics missions and to develop the scientific basis for future missions. Astrophysics Theory topics include formation of stars and planets; supernova explosions and gamma-ray bursts; the birth of galaxies; dark matter, dark energy and the cosmic microwave background.

### BALLOON PROJECT

The Balloon project offers inexpensive, high-altitude flight opportunities for scientists to conduct research and test new technologies before space flight application. Balloon experiments cover a wide range of disciplines in astrophysics, solar, and heliospheric physics, as well as Earth upper-atmosphere chemistry. Observations from balloons have even detected echoes of the Big Bang and probed the earliest galaxies. The Balloon project continues to increase balloon size and enhance capabilities, including an accurate pointing system to allow high quality astronomical imaging and a SPB that maintains the balloon's integrity at a high altitude to allow much longer flights.

### Program Schedule

The program issues solicitations every year. A Senior Review process assesses all missions in the extended operations phase every two years, and all data archives every three or four years.

Date	Significant Event
Feb 2014	NASA Research Announcement (NRA) Solicitation
Mar 2014	Senior Review Operating Missions
Feb 2015	NRA Solicitation
April 2015	Senior Review Data Archives
Feb 2016	NRA Solicitation
Mar 2016	Senior Review Operating Missions
Feb 2017	NRA Solicitation
Feb 2018	NRA Solicitation

## ASTROPHYSICS RESEARCH

Mar 2018	Senior Review Operating Missions
April 2019	Senior Review Data Archives

### Program Management & Commitments

Program Element	Provider
Research and Analysis Project	Provider: All NASA Centers Lead Center: HQ Performing Center(s): All Cost Share Partner(s): N/A
Balloon Project	Provider: WFF Lead Center: WFF Performing Center(s): WFF, HQ, Marshall Space Flight Center (MSFC) Cost Share Partner(s): N/A

### Acquisition Strategy

NASA issues solicitations for competed research awards each February through ROSES. Panels of scientists conduct peer reviews on all proposals. A Senior Review process reviews all missions in extended operations phase every two years, and all data archives every three or four years.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Balloon Management	Physical Science Laboratory, New Mexico State University (managing Columbia Scientific Balloon Facility, which is a government owned, contractor operated facility)	Palestine, TX and other balloon launch sites

## ASTROPHYSICS RESEARCH

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Archives Senior Review Panel	2011	A comparative evaluation of Astrophysics data archives.	Recommended improvements in archives	2015,2019
Quality	Astrophysics Research Program Review Panel	2011	Review of competed research projects.	Panel praised scope and impact of programs	TBD
Quality	Mission Senior Review Panel	2012	A comparative evaluation of Astrophysics operating missions.	Ranking of missions, citing strengths and weaknesses	2014, 2016, 2018

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Astrophysics Directed R&T	0.0	--	0.0	20.3	20.1	25.8	44.1
Contract Administration, Audit & Quality Assurance Services	14.7	--	15.0	15.5	15.5	15.5	15.5
Education and Public Outreach	10.1	--	15.0	15.0	15.0	15.0	15.0
Astrophysics Senior Review	0.0	--	21.0	24.4	28.0	32.9	41.0
Astrophysics Data Program	16.9	--	17.0	17.6	17.6	17.6	17.6
Astrophysics Data Curation and Archival Research	16.0	--	18.6	19.1	19.1	19.1	19.1
<b>Total Budget</b>	<b>57.8</b>	<b>--</b>	<b>86.6</b>	<b>111.8</b>	<b>115.3</b>	<b>125.8</b>	<b>152.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Launch of CIBER from WFF in June 2013, to measure the light of the earliest stars and galaxies

The Astrophysics Research program prepares for the next generation of missions through both theoretical research and applied technology investigations. This program uses data from current missions and suborbital science investigations to advance NASA's science goals. One of these is to create new knowledge as explorers of the universe, and to use that knowledge for the benefit of all humankind.

### Mission Planning and Other Projects

### DIRECTED RESEARCH AND TECHNOLOGY

This project funds the civil service staff that will work on emerging Astrophysics projects, instruments and research.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### CONTRACT ADMINISTRATION, AUDIT AND QUALITY ASSURANCE SERVICES

This project provides critical safety and mission product inspections and contract audit services from the Defense Contract Management Agency and Defense Contract Audit Agency, respectively. It also provides for supplier contract assurance audits, assessments, and surveillance by the NASA Contract Assurance Services Program.

### EDUCATION AND PUBLIC OUTREACH

The FY 2015 Budget provides \$15 million to support SMD-wide education and public outreach projects and activities. During FY 2015 SMD will assess its portfolio of education activities and competitively allocate funding to the highest priority education projects within NASA Science. These investments will provide a return on the public's investment in NASA's scientific research by sharing the story, the science and the adventure of NASA's scientific explorations of our home planet, the solar system, and the universe beyond.

### ASTROPHYSICS SENIOR REVIEW

The Astrophysics Senior Review project enables extension of the life of current operating missions. Every other year, the Astrophysics division conducts a senior review to do comparative evaluations of all operating missions that have successfully completed or are about to complete their prime mission operation phase. The senior review ratings help NASA determine which missions will receive funding for extended operations. Consistent with the 2012 Senior Review, NASA transferred funds previously held in this project to Spitzer, Planck, Chandra, Fermi, X-Ray Multi-Mirror Mission (XMM), Kepler, Hubble Space Telescope, Swift, and Suzaku. The next senior review will take place in the spring of 2014.

### ASTROPHYSICS DATA ANALYSIS PROGRAM (ADAP)

The ADAP solicits research that emphasizes the analysis of NASA space astrophysics data archived in the public domain at one of NASA's Astrophysics Data Centers. The size and scope of the archival astronomical data available to ADAP researchers grew dramatically, including data obtained from such major strategic missions as Spitzer and Kepler. The budget in coming years will ensure continued, effective use of this scientific resource as data holdings continue to grow from current operating missions such as Kepler, Fermi, Hubble Space Telescope, and Chandra.

### Recent Achievements

The number of proposals submitted to ADAP has tripled over the last several years, reflecting a dramatic increase in demand for the data from NASA's space astrophysics missions. The research programs supported under the ADAP typically combine data from multiple NASA space astrophysics missions and span a broad range of wavelengths. The multi-mission, multi-wavelength nature of these investigations enables unique science and plays a crucial role in realizing the full scientific potential of NASA's missions. In 2013, the program received 276 proposals in response to its annual solicitation. Of those,



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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NASA selected 33 proposals spanning the field of Astrophysics and exploiting the full range of NASA's archival data holdings for funding. Topics include:

- Continued analysis of the data from Kepler and Spitzer to study planets, probe active galactic nuclei accretion physics, and understand flares in cool stars;
- Mining the data from the Wide-field Infrared Survey Explorer (WISE), Spitzer, Herschel, Swift, and Galaxy Evolution Explorer (GALEX) surveys to explore the evolving physical processes in interacting galaxies and to discover the most luminous galaxies in the Universe;
- Combining Herschel, Planck, and Wilkinson Microwave Anisotropy Probe (WMAP) data to understand emission from the Interstellar Medium in the Milky Way and other galaxies;
- Using Suzaku and XMM-Newton archival observations to search for dark matter signatures in galaxy clusters;
- Combining Spitzer, Infrared Space Observatory (ISO), and Herschel infrared line emission data to model the diversity of protoplanetary disks; and
- Constraining galaxy evolution models by using Spitzer, Herschel, Hubble Space Telescope and Keck data to connect the interstellar gas and dust properties of distant galaxies.

### ASTROPHYSICS DATA CURATION AND ARCHIVAL RESEARCH (ADCAR)

The Astrophysics Data Centers constitute an ensemble of archives that receives processed data from individual missions and makes them accessible to the scientific community. After the completion of a mission, the relevant, active, multi-mission archive takes over all data archiving activities. ADCAR covers the activities of the Astrophysics Data Centers and NASA's participation in the Virtual Astronomical Observatory. The project implements priorities from the FY 2011 Archival Senior Review in FY 2012 and beyond.

#### Recent Achievements

The Astrophysics Data Centers are tackling challenges and opportunities presented by a tremendous growth of content. In FY 2013, the Mikulski Archive for Space Telescopes had 18 million database searches and delivered 240 terabytes of data to the astronomical community and the public; more than 1000 scientific publications used the Mikulski Archive for Space Telescopes data. New products included major data releases from the Kepler mission on newly discovered planets beyond the Solar System. The NASA/IPAC Extragalactic Database now supports long-running database queries using a new queuing and scheduling system. NASA/IPAC Extragalactic Database set a new query record in FY 2013, serving 14.7 million web requests in September alone. The Infrared Science Archive had several major data releases, including the AllWISE processed images and catalogs combining all phases of the WISE mission, enabling increased sensitivity to faint and transient sources. The Astrophysics Data System project increased its bibliographic data holdings by 7 percent to exceed 10 million records, including over 3 million scholarly papers. The Astrophysics Data System full-text publication archive is now the most complete in the physical sciences, and links between papers and science datasets grew by 39 percent.

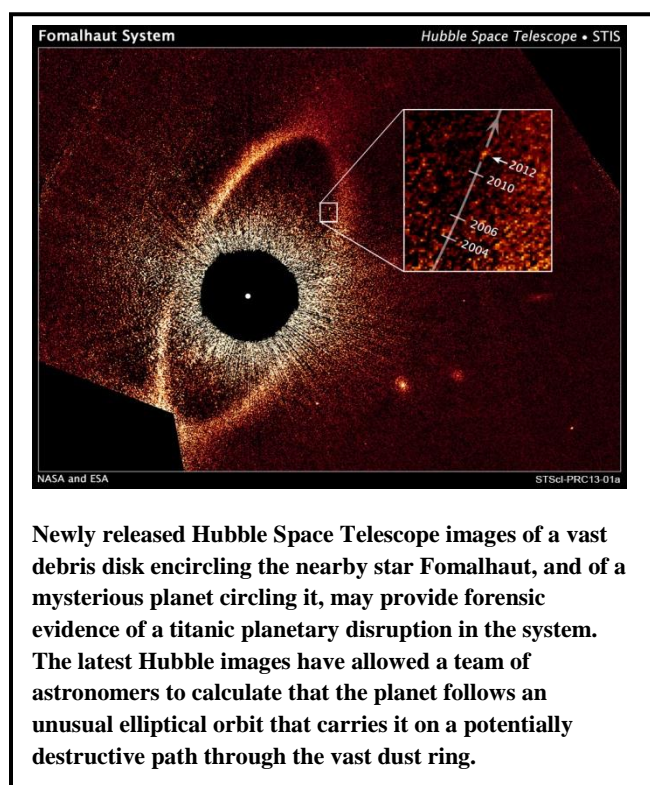
## COSMIC ORIGINS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Hubble Space Telescope (HST)	93.3	98.3	75.3	91.8	88.2	92.3	83.9
Stratospheric Observatory for Infrared Astronomy (SOFIA)	77.5	87.4	12.3	0.0	0.0	0.0	0.0
Other Missions and Data Analysis	48.1	--	32.7	14.6	20.0	21.9	21.9
<b>Total Budget</b>	<b>218.9</b>	<b>--</b>	<b>120.3</b>	<b>106.4</b>	<b>108.2</b>	<b>114.2</b>	<b>105.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



“How did we get here?” This simple, but fundamental question drives the broad science objectives of NASA’s Cosmic Origins program. Our search for an answer raises underlying questions and topic areas such as: how and when did the first stars and galaxies form? When did the universe first create the elements critical for life? How did galaxies evolve from the very first systems to the types we observe “in the here and now,” such as the Milky Way in which we live? How do stars and planetary systems form and change with cosmic time?

No individual space observatory or airborne observatory can completely address all of these questions, but in partnership, they can begin to unravel the answers. Currently operating facilities in the Cosmic Origins program are Hubble Space Telescope, Spitzer Space Telescope (SST), and the Stratospheric Observatory for Infrared Astronomy (SOFIA). Working collectively, across a wide swath of wavelengths from the far-ultraviolet through the far-infrared and sub-millimeter, they create a

comprehensive web of information and data that spans both the electromagnetic spectrum and time itself.

For more information, see: <http://cor.gsfc.nasa.gov/>.

## **COSMIC ORIGINS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The budget greatly reduces funding for SOFIA. NASA will work with current partner Germany and potential partners to identify a path forward for SOFIA with greatly reduced NASA funding. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.

## HUBBLE SPACE TELESCOPE OPERATIONS

Formulation	Development	Operations
-------------	-------------	------------

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	Notional			
				FY 2016	FY 2017	FY 2018	FY 2019
Total Budget	93.3	98.3	75.3	91.8	88.2	92.3	83.9
Change from FY 2014			-23.0				
Percentage change from FY 2014			-23.4%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Distribution of high water vapor concentration events observed by Aura MLS in the lower stratosphere. These events, driven by large-scale convective events and anti-cyclonic monsoonal circulation, did not correlate with any significant ozone loss over North America.

One of NASA's most successful and long-lasting science missions, the Hubble Space Telescope, has beamed hundreds of thousands of images back to Earth, shedding light on many of the great mysteries of astronomy. It helped scientists determine the age of the universe, the identity of quasars, and the existence of dark energy. Hubble launched in 1990 and is currently in an extended operations phase. The fourth servicing mission, completed in 2009, added new batteries, gyros, and instruments to extend its life even further into the future.

The Cosmic Origins program is studying concepts to dispose of Hubble safely after its mission has concluded. The status of the observatory and the orbital conditions that would lead to orbital decay and reentry will determine the timing for the disposal mission.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The FY 2015 request reflects a one-time reduction, based on a change in grants administration at the Space Telescope Science Institute.

### ACHIEVEMENTS IN FY 2013

Using the natural “lensing” magnification effect of a massive foreground galaxy cluster, the Hubble Space Telescope in collaboration with the Spitzer Telescope spotted MACS0647, the most distant galaxy

## HUBBLE SPACE TELESCOPE OPERATIONS

Formulation	Development	Operations
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ever seen. The telescopes observed the galaxy at only 420 million years after the big bang, or about 3 percent of the current 13.8 billion-year age of the universe. In fact, a new careful probe of the deepest Hubble images revealed an entire population of primitive galaxies that formed more than 13 billion years ago. Closer to home, Hubble uncovered a previously unknown moon of Neptune, and carefully tracked incoming Comet ISON, dubbed "comet of the century" because of its unusual brightness as it approaches the Sun.

### WORK IN PROGRESS IN FY 2014

In FY 2014 and beyond, NASA will support mission operations, systems engineering, software maintenance, ground systems support, and guest-observer science grants. Work continues on mission life extension initiatives, such as optimizing the use of the gyroscopes.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The Space Telescope Science Institute (STScI) will select Cycle 23 science observations. Similar to other recent competitions for Hubble observing time, NASA expects requested observational orbits to outnumber the available orbits by a factor of six to one, indicating that Hubble remains one of the world's preeminent astronomical observatories.

### Project Schedule

Date	Significant Event
Jun 2014	Announcement of Selected Cycle 22 Investigations
Dec 2014	Release of Cycle 23 Call for Proposals

### Project Management & Commitments

Element	Description	Provider Details	Change from Formulation Agreement
Observatory Operation	Provides safe and efficient control and utilization of Hubble, maintenance and operation of its facilities and equipment, as well as creation, maintenance, and utilization of Hubble operations processes and procedures	Provider: Lockheed Martin Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A

# HUBBLE SPACE TELESCOPE OPERATIONS

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Science management	Evaluates proposals for telescope time and manages the science program.	Provider: STScI/AURA Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): European Space Agency (ESA)	N/A

## Acquisition Strategy

All new grant and research selections are made competitively.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Observatory Operation	Lockheed Martin	Littleton, CO
Science management	STScI/AURA	Baltimore, MD

## INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Senior Review	2014	Evaluate efficiency and productivity of Hubble Operations	Maximize Hubble Space Telescope science return and reliability within available resources	2016, 2018, 2020

# STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations
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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted		Request FY 2015	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2014		FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0
Development/Implementation	941.4	77.5	87.4	87.4	0.0	0.0	0.0	0.0	0.0	0.0	1106.3
Operations/Close-out	0.0	0.0	0.0	0.0	12.3	0.0	0.0	0.0	0.0	0.0	12.3
<b>2014 MPAR LCC Estimate</b>	<b>976.4</b>	<b>77.5</b>	<b>87.4</b>	<b>87.4</b>	<b>12.3</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>1153.6</b>
<b>Total Budget</b>	<b>976.4</b>	<b>77.5</b>	<b>87.4</b>	<b>87.4</b>	<b>12.3</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>1153.6</b>
Change from FY 2014					-75.1						
Percentage change from FY 2014					-85.9%						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*



The Stratospheric Observatory for Infrared Astronomy (SOFIA), a joint project of NASA and the German Aerospace Center (DLR), shown operating from the Christchurch International Airport in New Zealand during July 2013. While flying from Christchurch, SOFIA observed celestial objects most easily observed from the Southern Hemisphere including the center of our Milky Way Galaxy, young stars, star forming regions, and supernova remnants in the southern Milky Way, and the Milky Way's two companion galaxies known as the Magellanic Clouds. The Budget greatly reduces funding for SOFIA. (Credit: NASA/Carla Thomas)

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

## PROJECT PURPOSE

SOFIA is a unique airborne astronomical observatory, capable of observing a wide variety of astronomical objects and phenomena. SOFIA can be used to investigate star birth and death and the formation of new planetary systems; identify complex molecules in space; observe planets, comets, and asteroids in our solar system, as well as nebulae and dust in galaxies.

The original case for compelling “Great Observatory” science from SOFIA assumed an overlap with the Spitzer Space Telescope for complementary science observations and at least one year of operations prior to the launch

of the Herschel Space Observatory. Because SOFIA development has taken much longer than originally envisioned (full operability capability is expected in 2014, eleven years after the launch of Spitzer and one year after the end of the Herschel mission), the observatory will no longer provide the kind of

## **STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)**

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Formulation	Development	Operations
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scientific impact and synergies with other missions as once planned. Additionally, the James Webb Space Telescope, planned to launch in 2018, will provide data at mid-infrared wavelengths, partially mitigating the absence of SOFIA.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The Budget greatly reduces funding for SOFIA, which has annual operating costs of almost \$80 million. SOFIA's annual operations budget is the second most expensive in the Astrophysics Division (after Hubble Space Telescope). This funding can have a larger impact supporting other science missions. NASA will seek to work with current partner Germany and other potential partners to identify a path forward for SOFIA with greatly reduced NASA funding. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.

### **PROJECT PARAMETERS**

SOFIA is designed as a highly modified Boeing 747SP aircraft with a large open-port cavity aft of the wings, housing a 2.5-meter telescope optimized for infrared/sub-millimeter wavelength astronomy.

### **ACHIEVEMENTS IN FY 2013**

In 2013, SOFIA logged 175 of 240 scheduled research hours, due to technical issues and cancelled flights during the government shutdown.

In June 2013, the Faint Object InfraRed CAmera for the SOFIA Telescope (FORCAST) instrument completed its commissioning flights, thereby becoming the third of four instruments to achieve the required maturity state to reach Full Operational Capability (FOC). The fourth instrument, First Light Infrared Test Experiment Camera (FLITECAM), began its commissioning flights.

SOFIA completed its first-ever scientific remote deployment in July 2013, performing observations of objects in the Southern Hemisphere sky while temporarily based in Christchurch, New Zealand. Over the course of 14 nights, the project performed nine science flights, demonstrating the most rapid flight tempo in the program's history. The observatory achieved 100 percent of its objectives during the deployment.

In August 2013, SOFIA successfully completed its first Program Implementation Review before the SOFIA Standing Review Board.

In addition, in August 2013, SOFIA's second-generation instrument--the upgraded High-resolution Airborne Wideband Camera (HAWC+)--completed its Preliminary Design Review (PDR).



## STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations
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### WORK IN PROGRESS IN FY 2014

SOFIA has completed science cycle 1 and has initiated science cycle 2. The operations team continues to implement Observatory performance upgrades, and aircraft and telescope heavy maintenance will begin in June 2014. Instrument commissioning activities continue and SOFIA is expected to achieve full operational capability. In 2014 NASA will initiate discussions with current partner Germany and potential partners to identify a path forward for SOFIA with greatly reduced NASA funding.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.

### SCHEDULE COMMITMENTS/KEY MILESTONES

SOFIA began Early Science flights in November 2010 and will reach full operational capability by March 2014.

Milestone	Confirmation Baseline Date	FY 2015 PB Request
FOC	Oct 2001	Mar 2014

### Development Cost and Schedule

No change to estimates since FY 2010.

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2007	919.5	70	2014	1106.3	20.3	FOC	Dec 2013	Mar 2014	3

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

## STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations
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### Development Cost Details

NASA added additional funds to the development budget to preserve the new instrument selection schedule and science hours and to fund risk reduction activities. Risk reduction activities previously planned for operations were moved into development. The program redefined the SOFIA milestone FOC as the capability to provide full science operational capability with four available instruments. Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>919.5</b>	<b>1,106.3</b>	<b>186.8</b>
Aircraft/Spacecraft	657.7	780.1	122.4
Science/Technology	199.6	221.5	21.9
Other Direct Project Costs	62.2	104.7	42.5

### Project Management & Commitments

The Armstrong Flight Research Center (AFRC) manages the overall SOFIA program and SOFIA airborne system. Ames Research Center (ARC) manages SOFIA science.

Element	Description	Provider Details	Change from Baseline
Platform	Refurbished Boeing 747SP modified to accommodate telescope	Provider: AFRC/L3 Lead Center: AFRC Performing Center(s): AFRC Cost Share Partner(s):	N/A
Science Operations Center	Science operations center will schedule observations, and manage data acquisition and processing	Provider: ARC/USRA Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): German Aerospace Centre (DLR)/DSI	N/A

# STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Telescope	2.5 meter diameter, dual mirror	Provider: DLR/DSI Lead Center: AFRC Performing Center(s): AFRC Cost Share Partner(s): DLR/DSI	N/A
Flight Operations	Flight crew, maintenance, and fuel	Provider: AFRC/CSC DynCorp Lead Center: AFRC Performing Center(s): AFRC Cost Share Partner(s): DLR/DSI	N/A
High-speed Photometer for Occultations (HIPO)	Simultaneous high-speed time-resolved imaging photometry at two optical wavelengths	Provider: Lowell Observatory Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A	N/A
First Light Infrared Test Experiment Camera (FLITECAM)	Large field-of-view, narrow- and broad-band photometric imaging and low-resolution spectroscopy from 1 to 5.5 micrometers	Provider: University of California Los Angeles Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A	N/A
Faint Object InfraRed CAmera for the SOFIA Telescope (FORCAST)	Large field-of-view, narrow- and broad-band photometric imaging and low-resolution spectroscopy from 1 to 5.5 micrometer	Provider: Cornell University Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A	N/A
Echellon-Cross-Echelle Spectrograph (EXES)	Echelon spectrometer, 5-28 microns R=105, 104, or 3000	Provider: ARC Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A	N/A
High-resolution Airborne Wideband Camera (HAWC)	Far-infrared bolometer camera, 50-240 microns	Provider: University of Chicago Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): N/A	Yes (HAWC will be upgraded to HAWC+ before being delivered to SOFIA)

# STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
German Receiver for Astronomy at Terahertz Frequencies (GREAT)	Infrared heterodyne spectrometer 60 to 200 microns	Provider: Germany - DLR/DSI Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): DLR/DSI, Max-Planck- Institute	N/A
Field Imaging Far-Infrared Line Spectrometer (FIFI-LS)	Imaging spectrometer 42 to 210 microns	Provider: Germany - DLR/DSI Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): DLR/DSI, University of Stuttgart	N/A
Upgraded High-resolution Airborne Wideband Camera (HAWC+)	HAWC far-infrared camera to be upgraded with the addition of polarimetry capability and new state-of-the-art detectors	Provider: JPL, GSFC Lead Center: ARC Performing Center(s): JPL, GSFC Cost Share Partner(s): N/A	Yes (new selection)

## Acquisition Strategy

All major contracts have been awarded.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Platform	L3 Communications	Palmdale, CA
Cavity Door Drive System	Woodward MPC	Skokie, IL
Aircraft Maintenance Support	L3 Vertex Aerospace (under AFRC shared service contract)	Palmdale, CA
Science Operations	University Space Research Association	Palmdale and Moffett Field, CA

# STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

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Formulation	Development	Operations
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## INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Operations Optimization Review Team (OORT) Evaluation	Operations Optimization Review Team	Nov 2011	Evaluate plans and processes for the operational phase and identify any means of improving efficiency	Program has implemented recommendations to improve scientific productivity, crew safety, and operational efficiency.	N/A
Program Implementation Review (PIR)	SRB	Aug 2013	Assess program performance and review progress against Full Operational Capability milestone	Program approved for continuation by APMC.	N/A

## CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT

SOFIA is an airborne observatory that will study the universe in the infrared spectrum. These infrared observations allow scientists to study the dust between stars, the formation of stars and new solar systems, the chemistry of the universe, and the deep universe where the most distance galaxies are seen in infrared light. SOFIA will host a complement of scientists, computer engineers, graduate students, and educators on nightlong research missions. SOFIA will be a major factor in the development of observational techniques and of new instrumentation and in the education of young scientists and teachers in the discipline of infrared astronomy.

NASA and DLR are working together to construct SOFIA, a Boeing 747SP aircraft modified by L3 Communications Integrated Systems to accommodate a 2.5 meter reflecting telescope. SOFIA will be the largest airborne observatory in the world and will make observations that are impossible for even the largest and highest of ground-based telescopes. SOFIA will operate at 41,000 feet using US and German instruments and flights will last, on average, six to eight hours.

# STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations
2010 Issues	Corrective Action Plan	
<p>Issue 1: Issue 1: Definition of Full Operational Capability</p> <p>Current Status: The Full Operational Capability milestone requirements have been revised to emphasize science instrument observational capability (4 science instruments), the overall program has been replanned in terms of schedule (no change in Full Operational Capability date, however), and the NASA Agency Program Management Council has approved the replan.</p>	<p>Programmatic: Review of the definition of the Full Operational Capability milestone technical requirements by the independent Standing Review Board resulted in a finding that the original definition (800 flight hours per year) was an improper definition in that insufficient science emphasis was contained in the definition. Therefore, the definition of Full Operational Capability was revised to focus on science instrument capability (the requirement was revised to four available science instruments, consistent with the Major Program Annual Report definition), and the overall program was replanned around that definition. The replanned program plan was approved by the NASA Agency Program Management Council (APMC) on October 6, 2010. This did not cause a change in the externally committed FOC date of December 2014, but does emphasize science in the definition.</p>	
<p>Issue 2: Late delivery of Cavity Door Drive System</p> <p>Current Status: The cavity door drive system controller and actuator was delivered and integrated in the SOFIA observatory, and flight testing to clear the full flight envelope has been completed. This permits the continuation of SOFIA system testing, leading up to the first science flights in December 2010.</p>	<p>Programmatic: Late delivery of software that operates the telescope observation doors on the aircraft resulted in later-than-planned initiation of open door flight-testing and science observation. NASA stationed representatives at Woodward's facility to support and oversee the vendor until delivery of the cavity controller and actuator.</p>	

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Cosmic Origins Program Management	2.7	--	2.6	2.7	2.8	2.9	2.9
Cosmic Origins SR&T	8.6	--	8.8	8.2	15.2	17.0	17.0
Cosmic Origins Future Missions	0.3	--	1.6	1.0	1.0	2.0	2.0
SIRTF/Spitzer	15.3	--	14.2	0.0	0.0	0.0	0.0
Herschel	21.1	--	5.5	2.7	1.0	0.0	0.0
<b>Total Budget</b>	<b>48.1</b>	<b>--</b>	<b>32.7</b>	<b>14.6</b>	<b>20.0</b>	<b>21.9</b>	<b>21.9</b>



Massive stars can wreak havoc on their surroundings, as can be seen in this new view of the Carina nebula from NASA's Spitzer Space Telescope. The bright star at the center of the nebula is Eta Carinae, one of the most massive stars in the galaxy. Its blinding glare is sculpting and destroying the surrounding nebula. Eta Carinae is a true giant of a star. It is around 100 times the mass of our sun and is burning its nuclear fuel so quickly that it is at least one million times brighter than the sun. It has brightened and faded over the years, and some astronomers think it could explode as a supernova in the not-too-distant future.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Other Missions and Data Analysis supports the Spitzer Space Telescope, the scientific applications of which continue to expand, as well as NASA's partnership with European Space Agency (ESA) on the groundbreaking Herschel mission. Spitzer determined the mass and age of the youngest known galaxies, seen as they were when the Universe was one-tenth or less of its current size and age. Herschel detected within our galaxy the first known molecule incorporating an argon atom. The science team expects many more discoveries over the next several years as data from both observatories are analyzed.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Mission Planning and Other Projects

#### **COSMIC ORIGINS PROGRAM MANAGEMENT**

Cosmic Origins program management provides programmatic, technical, and business management, as well as program science leadership and coordination for education and public outreach products and services.

##### **Recent Achievements**

The Program Office helped to facilitate the activities of the Astrophysics Roadmap Team, a community team charged with developing a 30-year vision for astrophysics.

#### **COSMIC ORIGINS STRATEGIC RESEARCH AND TECHNOLOGY**

Cosmic Origins SR&T supports Hubble fellowships, program-specific research and advanced technology development efforts such as the Strategic Astrophysics Technology solicitation issued in FY 2012. In addition, funding supports the study of a future ultraviolet/optical space capability, and Hubble disposal mission planning.

##### **Recent Achievements**

In late FY 2013, an Advanced Mirror Technology and a Far-Infrared Heterodyne Array Technology were selected for funding under the Cosmic Origins Strategic Astrophysics Technology (COR SAT) solicitation. In addition, the other eight technologies selected under COR SAT during previous years made significant progress.

#### **COSMIC ORIGINS FUTURE MISSIONS**

This funds early concept studies (pre-Phase A) for future Cosmic Origins missions, in accordance with the NASA strategic plan.

##### **Recent Achievements**

NASA issued a call for white papers to seek input for potential Wide-Field Infrared Survey Telescope (WFIRST) coronagraphic science investigations.



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Operating Missions

#### **SIRTF/SPITZER**

The Spitzer Space Telescope, launched in 2003 as the final element of NASA's series of Great Observatories, is now in extended operations. Spitzer is an infrared telescope using two channels of the Infrared Array Camera instrument to study exoplanet atmospheres, early clusters of galaxies, near-Earth asteroids, and a broad range of other phenomena. Spitzer completed its cryogenic mission in FY 2009, and extended warm operations through FY 2014. The 2014 Senior Review may recommend extending the mission beyond 2014.

#### **Recent Achievements**

Spitzer astronomers reported the first direct detection of what may be the most distant galaxies from Earth. These galaxies, also observed by Hubble, provide a glimpse of the Universe when it was less than 10 percent of its current age. Spitzer and Hubble also began the Frontier Fields Initiative, a coordinated effort using Spitzer and Hubble Space Telescope Directors Discretionary Time to observe six lensing clusters, and corresponding blank fields, to unprecedented depths. These observations take advantage of the ability of galaxy clusters to act as powerful cosmological lenses and magnify the extremely distant, faint Universe. Spitzer observations of the potential Asteroid Retrieval Mission target BD2009 constrained its size of approximately less than 20 feet across. The Exoplanet science community used Spitzer to measure the radius of the exoplanet GJ1214b. NASA discovered a second and third transiting exoplanet each of around 0.6 Earth radii in the GJ 436 system making this the first multiple transiting exoplanet system found outside the Kepler field.

#### **HERSCHEL**

The Herschel Space Observatory is a collaborative mission with ESA that launched on May 14, 2009. Herschel can detect the coldest and dustiest objects in space, such as cool cocoons where stars form and dusty galaxies bulking up with new stars. It has the largest single mirror ever built for a space telescope and it collects long wavelength radiation from some of the coldest and most distant objects in the universe. NASA contributed key technologies to two instruments onboard Herschel, and hosts US astronomer access to data through the NASA Herschel Science Center. Herschel's on-board supply of helium expired in the middle of FY 2013, and the focus of the mission has turned to analysis of the vast stores of data already obtained.

#### **Recent Achievements**

The Herschel Space Observatory continued extremely efficient and productive operations in FY 2013 until cryogen exhaustion on April 29, 2013 ended astronomical observations. Herschel is particularly effective in probing conditions in the interstellar medium of galaxies via the ensemble of rotational lines of carbon monoxide. This is a critical step in understanding how the rate of formation of new stars varies over cosmic time. Scientists also reported exciting new results on conditions in the Milky Way, including

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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the detection of the first molecule incorporating an argon atom. Argon is a stable element that previously had never been observed as part of a molecule.

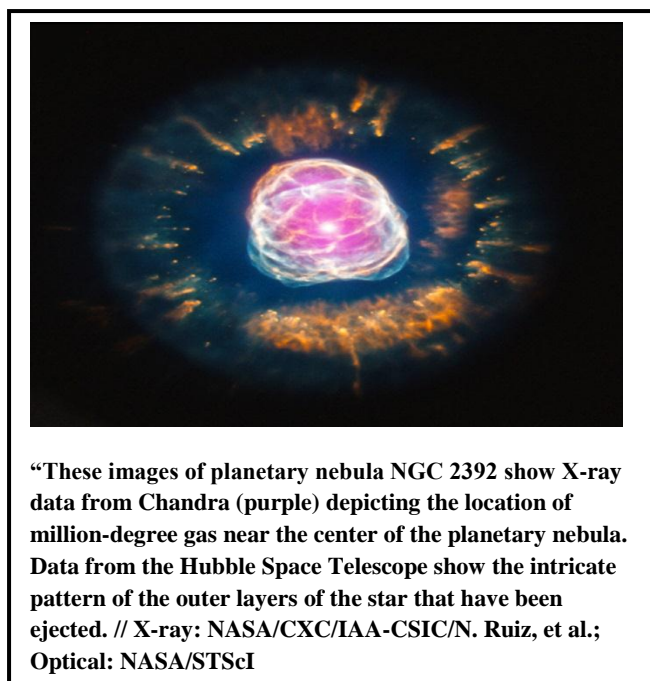
## PHYSICS OF THE COSMOS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Other Missions and Data Analysis	124.5	--	108.8	100.9	86.6	89.4	142.4
<b>Total Budget</b>	<b>124.5</b>	<b>--</b>	<b>108.8</b>	<b>100.9</b>	<b>86.6</b>	<b>89.4</b>	<b>142.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The universe can be viewed as a laboratory that enables scientists to study some of the most profound questions at the intersection of physics and astronomy. How do matter, energy, space, and time behave under extreme gravity? What is the nature of dark energy and dark matter? How did the Universe grow from the Big Bang to its present size? The Physics of the Cosmos (PCOS) program incorporates cosmology, high-energy astrophysics, and fundamental physics projects that address central questions about the nature of complex astrophysical phenomena such as black holes, neutron stars, dark matter and dark energy, cosmic microwave background, and gravitational waves.

The operating missions within the PCOS program are beginning to provide answers to the fundamental questions above. Scientists using data from the Fermi mission are trying to determine what composes mysterious dark

matter and how black holes accelerate immense jets of material to nearly the speed of light. The Planck mission observed the earliest moments of the universe and has provided a high-resolution map of the cosmic microwave background. XMM-Newton is helping scientists solve cosmic mysteries, including enigmatic massive black holes. The Chandra mission continues to reveal new details of celestial X-ray phenomena, such as the collisions of clusters of galaxies that directly detect the presence of dark matter. It unveiled a population of faint, obscured massive black holes that may provide the early seeds for galaxy formation and growth since the birth of the universe nearly 14 billion years ago.

PCOS includes a vigorous program to develop technologies necessary for the next generation of space missions to address the science questions of this program.

For more information, see: <http://nasascience.nasa.gov/about-us/smd-programs/physics-of-the-cosmos>.

## **PHYSICS OF THE COSMOS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

In October 2013, ESA terminated mission operations of Planck. The funding in FY 2015 reflects the final year of funding for data analysis by the US Planck science team and archiving by NASA's Planck data center.

## OTHER MISSIONS AND DATA ANALYSIS

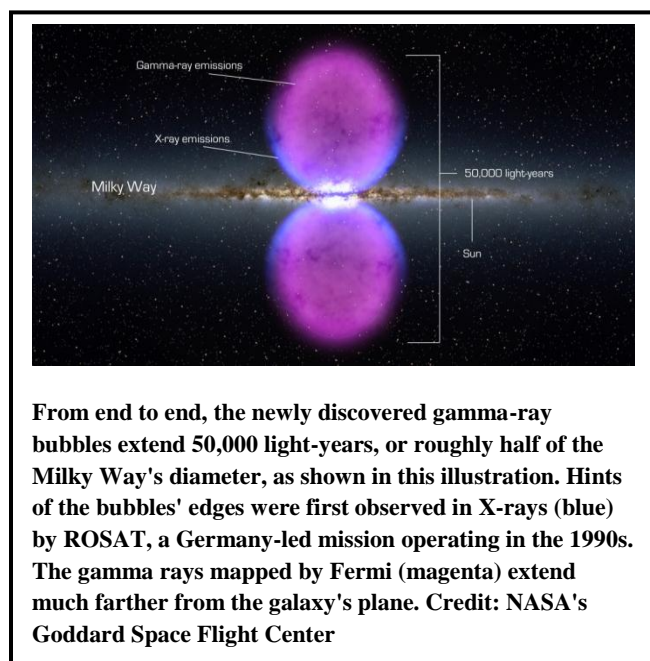
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Physics of the Cosmos SR&T	15.9	--	10.6	15.8	21.1	22.8	34.7
Euclid	13.8	--	15.0	7.3	5.9	5.9	6.0
Physics of the Cosmos Program Management	2.9	--	2.8	2.8	2.9	3.0	3.0
Physics of the Cosmos Future Missions	0.4	--	1.0	1.0	1.1	2.1	43.0
Fermi Gamma-ray Space Telescope	24.9	--	18.6	18.6	0.0	0.0	0.0
Chandra X-Ray Observatory	57.3	--	55.8	55.4	55.6	55.6	55.6
XMM	1.9	--	1.0	0.0	0.0	0.0	0.0
Planck	7.3	--	4.1	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>124.5</b>	<b>--</b>	<b>108.8</b>	<b>100.9</b>	<b>86.6</b>	<b>89.4</b>	<b>142.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The FY 2015 budget supports NASA's participation in Euclid, and the extension of the Chandra and Planck missions per the 2012 Senior Review of Operating Missions.

### Mission Planning and Other Projects

#### PCOS SUPPORTING RESEARCH AND TECHNOLOGY

PCOS Supporting Research and Technology supports Einstein Fellowships and program-specific research and early technology development efforts to prepare for the next generation of PCOS space missions. The Space Technology (ST)-7 project is developing

enhanced thrusters scheduled for launch in 2015 on the ESA Laser Interferometer Space Antenna (LISA)-Pathfinder mission. These new thrusters will be able to apply thrust equivalent to the weight of a single

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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grain of sand, enabling ESA to conduct the LISA-Pathfinder gravitational technology demonstration experiment.

### Recent Achievements

The PCOS program released its updated Program Annual Technology Report. This report summarizes the status of technology development funded by the program in FY 2013 and describes the prioritization of future technology needs. A copy of the report can be found at: [http://pcos.gsfc.nasa.gov/technology/PCOS\\_PATR\\_2013.pdf](http://pcos.gsfc.nasa.gov/technology/PCOS_PATR_2013.pdf)

## EUCLID

NASA is collaborating on Euclid, an ESA mission selected as part of ESA's Cosmic Visions program in June 2012 and scheduled for launch in 2020. Euclid seeks to investigate the accelerated expansion of the universe, the so-called "dark energy," using a Visible Instrument and a Near Infrared Spectrometer and Photometer instrument, as well as ground-based data. Responsibility for developing the two instruments and the Science Data Centers rests with the Euclid Consortium, comprised of over 950 scientists and engineers from over 50 institutes in Europe, the United States, and Canada. In the Euclid mission, NASA contributes flight detector subsystems for the Near Infrared Spectrometer and Photometer instrument in exchange for membership in the Euclid Science Team and Consortium and competed science opportunities for US investigators.

### Recent Achievements

In September 2013, the NASA portion of the Euclid mission entered implementation. In FY 2014, the project awarded a contract for the procurement of the flight hardware to be delivered to ESA.

## PCOS PROGRAM MANAGEMENT

PCOS program management provides programmatic, technical, and business management, as well as program science leadership.

### Recent Achievements

In FY 2014, the PCOS Program Office led a study for an x-ray probe with an external Science and Technology Definition Team (STDT). The STDT will deliver the preliminary report in the spring of 2014 and the final report in the winter of 2015.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### PCOS FUTURE MISSIONS

PCOS Future Missions funding supports future mission concept studies.

## Operating Missions

### PLANCK

Planck's objective is to analyze, with the highest accuracy ever achieved, the remnants of the radiation that filled the universe immediately after the Big Bang. Planck enables scientists to address fundamental questions, such as the initial conditions for the evolution in the universe, the overall geometry of space, the rate at which the universe is expanding, and the nature and amount of the constituents of the universe. Planck, launched in May 2009, is an ESA-led telescope with substantial NASA contributions.

#### Recent Achievements

On October 23, 2013, ESA sent the last command to the Planck Space Telescope, which ended mission operations for the mission, having already placed the spacecraft in its final heliocentric orbit. The Planck mission, and NASA provided element, met the level one requirements for the prime mission, and the mission continued operations in an extended phase successfully for another 2.5 years. Data analysis and archival activities will continue through FY 2015.

### FERMI

The Fermi Gamma-ray Space Telescope explored the extreme environments in the universe from black holes to gamma-ray bursts and expanded knowledge of their high-energy properties. Fermi data are answering long-standing questions across a broad range of topics, including solar flares, the origin of cosmic rays, and the nature of dark matter. Fermi, a NASA mission with strong international and Department of Energy involvement, launched in June 2008.

#### Recent Achievements

Fermi entered extended operations in August 2013. During the prime mission lifetime of five years, Fermi met all of its level one requirements. The Fermi space observatory explores the extreme universe through the detection of gamma rays, the most energetic form of light, emitted by a variety of high-energy astrophysical phenomena. During the last year, researchers used Fermi observations to (among other things) estimate the intensity of the extragalactic background light (i.e., the light collectively emitted by stars and other objects throughout the history of the universe), and to obtain direct evidence indicating that the remnants of exploded stars (supernovae) are the sources of high-energy particles (cosmic rays) in our galaxy. A significant event occurred on April 27, 2013, when Fermi detected a relatively nearby (3.6 billion light-years) gamma-ray burst (GRB 130427A) that set records for brightness, highest energy, and duration. Gamma-ray bursts GRBs are sudden, brief flashes of gamma rays, most likely emitted by

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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processes involving the relativistic plasma jets and shocks that are generated when the core of an exploding massive star collapses to form a black hole.

### CHANDRA

Launched in 1999, Chandra is transforming our view of the universe with its high quality X-ray images, providing unique insights into violent events and extreme conditions such as explosions of stars, collisions of galaxies, and matter around black holes. Chandra enables observations of the Bullet Cluster of galaxies that provide direct evidence for the existence of dark matter. In addition, studies of clusters of galaxies using Chandra data have greatly strengthened the case for the existence of dark energy. Chandra observations of the remains of exploded stars, or supernovas, have advanced our understanding of the behavior of matter and energy under extreme conditions. Chandra also discovered and studied hundreds of supermassive black holes in the centers of distant galaxies.

#### Recent Achievements

With its unique vision of some of the hottest and most energetic phenomena in the cosmos, Chandra delivered several outstanding results over the past year. Astronomers used Chandra to show that the remains from the explosion of a star likely contain the youngest known black hole in our Milky Way galaxy. Chandra also made the first detection in X-rays of an exoplanet passing in front of its parent star, a result that measures some of the characteristics of the atmosphere of this distant world.

### X-RAY MULTI-MIRROR (XMM)

XMM provides unique data for studies of the fundamental processes of black holes and neutron stars. It studies the evolution of chemical elements in galaxy clusters and the distribution of dark matter in galaxy clusters and elliptical galaxies. XMM, an ESA-led mission with substantial NASA contributions, launched in December 1999. NASA provides the US Guest Observer Facility at GSFC.

#### Recent Achievements

During the past year, XMM observations yielded a number of important new science results. Scientists thought the violent winds observed from stars much more massive than the Sun consisted of a smooth flow of hot gas. However, recent XMM observations have revealed that these winds are actually fragmented into hundreds of thousands of clumps, thus prompting an entire re-thinking of previous models of these objects. XMM recently obtained the first measurement of a small surface feature on a Magnetar (a highly magnetized pulsar), providing further evidence that these objects contain some of the strongest magnetic fields in the Universe. Joint XMM/Nuclear Spectroscopic Telescope Array (NuSTAR) observations of a rotating supermassive black hole in the heart of a spiral galaxy similar to our own Milky Way provided new insights into how galaxies form and grow.



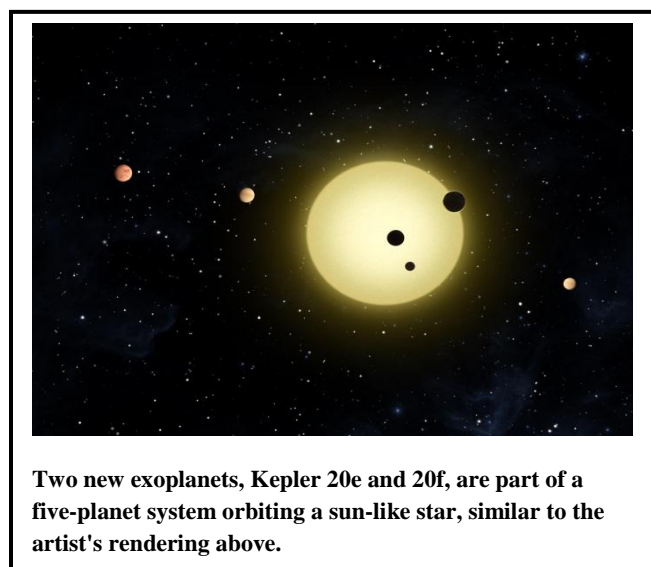
## EXOPLANET EXPLORATION

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Other Missions and Data Analysis	52.8	--	47.5	46.4	60.4	89.8	237.3
<b>Total Budget</b>	<b>52.8</b>	<b>--</b>	<b>47.5</b>	<b>46.4</b>	<b>60.4</b>	<b>89.8</b>	<b>237.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Humankind stands on the threshold of a voyage of unprecedented scope and ambition, promising insight into timeless questions: Are we alone? Is Earth unique, or are planets like ours common? One of the most exciting new fields of research within the NASA Astrophysics portfolio is the search for planets, particularly Earth-like planets, around other stars.

Since the discovery of the first exoplanets, in the mid-1990s, astronomers have discovered over 1000 planets orbiting stars of all shapes and sizes in our galaxy. At first, most of the planets discovered were so-called “Hot Jupiter’s”—gas giants similar in size to the planet Jupiter, but orbiting much closer to their parent stars. However, as time goes on, scientists are gradually finding smaller and even smaller

planets in larger orbits around their parent stars. An increasing number of these planets have sizes approaching that of the Earth, and are almost certainly rocky. NASA’s Exoplanet Exploration program is advancing along a path of discovery leading to a point where scientists can directly study the atmospheres and surface features of habitable, rocky planets, like Earth, around other stars in the solar neighborhood.

In the future, NASA aims to develop systems that will allow scientists to take the pivotal step from identifying an exoplanet as Earth-sized, to determining whether it is truly Earth-like, and possibly even detecting if it bears the fingerprints of life. Such an ambitious goal includes significant technological challenges. An important component of the Exoplanet Exploration effort is a robust technology development program with the goal of enabling a future direct detection mission.

For more information, go to: <http://exep.jpl.nasa.gov/>.

## **EXOPLANET EXPLORATION**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

In May 2013, the Kepler spacecraft suffered the failure of a second of its four on-board reaction wheels. That failure left the spacecraft incapable of maintaining the fine pointing performance that is critical to the mission's high-precision photometric measurements. The spacecraft is currently in a fuel-efficient safe mode, and the primary science mission was completed. Engineering tests demonstrated that it was not possible to recover either of the two failed reaction wheels. Study of a potential 2-wheel controlled Kepler mission, including its scientific potential, technical feasibility, and operational cost is part of the Astrophysics Senior Review for mission extensions in spring 2014.

Before the reaction wheel failures, the Kepler mission exceeded its baseline mission requirement, returning almost four and one-half years of unparalleled photometric measurements. That data will continue to drive scientific discoveries in a variety of fields, especially the search for Earth-sized exoplanets, for many years to come. The drive to determine the abundance of habitable, Earth-sized planets in the galaxy will continue through the completion of the analysis of the Kepler mission data archive by the Kepler Science Team.

## OTHER MISSIONS AND DATA ANALYSIS

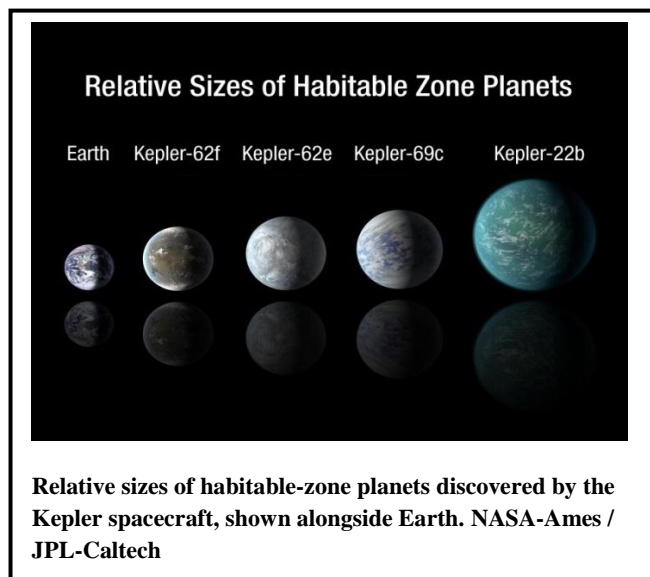
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Astrophysics Decadal Strategic Mission	0.0	56.0	14.0	14.0	21.1	51.4	198.0
Exoplanet Exploration SR&T	20.5	--	17.8	18.2	24.9	25.1	25.2
Exoplanet Exploration Program Management	4.2	--	5.8	5.8	5.8	6.0	5.9
Exoplanet Exploration Future Missions	0.7	--	2.0	1.2	1.1	1.0	2.0
Keck Operations	5.7	--	6.0	6.1	6.1	6.2	6.2
Large Binocular Telescope Interferometer	2.6	--	2.0	1.1	1.3	0.0	0.0
Kepler	19.1	--	0.0	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>52.8</b>	<b>--</b>	<b>47.5</b>	<b>46.4</b>	<b>60.4</b>	<b>89.8</b>	<b>237.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

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### Mission Planning and Other Projects

#### ASTROPHYSICS DECADAL STRATEGIC MISSION (ADSM)

NASA is studying options for how to address the NRC's 2010 Astrophysics Decadal highest science recommendations in the large and medium categories: the science of Wide-Field Infrared Survey Telescope (WFIRST) and the maturation of technology for a potential future exoplanet characterization mission.

#### Recent Achievements

NASA has completed concept studies of three different mission options to provide the science of WFIRST. They include: a stand-alone mission addressing all the WFIRST science objectives as identified in the decadal report; a stand-alone mission which can do as much of the WFIRST science objectives as identified in the decadal report that could be done at a probe-class mission; and a mission using telescope assets received from the National Reconnaissance Office, which can do the WFIRST science objectives

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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and fly a coronagraph for exoplanet science addressing the maturing of technology priority. NASA will continue studying the third option during FY 2014 to mature the concept for evaluation.

### EXOPLANET EXPLORATION STRATEGIC RESEARCH AND TECHNOLOGY

Exoplanet Exploration Strategic Research and Technology supports the Sagan Postdoctoral Fellowships, program-specific scientific research, and technology development activities that support and enable future Exoplanet Exploration missions.

In FY 2013, NASA supported approximately nine competitively selected technology development projects involving 14 different investigators, and 17 Sagan fellows. The selected technology development projects all focus on advancing technologies for separating the feeble reflected light of an exoplanet from the overwhelming glare of its parent star so that it can be analyzed for clues to the planet's nature. Those technologies will one day enable the ultimate goal of NASA's Exoplanet Exploration Program: a future mission capable of imaging and measuring the spectra of habitable, Earth-like exoplanets in the solar neighborhood. In 2015, NASA will continue to work on technologies for future telescopes.

#### Recent Achievements

New coronagraph techniques have demonstrated suppression of starlight glare to a few parts in a billion and only a few image diameters away from the bright parent star. Coronagraphs and starshades are enabling technologies for the direct detection of exoplanets around stars. They block out the light from the stars and, thus, make possible the detection of planets orbiting the parent star. NASA could use this technology in possible future missions enabling direct imaging of exoplanets. In addition, star shades that are many tens of meters in diameter, an alternative to coronagraphs, require precision dimensional control after a stowed launch. A recent deployment test has shown that the required control and repeatability is achievable.

### EXOPLANET EXPLORATION PROGRAM MANAGEMENT

Exoplanet Exploration program management provides programmatic, technical, and business management, as well as program science leadership. The program management coordinates supports and tracks the progress of the program's numerous technology development tasks, and oversees the program's diverse portfolio of projects, including Large Binocular Telescope Interferometer (LBTI), Kepler, and the NASA Exoplanet Science Institute.

#### Recent Achievements

Scientists have confirmed more than 1,000 exoplanets, with more than an additional 3,500+ candidates discovered by the Kepler mission for continuing investigation. The current estimate is that one in five solar type stars has an earth sized planet in the habitable zone – the region of planetary orbits where liquid water can exist. The program is managing design studies of probe scale exoplanet exploration mission opportunities and identification of coronagraph instrument options supporting the ADSM concept study. These study results will be available early in FY 2015.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### EXOPLANET EXPLORATION FUTURE MISSIONS

Exoplanet Exploration Future Missions funding supports the execution of the exoplanet mission science and technology definition teams, and ultimately the formulation, development, and implementation of a future Exoplanet Exploration flight mission.

#### Recent Achievements

The project formed Community-based Science and Technology Definition Teams to study two probe scale exoplanet mission concepts. One is a coronagraphic telescope approach and the second is a star shade flying in long-range formation with a separate free flying telescope. An associated technical/engineering study group supports each Science and Technology Definition Teams. These teams will deliver interim reports in the spring and summer of 2014 and a final report in February 2015.

### Operating Missions

#### KECK OPERATIONS

Keck Operations is the NASA portion of the Keck Observatory partnership. NASA uses its share of observing time in support of all Astrophysics science programs. Observation time is competed, selected, and managed by the NASA Exoplanet Science Institute. The Institute has awarded a significant portion of the observing time to studies of potential planets identified by Kepler.

#### Recent Achievements

The Keck Observatory achieve, a partnership between the NASA Exoplanet Science Institute and the Keck Observatory ingests and curates existing and new data from the Keck Observatory. Keck Observatory achieve provides public access to non-proprietary data and limited access to proprietary observations. NASA received 83 proposals for use on NASA Keck Single Aperture telescope time during the first half of calendar 2014. This is a healthy oversubscription rate of 3.75 to 1.

#### LARGE BINOCULAR TELESCOPE INTERFEROMETER

The LBTI is the NASA portion of the Large Binocular Telescope partnership. Engineers designed the LBTI to allow high contrast, high spatial resolution infrared imaging of the dust clouds around nearby stars. The system surveys nearby stars for dust and debris disks that may hamper the detection of planets around those stars. This information will be crucial for designing future space observatories capable of detecting and characterizing those planets.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

Completion and commissioning of LBTI occupied most of FY 2013. Some delays occurred due to poor weather and observatory issues unrelated to LBTI, itself. The project expects the LBTI instrument to be ready for full scientific operations by spring 2014.

### KEPLER

Kepler, launched in March 2009, is specifically designed to survey the distant stars in this region of the Milky Way galaxy to detect and characterize rocky planets in or near the "habitable zone" of their host star. The habitable zone encompasses the distances from a star where liquid water can exist on a planet's surface. As time progresses, smaller planets with longer orbital periods emerge from the data.

The Kepler project has now refocused its efforts on evaluating the possibility of conducting science operations with the spacecraft under the control of only the two remaining, healthy reaction wheels. NASA is considering the two-wheel Kepler mission as part of the Astrophysics Senior Review of Operating Missions in spring 2014.

### Recent Achievements

The Kepler Science Team announced in November 2013 the latest findings resulting from the analysis of the first three years of data from the Kepler Space Telescope. Included in these findings was the discovery of 833 new candidate exoplanets, which brings the total number of Kepler exoplanet candidates to over 3500. Twenty-four of the new candidates orbit in the habitable zone of their parent star, and ten of those new habitable zone candidates are less than twice the size of the Earth. These results also demonstrate that most stars in our galaxy have at least one planet, suggesting that the majority of stars in the night sky are likely to host planetary systems, perhaps some like our solar system.

An independent statistical analysis of nearly all four years of Kepler data conducted by a research team at the University of California at Berkeley suggests that perhaps as many as one in five stars like the sun hosts a planet no larger than twice the size of Earth in its habitable zone.

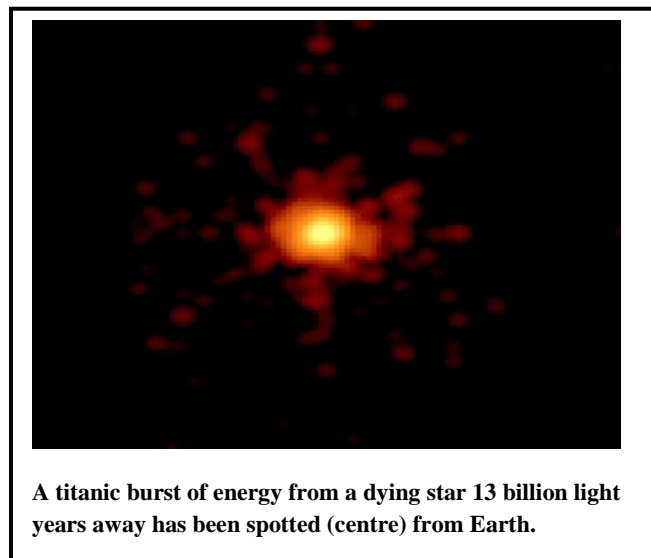
## ASTROPHYSICS EXPLORER

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Transiting Exoplanet Survey Satellite (TESS)	34.8	--	<b>98.8</b>	100.8	102.7	13.9	9.1
Other Missions and Data Analysis	30.3	--	<b>40.9</b>	63.0	72.2	154.7	177.2
<b>Total Budget</b>	<b>65.1</b>	<b>--</b>	<b>139.7</b>	<b>163.7</b>	<b>174.9</b>	<b>168.7</b>	<b>186.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

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The Astrophysics Explorer program provides frequent flight opportunities for world-class astrophysics investigations using innovative and streamlined management approaches for spacecraft development and operations. The program is highly responsive to new knowledge, new technology, and updated scientific priorities by launching smaller missions that can be conceived and executed in a relatively short development cycle. Priorities are based on an open competition of concepts solicited from the scientific community. The program emphasizes the accomplishments of missions under the control of the scientific research community within constrained mission life-cycle costs.

Explorers (EX) missions cost up to \$250 million in total, excluding launch services. Small Explorers (SMEX) may cost about half that, excluding launch services. Explorer missions of opportunity (MO) have a total NASA cost of under \$75 million and may be of several types. The most common are partnering MOs, investigations that are part of a non-NASA space mission. These missions are conducted on a no-exchange-of-funds basis with the organization sponsoring the mission. Other possible types are new science missions using existing spacecraft and small complete missions. NASA intends to solicit proposals for missions of opportunity associated with each announcement of opportunity issued for EX and SMEX investigations, and perhaps more frequently.

For more information on Explorer missions, see <http://explorers.gsfc.nasa.gov/missions.html>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

Transiting Exoplanet Survey Satellite (TESS) and Neutron Star Interior Composition Explorer (NICER) budgets have separate project lines within Explorer.

## ASTROPHYSICS EXPLORER

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### ACHIEVEMENTS IN FY 2013

Astrophysics Explorer program competitively down selected one Standard Explorer (EX) class mission TESS and one Explorer MO NICER in April 2013.

### WORK IN PROGRESS IN FY 2014

The NuSTAR mission will complete its prime mission. The program plans to deliver Soft X-Ray Spectrometer (SXS) for ASTRO-H and a Senior Review will be held to determine mission extensions. NICER will be confirmed to proceed into development. The program will have its program independent review and will release the next Announcement of Opportunity (AO) for SMEX and MO.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The TESS mission will undergo its confirmation review and concept studies for the next SMEX and mission of opportunity will be completed. ASTRO-H will complete its integration and testing.

### Program Elements

None.

### Program Schedule

Date	Significant Event
Sep 2014	AO Announcement of SMEX and MO opportunity to propose
Feb 2017	Select 1 SMEX and 1MO mission for implementation
Sep 2016	AO Announcement for EX and MO opportunity to propose
Feb 2019	Select 1 EX and 1MO mission for implementation

### Acquisition Strategy

NASA selects all Explorer missions through a competitive Announcement of Opportunity.



## ASTROPHYSICS EXPLORER

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Independent Review	SRB	May 2009	Assess performance of program	Successful	Sep 2014
Program Independent Review	SRB	Sep 2014	Assess performance of program	TBD	

# TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

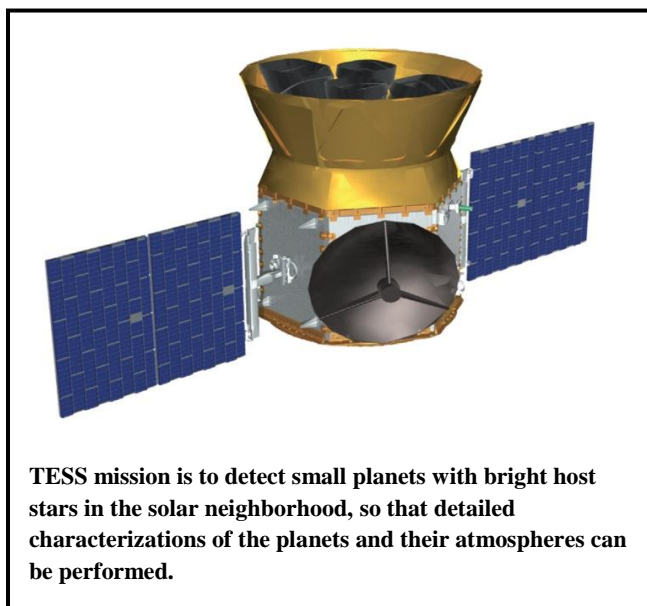
Formulation	Development	Operations
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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>34.8</b>	<b>--</b>	<b>98.8</b>	<b>100.8</b>	<b>102.7</b>	<b>13.9</b>	<b>9.1</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

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## PROJECT PURPOSE

The Transiting Exoplanet Survey Satellite (TESS) Mission objective is to survey the brightest stars near the earth for transitioning exoplanets over a two-year period. The TESS project will use an array of wide-field cameras to perform an all-sky survey. It will scan nearby stars for exoplanets.

TESS will carry out the first space-borne all-sky Exoplanet transit survey, covering 400 times as much sky as any previous mission, including Kepler. It will identify thousands of new planets in the solar neighborhood, with a special focus on planets comparable in size to the Earth. TESS will be in a special orbit, one that is not too close, and not too far, from both the Earth and the moon. As a result, every two weeks

TESS will approach close enough to the Earth for high data-downlink rates, while remaining above the planet's harmful radiation belts. This special orbit will remain stable for decades, keeping TESS's sensitive cameras in a very stable temperature range.

With TESS, it will be possible to study the masses, sizes, densities, and orbits of a large cohort of small planets, including a sample of rocky worlds in the habitable zones of their host stars. TESS will provide prime targets for further characterization by the James Webb Space Telescope, as well as other large ground-based and space-based telescopes of the future.

Previous sky surveys with ground-based telescopes have mainly picked out giant exoplanets. In contrast, TESS will examine a large number of small planets around the very brightest stars in the sky. TESS will record the nearest and brightest main sequence stars hosting transiting exoplanets, which will forever be the most favorable targets for detailed investigations.

## TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations
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### EXPLANATION OF MAJOR CHANGES IN FY 2015

TESS has entered into Phase B of formulation.

### PROJECT PRELIMINARY PARAMETERS

TESS will be launched into a high earth elliptical orbit. TESS will make observations in the visible and infrared spectrum utilizing four telescopic charge-coupled device cameras. In order to obtain imagery from both locations in both northern and southern hemispheres of the sky, TESS will orbit every 13.7 days. TESS will downlink the data it has collected during the orbit to earth over a period of approximately 3 hours.

### ACHIEVEMENTS IN FY 2013

TESS was selected to continue into Phase B formulation.

### WORK IN PROGRESS IN FY 2014

TESS is continuing Phase B activities, including the Systems Requirements Review (SSR) planned for Feb 2014.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The TESS confirmation review is planned for early FY 2015 to be followed by start of development.

### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	April 2013	
SRR	N/A	Feb 2014
KDP-C	N/A	FY 2015
Launch	N/A	Q4 FY 2017
Phase E complete	N/A	FY 2020

## TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations
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### Formulation Estimated Life Cycle Cost Range and Schedule Range Summary

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Apr 2013	\$350-\$400M	Launch	4th Quarter FY 2017

### Project Management & Commitments

Element	Description	Provider Details	Change from Formulation Agreement
Wide Field Camera 3 (WFC3)	Visible-IR telescopic CCDs detectors	Provider: Massachusetts Institute of Technology Lead Center: Lincoln Laboratories Performing Center(s):N/A Cost Share Partner(s):N/A	None
Spacecraft Bus	LEO Star 3-axis stabilized Spacecraft bus	Provider: Orbital Science Corporation Lead Center:N/A Performing Center(s):N/A Cost Share Partner(s):N/A	None
Launch Vehicle	Launch Vehicle	Provider: TBD Lead Center: Kennedy Space Center Performing Center(s):N/A Cost Share Partner(s):N/A	None

### Project Risks

Risk Statement	Mitigation
If specific launch vehicles are not available then potential exists for schedule and budgetary impacts.	Plan to select launch vehicle in FY 2015 which will identify specific launch vehicle interfaces

# TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations
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## Acquisition Strategy

NASA selected the mission through a competitive Announcement of Opportunity.

## MAJOR CONTRACTS/AWARDS

The project has not yet awarded any major contracts.

## INDEPENDENT REVIEWS

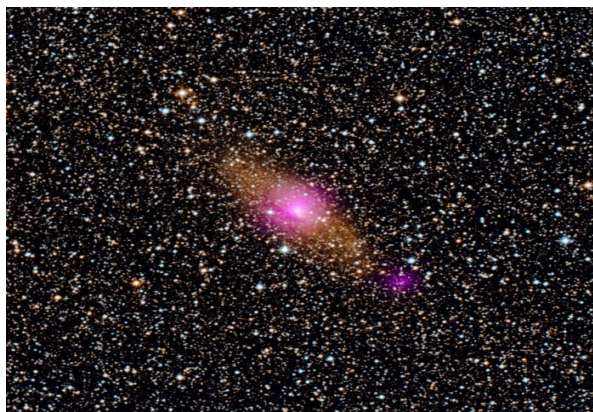
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	SRB	Feb 2014	SRR	TBD	Preliminary Design Review (PDR)
Performance	SRB	Sep 2014	PDR	TBD	Critical Design Review (CDR)
Performance	SRB	Apr 2015	CDR	TBD	Systems Integration Review (SIR)
Performance	SRB	Oct 2016	SIR	TBD	Launch Readiness Reviews (LRR)
Performance	Standing Review Board	2017	LRR	TBD	N/A

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Astrophysics Explorer Program Management	4.8	--	4.0	7.2	7.6	7.1	4.4
ASTRO-H (SXS)	8.9	--	14.4	11.0	12.0	11.4	9.5
Astrophysics Explorer Future Missions	0.6	--	5.6	28.0	49.1	134.9	163.3
Neutron Star Interior Composition Explorer	6.4	--	11.1	11.6	3.6	1.4	0.0
Wide-Field Infrared Survey Explorer	0.6	--	0.0	0.0	0.0	0.0	0.0
SWIFT	4.9	--	5.0	5.1	0.0	0.0	0.0
Suzaku (ASTRO-E II)	0.3	--	0.3	0.0	0.0	0.0	0.0
Nuclear Spectroscopic Telescope Array	1.9	--	0.4	0.0	0.0	0.0	0.0
Gravity and Extreme Magnetism (SMEX 13)	2.0	--	0.0	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>30.3</b>	<b>--</b>	<b>40.9</b>	<b>63.0</b>	<b>72.2</b>	<b>154.7</b>	<b>177.2</b>



The Nuclear Spectroscopic Telescope Array (NuSTAR) took this x-ray image of two black holes in the Circinus Galaxy which is 13 million light-years away. The two black holes, shown as magenta-colored objects superimposed on the optical galaxy image, consist of a supermassive black hole at the galaxy center, and a smaller black hole on the galaxy edge.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Astrophysics Explorers Other Missions and Data Analysis includes funding for small missions in formulation and development (Astro-H, NICER), operating missions (NuSTAR, Swift, Suzaku), and funding for future mission selections and program management functions. Operations of the WISE mission is no longer funded by Astrophysics, and data archival activities will cease after FY 2014. Planetary Science will continue to use WISE in support of its NEOO project.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Mission Planning and Other Projects

#### ASTROPHYSICS EXPLORER PROGRAM MANAGEMENT

Astrophysics Explorer program management provides programmatic, technical, and business management of ongoing missions in formulation and development.

#### ASTRO-H (SXS)

NASA is providing a High-Resolution Soft X-Ray Spectrometer (SXS) instrument to Japan, for a 2015 launch onboard the Japanese Astro-H –IIA spacecraft. The SXS instrument is a cryogenically cooled high-resolution X-ray spectrometer that will allow the most detailed studies of a wide range of astronomical systems from nearby stars to distant active galaxies. Using this unprecedented capability, the mission will conduct a number of fundamental studies, including tracing the growth history of the largest structures in the universe, obtaining insights into the behavior of material in extreme gravitational fields, determining the spin of black holes, probing shock acceleration structures in clusters of galaxies, and investigating the detailed physics of black hole jets. The Science Enhancement Option (SEO) supports mission planning, development and maintenance of data analysis software, development of a data processing pipeline, as well as production and maintenance of Astro-H data archives. The SEO will also fund a Guest Observer (GO) Program, including proposal support and grant support.

#### Recent Achievements

Completed manufacture and test of major components of the SXS instruments. Delivered to JAXA the completed Flight Model Soft X-Ray telescope mirror in Early February 2013.

#### ASTROPHYSICS EXPLORER FUTURE MISSIONS

Astrophysics Explorer Future Missions funding supports future astrophysics Explorer missions and missions of opportunity through concept studies and selections.

#### NEUTRON STAR INTERIOR COMPOSITION EXPLORER

The NICER instrument, to be located on the external logistics carrier of the International Space Station, will perform high time resolution and spectroscopic observations of neutron stars to uncover the nature and probe the physics of ultra-dense matter in the core of neutron stars. NICER will explore the exotic states of matter inside these stars, where density and pressure are higher than in atomic nuclei. NICER will enable rotation-resolved spectroscopy of the thermal and non-thermal emissions of neutron stars in the soft X-ray band with unprecedented sensitivity, probing interior structure, the origins of dynamic phenomena, and the mechanisms that underlie the most powerful cosmic particle accelerators known.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

After selection in April 2013, the project initiated several procurements for major subsystems of the instrument. In addition, the project has completed preliminary design of the subsystems and will perform a PDR of the subsystems in December 2013.

### THE WIDE-FIELD INFRARED SURVEY EXPLORER (WISE)

WISE is a Medium Explorer class mission that launched in December 2009. It has surveyed the entire sky in four mid-infrared bands and mapped it with better sensitivity than previous infrared all-sky surveys. During its mission, WISE identified the nearest and coolest stars, the origins of stellar and planetary systems, and the most luminous galaxies in the universe. Its legacy is a rich database that will enable astronomers to address questions posed by the Cosmic Origins program. WISE ended its prime mission in October 2010, after which NASA continued to use it for observing asteroids until February 2011, when the satellite was turned off and placed into dormant mode. Data analysis activities are funded through FY 2014.

## Operating Missions

### SWIFT

Swift is a multi-wavelength space-based observatory that studies the position, brightness, and physical properties of gamma-ray bursts. Swift is a Medium Explorer class mission that launched in 2004 and is now in extended mission operations.

### Recent Achievements

Swift continues to observe gamma-ray bursts at a rate of around 90 per year, as well as non-gamma-ray burst targets. Swift studies using X-ray and ultraviolet observations provided new insights into the elusive origins of Type Ia supernovae. The lack of X-rays from a combined sample of 53 nearby supernovae Ia showed that supergiant stars, and even sun-like stars in a later red giant phase, likely are not present in the host binaries. No ultraviolet emission was detected from the interaction of the outgoing supernovae shock with its companion, suggesting that the companion to the white dwarf is either a small star similar to our sun or another white dwarf.

### SUZAKU (ASTRO-E II)

Suzaku is Japan's fifth X-ray astronomy mission, which launched in July 2005 and is now in extended mission operations. It was developed at the Institute of Space and Astronautical Science of Japan Aerospace Exploration Agency (ISAS/JAXA) developed Suzaku in collaboration with US (NASA and MIT) and Japanese institutions. NASA provides software to analyze Suzaku data and operates a Guest Observer Facility for US observers.



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

Suzaku yielded a number of major new findings during the past year. Suzaku's observations of the x-ray spectrum of the remnant of Kepler's Supernova, the remains of a white dwarf star that exploded in 1604, revealed that the original star was about 3 times richer in metals than the Sun. This indicates that it must have formed fairly recently in cosmic time from the remains of earlier generations of exploded stars, and has implications for cosmological studies that use this type of supernovae as cosmic distance markers. On a much larger scale, Suzaku observations of the vast cluster of galaxies in the constellation Perseus revealed that iron (and presumably other heavy elements) is distributed uniformly across the cluster. This result indicates that most of the Iron was formed very early in the history of the universe, before the Perseus Cluster was fully formed. This in turn provides evidence that a huge number, more than 40 billion Type 1a supernovae, the same type as Kepler's Supernova, exploded before the cluster formed in an epoch of extremely active star formation.

### NUCLEAR SPECTROSCOPIC TELESCOPE ARRAY (NuSTAR)

The NuSTAR mission launched in June 2012 and has begun its two-year mission, which enables scientists to locate massive black holes in other galaxies, locate and examine the remnants of collapsed stars in our galaxy, observe selected gamma-ray sources, and observe any new supernovae in the local group of galaxies. NuSTAR's key science products are sensitive X-ray survey maps of the celestial sky. NuSTAR offers opportunities for a broad range of science investigations, ranging from probing cosmic ray origins and studying the extreme physics around collapsed stars, to mapping micro flares on the surface of the Sun. NuSTAR also performs follow-up observations to discoveries made by Chandra and Spitzer scientists. NuSTAR research teams collaborate with those using Fermi to make simultaneous observations. The NuSTAR mission will complete its prime mission in August 2014.

### Recent Achievements

NuSTAR teamed with the ESA's XMM-Newton mission, to measure definitively, for the first time, the spin rate of a black hole with a mass 2 million times that of our sun. The supermassive black hole lies at the dust and gas-filled heart of the galaxy NGC 1365, and it is spinning almost as fast as Einstein's theory of gravity will allow. These observations also provide a powerful test of Einstein's theory of general relativity, which says that gravity can bend space-time, the fabric that shapes our universe, and the light that travels through it. NuSTAR is also helping to solve a long-standing mystery dating back to 1962, when astronomers observed a uniform, diffuse X-ray glow of unknown origin emanating from over the entire sky. This X-ray glow, called the diffuse X-ray background, is brightest in the high-energy range in which NuSTAR is sensitive. NuSTAR recently found 10 supermassive black holes that radiate strongly in this energy range, suggesting that the combined radiation from all black holes could explain this glow.

# JAMES WEBB SPACE TELESCOPE

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Budget Authority (in \$ millions)	Actual	Enacted	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Budget	627.6	658.2	645.4	620.0	569.4	534.9	305.0

## James Webb Space Telescope

James Webb Space Telescope ..... JWST-2

# JAMES WEBB SPACE TELESCOPE

Formulation	Development								Operations	
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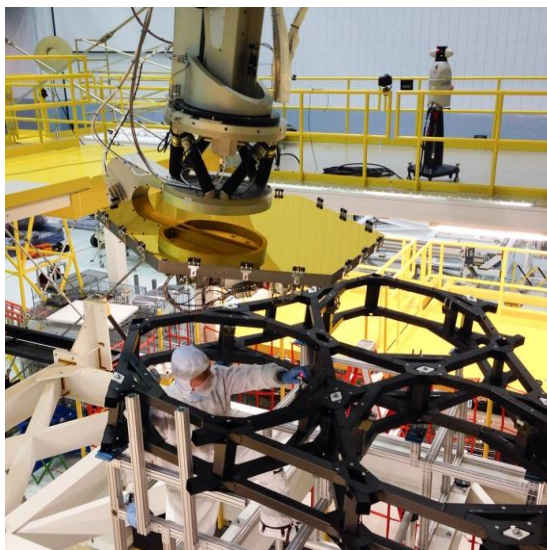
## FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	1800.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1800.1
Development/Implementation	2259.4	627.6	658.2	645.4	620.0	569.4	534.9	228.0	47.5	6190.4
Operations/Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.0	760.0	837.0
<b>2014 MPAR LCC Estimate</b>	<b>4059.5</b>	<b>627.6</b>	<b>658.2</b>	<b>645.4</b>	<b>620.0</b>	<b>569.4</b>	<b>534.9</b>	<b>305.0</b>	<b>807.5</b>	<b>8827.5</b>
<b>Total Budget</b>	<b>3987.4</b>	<b>627.6</b>	<b>658.2</b>	<b>645.4</b>	<b>620.0</b>	<b>569.4</b>	<b>534.9</b>	<b>305.0</b>	<b>807.5</b>	<b>8755.4</b>
Change from FY 2014				-12.8						
Percentage change from FY 2014				-1.9%						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*The 2014 MPAR Project Cost Estimate includes \$72.1 million for Construction of Facilities (CoF) funds in FY 2010 to FY 2012, which are budgeted in the CECR account. The life cycle cost (including CoF funds) is \$8.828 billion.*



Technicians practice building JWST's primary mirror.

## PROJECT PURPOSE

The James Webb Space Telescope (JWST) is a large, space-based astronomical observatory. The mission is a logical successor to the Hubble Space Telescope, extending beyond Hubble's discoveries by looking into the infrared spectrum, where the highly red-shifted early universe must be observed, where relatively cool objects like protostars and protoplanetary disks emit infrared light strongly, and where dust obscures shorter wavelengths. With more light-collecting area than Hubble and with near to mid-infrared-optimized instruments, JWST will observe objects farther away and further back in time.

The four main science goals are:

- Search for the first galaxies or luminous objects formed after the Big Bang;
- Determine how galaxies evolved from their formation until now;

## JAMES WEBB SPACE TELESCOPE

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Formulation	Development	Operations
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- Observe the formation of stars from the first stages to the formation of planetary systems; and
- Measure the physical and chemical properties of planetary systems and investigate the potential for life in those systems.

While Hubble greatly improved knowledge about distant objects, its infrared coverage is limited. Light from distant galaxies is redshifted out of the visible part of the spectrum into the infrared by the expansion of the universe. JWST will explore the poorly understood epoch when the first luminous objects in the universe came into being after the Big Bang. The focus of scientific study will include the first light of the universe, assembly of galaxies, origins of stars and planetary systems, and origins of the elements necessary for life.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PARAMETERS

JWST is an infrared optimized observatory that will conduct imaging and spectrographic observations in the 0.6 to 27 microns wavelength range and will be 100 times more capable than Hubble.

The 6.5-meter primary mirror consists of 18 actively controlled segments that, along with the rest of the telescope optics and instruments, are passively cooled to about 40 degrees Kelvin by a multilayer sunshield the size of a tennis court. JWST will launch from Kourou, French Guiana, on an Ariane 5 rocket supplied by the European Space Agency (ESA). JWST will operate in deep space about one million miles from Earth.

JWST's instruments include the Near Infrared Camera (NIRCam), Near Infrared Spectrograph (NIRSpec), Mid Infrared Instrument (MIRI), and the Fine Guidance Sensor (FGS) /Near Infrared Imager and Slitless Spectrograph (FGS/NIRISS).

NIRCam takes images with a large field of view and high resolution, over the wavelength range of 0.6 to 5 micrometers. NIRCam also aligns and focuses the optical telescope. NIRCam detects light from the earliest stars and galaxies in the process of formation; stars in nearby galaxies; young stars in the Milky Way; and Solar System Kuiper Belt objects. NIRCam is equipped with coronagraphs, which allows astronomers to view dimmer objects near stars. With the coronagraphs, astronomers hope to determine the characteristics of planets orbiting nearby stars.

A spectrograph disperses light from an object into a spectrum. The atoms and molecules in the object imprint lines on its spectrum that uniquely fingerprint each chemical element present. Analyzing the spectrum of an object provides information on its physical properties, including temperature, mass, and chemical composition and motion.

NIRSpec can obtain simultaneous spectra of more than 100 objects in a single exposure, over the wavelength range of 0.6 to 5 micrometers.

## JAMES WEBB SPACE TELESCOPE

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Formulation	Development	Operations
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MIRI takes wide-field images and narrow-field spectra, over the wavelength range of 5 to 28 micrometers. MIRI operates at about seven degrees Kelvin, which an on-board cooling system makes possible.

FGS is a camera that provides fine pointing control and locks the telescope onto its target. The sensor operates over a wavelength range of 1 to 5 micrometers. The NIRISS instrument provides unique imaging and spectroscopic modes to investigate the distant universe as well as exoplanets.

For more information, go to <http://www.jwst.nasa.gov>.

### ACHIEVEMENTS IN FY 2013

In FY 2013, NASA made tremendous progress in the development, fabrication, and testing of many components of the JWST system. The project successfully integrated the first two precision scientific instruments, MIRI and FGS/NIRISS, into the Integrated Science Instrument Module (ISIM). The project also successfully completed the following significant and technically challenging developments and tests:

- Cryogenic test of the Optical Simulator in preparation for ISIM testing;
- Completion and delivery of the large shipping container for use in transportation of large JWST components (both on land and in the air);
- Completion and delivery of the primary mirror backplane support structure, including wings, to the project for cryogenic testing;
- Fabrication and test of the engineering model sunshield membranes. The tests precisely measured the shape of the membranes to ensure proper deployment;
- Completion of the eighteen primary mirror segment motors on schedule;
- Achieved adequate mass margin for observatory on schedule and in preparation for the spacecraft critical design review;
- Delivered NIRSpec and NIRCам optical module to Goddard Space Flight Center (GSFC); and
- Initiated the first ISIM level thermal vacuum test.

### WORK IN PROGRESS IN FY 2014

In FY 2014, the project plans to complete the following development and test efforts:

- Complete the analysis of the first risk-reduction cryo vacuum test of ISIM;
- Integration of the NIRCам and NIRSpec instruments into ISIM;
- Installation of the new near-infrared detectors into the NIRCам;
- Cryo vacuum testing of the Optical Telescope Element (OTE) primary mirror backplane support structure;
- Final deliveries of the primary mirror segment assemblies to NASA GSFC;
- Complete the critical design review of the spacecraft bus;
- Development and testing of the MIRI flight cryo cooling compressor components; and
- Delivery of the flight cryo cooling compressor components to JPL for end-to-end testing.

## JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations
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In FY 2014, the project will begin the following development and testing efforts:

- Second cryo vacuum ISIM test; and
- Fabrication of the flight sunshield membranes.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The President's FY 2015 budget request provides the full level of funding required to keep JWST on schedule for a 2018 launch. In FY 2015, the project plans to:

- Complete and deliver the flight cryogenic cooler tower assembly;
- Install new infrared detectors into the FGS/NIRISS and NIRSpec instruments and new microshutters into the NIRSpec;
- Deliver the OTE flight structure, including primary mirror backplane support structure, backplane support fixture, and wings to NASA GSFC;
- Continue manufacturing the flight sunshield membranes, sunshield structure, and flight spacecraft bus structure;
- Initiate integration of the 18 flight primary mirror segments assemblies into the OTE and the test of the third and final cryogenic vacuum test of the ISIM, with all flight instruments and new detectors; and
- Conduct the final ISIM level cryo-vacuum test.

### SCHEDULE COMMITMENTS/KEY MILESTONES

NASA plans to launch JWST in October 2018 to begin a five-year prime mission. The following timeline shows the development agreement schedule per the rebaseline plan from September 2011.

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	Jul 2008	Jul 2008
Mission CDR	Mar 2010	Mar 2010
Rebaseline/KDP-C Amendment	Sep 2011	Sep 2011
SIR	Jul 2017	Jul 2017
Launch	Oct 2018	Oct 2018
Begin Phase E	Apr 2019	Apr 2019
End of Prime Mission	Apr 2024	Apr 2024

# JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations
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## Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2012	6,197.9	66	2014	6,190.4	-0.1%	LRD	Oct 2018	Oct 2018	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

## Development Cost Details

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>6,197.9</b>	<b>6,190.4</b>	<b>-7.5</b>
Aircraft/Spacecraft	2,955.0	3,199.9	244.9
Payloads	695.1	794.3	99.2
Systems I&T	288.4	295.0	6.6
Launch Vehicle	0.9	0.7	0.2
Ground Systems	652.3	560.5	-91.8
Science/Technology	42.7	42.4	-0.3
Other Direct Project Costs	1,563.5	1,297.6	-265.9

# JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations
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## Project Management & Commitments

NASA Headquarters is responsible for JWST program management. GSFC is responsible for JWST project management.

Element	Description	Provider Details	Change from Baseline
Observatory	Includes OTE, spacecraft, sunshield, observatory assembly integration and testing, and commissioning. The observatory shall be designed for at least a five year lifetime. Northrop Grumman Aerospace Systems has the lead for the OTE, sunshield, spacecraft bus, and selected assembly, integration, and testing activities.	Provider: NGAS and GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Mission management and system engineering	Includes management of all technical aspects of mission development, and system engineering of all components	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Integrated Science Instrument Module (ISIM)	Contains the science instruments and FGS. Provides structural, thermal, power, command and data handling resources to the science instruments and FGS	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Near Infrared Camera (NIR Cam) Instrument	Operates over the wavelength range of 0.6 to 5 microns, and optimized for finding first light sources	Provider: University of Arizona, Lockheed Martin Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Near Infrared Spectrometer (NIRSpec)	Operates over the wavelength range 0.6 to 5 microns with three observing modes	Provider: ESA Lead Center: ESA Performing Center(s): N/A Cost Share Partner(s): ESA	N/A



# JAMES WEBB SPACE TELESCOPE

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Mid-Infrared Instrument (MIRI)	Operates over the wavelength range 5 to 27 microns, providing imaging, coronagraphy, and spectroscopy	Provider: ESA, University of Arizona, JPL Lead Center: GSFC Performing Center(s): Cost Share Partner(s): ESA	N/A
Fine Guidance	Provides scientific target pointing information to the observatory's attitude control sub-system	Provider: CSA Lead Center: CSA Performing Center(s): N/A Cost Share Partner(s): CSA	N/A
Launch vehicle and launch operations	Ariane 5 Evolution Cryotechnique-Type A	Provider: ESA Lead Center: ESA Performing Center(s): N/A Cost Share Partner(s): ESA	N/A
Ground control system and science operations and control center	Includes mission operations and science operations center	Provider: Space Telescope Science Institute Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A

## Project Risks

Risk Statement	Mitigation
If: NIRCam electronics box delivery changes to a later date, Then: Changes to the ISIM integration and test plan, flow, and schedule will be required.	The Project will adjust ISIM integration and test plan, flow, and schedule to reflect estimated delivery dates for NIRCam electronics boxes.
If: Cryogenic cooler component delivery changes to a later date, Then: Changes to cryogenic cooler acceptance testing, end-to-end testing, and spacecraft integration and test plans and schedules will be required.	The Project will adjust cryogenic cooler acceptance and end-to-end test plan, flow, and schedule to reflect estimated delivery dates for cryogenic cooler components. The Project would update the spacecraft integration and test plan and schedule to reflect delivery dates for cryogenic cooler component delivery.

# JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations
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## Acquisition Strategy

All major contracts have been awarded.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Science and Operations Center	Space Telescope Science Institute	Baltimore, MD
NIRCam	University of Arizona; Lockheed Martin	Tucson, AZ Palo Alto, CA
Observatory	(NGAS) Ball Aerospace ITT/Exelis Alliant Techsystems	Redondo Beach, CA Boulder, CO Rochester, NY Edina, MN
Near Infrared Detectors	Teledyne Imaging Systems	Camarillo, CA

## INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Standing Review Board (SRB)	Apr 2010	Critical Design review	Determined mission design is mature and recommended a more in depth review of the integration and testing plan.	N/A
Quality	Test Assessment Team	Aug 2010	Evaluate plans for integration and testing. See the full report at <a href="http://www.jwst.nasa.gov/publications.html">http://www.jwst.nasa.gov/publications.html</a>	The team recommended several changes to test plan.	N/A
Other	Independent Comprehensive Review Panel	Oct 2010	Determine the causes of cost growth and schedule delay on JWST, and estimate the launch date and budget, including adequate reserves.	The report made 22 recommendations covering several areas of management and performance	N/A

## JAMES WEBB SPACE TELESCOPE

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	Aerospace Corp	Apr 2011	Analysis of alternatives	Determined that JWST design was still the best value to achieve the primary scientific objectives of the mission.	N/A
Other	SRB	May 2011	Review technical, cost, and schedule plans	The SRB proposed rebaselined project technical, cost, and schedule plans and made recommendations to Agency.	N/A
Performance	NASA Headquarters Office of Evaluation	Jun 2012	Replan assessment review	A review assessed progress against replan.	N/A
Performance	SRB	N/A	OTIS Pre-Environmental Review		Jun 2016
Performance	SRB	N/A	Spacecraft Element Readiness Review		Apr 2016
Performance	SRB	N/A	Systems Integration Review		Jul 2017
Performance	SRB	N/A	Flight Readiness Review		Sep 2018

### CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT

NASA informed Congress by letters dated October 28, 2010, April 21, 2011, and October 24, 2011, that JWST experienced a significant cost overrun and schedule delay. NASA addressed the root causes of the overrun and delays vigorously, and subsequently rebaselined the project with an executable budget and schedule. On April 21, 2011, NASA transmitted the final report of the Independent Comprehensive Review Panel (ICRP). NASA's detailed response to the ICRP included recommendations to correct past problems, reduce the risk of future cost growth and schedule delays, and improve JWST performance.

The current projected JWST launch readiness date is October 2018, the development cost estimate is \$6.190 billion, and the life cycle cost estimate is \$8.827 billion. The revised JWST cost and schedule incorporates 13 months of schedule reserve within the planned funding for development.

## JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations
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The following table describes the issues that NASA addressed during the rebaseline of JWST in 2011.

2010 Issues	Corrective Action Plan
<p>Issue 1: Cost and schedule overrun</p> <p>Current Status: Revised cost and schedule baseline has been approved by the Agency and sent to Congress. Subsequent to the submission of the revised baseline to Congress, Congress approved the FY 2012 NASA appropriation and included the funding required to support the revised development cost and schedule baseline, and included language capping JWST formulation and development costs at \$8 billion.</p>	<p>Programmatic: NASA revised the program management structure, with the creation of a NASA Headquarters program office reporting programmatically to the NASA Associate Administrator. NASA also increased visibility and communication at both the Agency and Center levels.</p> <p>Technical: No action required</p> <p>Cost: Bottom-up review resulted in a revised life cycle cost estimate of \$8.828 billion. This estimate is consistent with the 66 percent joint confidence level with a cost confidence level that is significantly higher than the 80 percent recommended by the ICRP.</p> <p>Schedule: Bottom-up review resulted in a revised development schedule, with launch in October 2018. The revised schedule incorporates 13 months of funded schedule reserve.</p>
<p>Issue 2: Testing concerns</p> <p>Current Status: Findings from the Independent Test Assessment Team have been incorporated into the plans for testing within the JWST integration and test phase and within the revised development cost and schedule baseline.</p>	<p>To address testing concerns from the mission CDR, NASA chartered an independent Test Assessment Team to conduct a review of plans for environmental and functional testing. The findings of this review have now been incorporated into the plans for testing within the JWST integration and test phase and the revised development cost and schedule baseline.</p>

# HELIOPHYSICS

Budget Authority (in \$ millions)	Actual	Enacted	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Heliophysics Research	165.3	--	<b>217.4</b>	158.3	167.6	169.7	169.9
Living with a Star	174.9	--	<b>266.4</b>	355.8	378.2	398.9	282.7
Solar Terrestrial Probes	203.9	--	<b>61.4</b>	41.5	42.1	30.5	129.4
Heliophysics Explorer Program	59.1	95.2	<b>123.6</b>	91.9	88.7	74.3	93.4
<b>Total Budget</b>	<b>603.2</b>	<b>654.0</b>	<b>668.9</b>	<b>647.6</b>	<b>676.6</b>	<b>673.3</b>	<b>675.5</b>

## Heliophysics

HELIOPHYSICS RESEARCH .....	HELIO-2
Other Missions and Data Analysis .....	HELIO-9
LIVING WITH A STAR .....	HELIO-15
Solar Probe Plus (SPP) .....	HELIO-16
Solar Orbiter Collaboration (SOC) .....	HELIO-21
Other Missions and Data Analysis .....	HELIO-27
SOLAR TERRESTRIAL PROBES .....	HELIO-32
Magnetospheric Multiscale (MMS) .....	HELIO-33
Other Missions and Data Analysis .....	HELIO-39
HELIOPHYSICS EXPLORER PROGRAM .....	HELIO-42
Ionospheric Connection Explorer (ICON) .....	HELIO-45
Other Missions and Data Analysis .....	HELIO-49

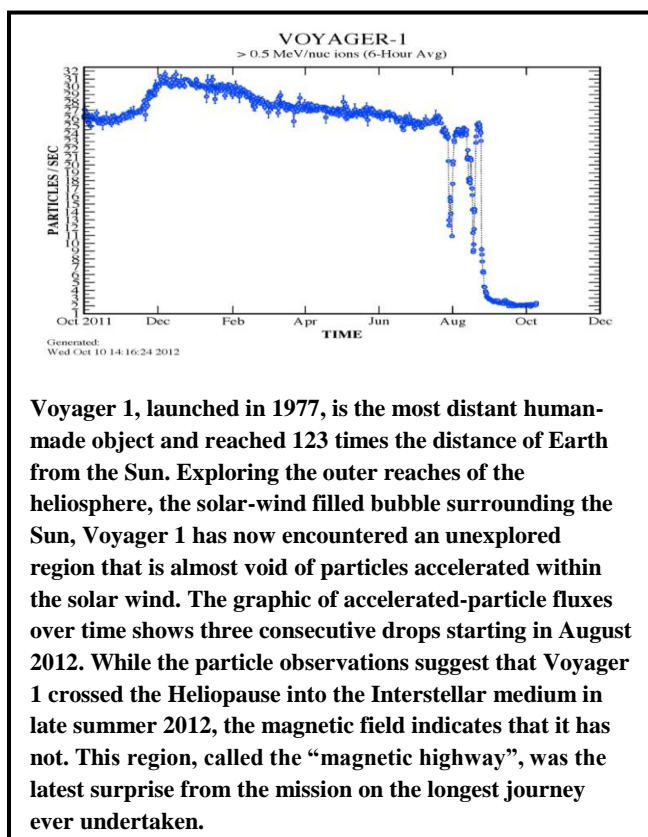
# HELIOPHYSICS RESEARCH

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Research Range	20.5	--	21.3	21.6	21.7	21.7	21.7
Sounding Rockets	56.1	--	65.6	48.0	53.0	53.0	53.0
Heliophysics Research and Analysis	35.1	--	33.9	34.0	33.9	33.9	33.9
Other Missions and Data Analysis	53.5	--	96.7	54.6	59.1	61.1	61.4
<b>Total Budget</b>	<b>165.3</b>	<b>--</b>	<b>217.4</b>	<b>158.3</b>	<b>167.6</b>	<b>169.7</b>	<b>169.9</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Heliophysics seeks to understand the Sun and its interactions with Earth and the solar system. The goal of the Heliophysics Research program is to understand the Sun, heliosphere, and planetary environments as a single connected system and to answer these fundamental questions about this system's behavior.

What causes the Sun to vary?

How do Earth and the heliosphere respond to the Sun's changes?

What are the impacts on humanity?

The Heliophysics Research program advances knowledge of solar processes and the interaction of solar plasma and radiation with Earth, the other planets and the Galaxy. By analyzing the connections between the Sun, solar wind, planetary space environments, and our place in the Galaxy, we are uncovering the fundamental physical processes that occur throughout the Universe. Understanding the connections between the Sun and its planets will allow us to improve predictions on the impacts of solar

variability on humans, technological systems, and even the presence of life itself.

For more information, go to: <http://science.nasa.gov/about-us/smd-programs/heliophysics-research>.

## HELIOPHYSICS RESEARCH

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### EXPLANATION OF MAJOR CHANGES IN FY 2015

The request reflects the initial steps to terminate the Cluster II mission, per the recommendation of the Heliophysics Senior Review, with support limited to one instrument in FY 2014, with Phase F operations only in FY 2015, and complete phase out by FY 2016. The budget for Science Data & Computing, totaling \$2 million per year, is now within Planetary Science, the principal beneficiary of this science data archive.

### ACHIEVEMENTS IN FY 2013

Voyager 1 made national and international headlines by returning data suggesting that it has crossed the Heliopause. The Heliopause is the boundary between our solar system and interstellar space. Thirty-five years after launch, Voyager 1, the first human-made object to explore interstellar space, is still returning data and now is reaching the most remote locations ever encountered by any NASA spacecraft.

Like the wind adjusting course in the middle of a storm, scientists discovered that the particles streaming into the solar system from interstellar space have most likely changed direction over the last 40 years. Such information can help us map out our place within the galaxy surrounding us, and help us understand our place in space. The results, based on data spanning four decades from 11 different spacecraft, were published in *Science* on September 5, 2013.

Scientists have long assumed that our solar system, like a comet, has a tail. Just as any object moves through another medium – for example, a meteor traveling through Earth's atmosphere – causes the particles to form a stream trailing off behind it. But, the tail of our solar bubble, called the heliosphere, has never actually been observed, until now. NASA's Interstellar Boundary Explorer, or IBEX, mapped the boundaries of the tail of the heliosphere, something that has never before been possible.

Two missions with a total of three spacecraft, SOHO and STEREO, tracked comet ISON over a five-day period from November 20 to November 25, 2013. The comet broke up under the intense heat and gravitational forces of the sun. These observations provide a great opportunity for scientists to see the insides of the comet and better understand its composition. This information holds clues about what material was present during the solar system's formation when this comet was born.

Using data from THEMIS, ARTEMIS, and Cluster missions in conjunction with three of NOAA's GOES (Geostationary Operational Environmental Satellites) spacecraft, researchers compared observations where the supersonic solar wind brakes to flow around the magnetosphere of Earth to what happens inside the magnetosphere. They found that instabilities drive perturbations in the solar wind particles streaming towards the Earth and that these perturbations correlate with a type of ultra-low frequency magnetized wave inside the magnetosphere, thought to be important for changes in the radiation belts.

A new study based on data from Cluster shows that it is easier for the solar wind to penetrate Earth's magnetic environment, the magnetosphere, than previously thought. Scientists from NASA's Goddard Space Flight Center in Greenbelt, Maryland have, for the first time, directly observed the presence of certain waves in the solar wind—called Kelvin-Helmholtz waves that can help transfer energy into near-Earth space—under circumstances when previous theories predicted they were not expected.

The Sounding Rocket program launched 19 sounding rocket investigations. Notable science results include a better understanding of the processes that heat the Sun's corona, using the High Resolution

## HELIOPHYSICS RESEARCH

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Coronal Imager (Hi-C) that captured the highest resolution images ever taken of the Sun's corona. Hi-C observed for the first time a process termed "solar braiding," that transfers energy from the sun's magnetic field to the corona. Charge and Mass of Meteoric Smoke Particles (CHAMPS) sounding rockets, launched from the Andoya Rocket Range in northern Norway, provided the first measurements of the number, density, and size of meteoric dust particles, which seem to seed noctilucent clouds. Such particles are so light and so ubiquitous that scientists refer to them as smoke. Tracking how this smoke swirls around Earth has implications for understanding weather and climate patterns.

The Sunrise Balloon offered unique insights into a layer on the sun called the chromosphere. Sunrise provided the highest-resolution images to date in ultraviolet light of this thin corrugated layer, which lies between the sun's visible surface and the sun's outer atmosphere, the corona. NASA launched Sunrise from Kiruna in the north of Sweden and, after five days drifting over the Atlantic, it landed on the remote Boothia Peninsula in northern Canada, gathering information about the chromosphere throughout its journey.

### WORK IN PROGRESS IN FY 2014

For the first time, NASA is selecting and funding Heliophysics projects based on the newly restructured portfolio of competed research programs, the first step of implementing the Diversify, Realize, Integrate, Venture, Educate (DRIVE) initiative in the National Academies' 2013 Decadal Survey for Solar and Space Physics. The 2013 Research Opportunities in Space and Earth Sciences NASA Research Announcement (ROSES NRA) reflects the restructured portfolio.

NASA has created a newly combined Heliophysics Supporting Research element that combines the previous Solar and Heliospheric Supporting Research & Technology (SR&T) element and the Geospace SR&T element. This will maximize science output given the limited availability of funds and foster a more integrated systems approach.

The new Heliophysics Technology and Instrument Development for Science element will now combine development of all Heliophysics sounding rocket and balloon payloads, new instrument concepts, and laboratory measurements of relevant atomic and plasma parameters. One recent selection will spearhead NASA's capabilities in providing observations of the energetic particle environment in the Geospace system via CubeSats. NASA may develop future International Space Station (ISS) and potential Commercial Reusable Sounding Rocket payloads in this element.

The Heliophysics Guest Investigator program held a ROSES-13 special solicitation for Van Allen Probes science that will lead to additional breakthroughs in understanding of the formation and dynamics of Earth's radiation belts. NASA plans a special opportunity for analysis of data from the Interface Region Imaging Spectrograph (IRIS) mission, to take advantage of critical new observations from the solar corona.

Also in response to Decadal Survey recommendations addressing Heliophysics Grand Challenges, NASA is supporting large team efforts to make significant progress in understanding complex processes with broad importance. Increasingly, major advances in the field result from the close interactions between observers, theorists, and modelers. Thus, a coherent attack on the most challenging broad problems requires the efforts of a synergistically interacting group of multidisciplinary teams led by a single Principal Investigator (PI).



## HELIOPHYSICS RESEARCH

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NASA continues to pursue the Peregrine Motor Project, with the goal of providing a reliable, affordable alternative to existing sounding rocket motors. NASA will complete the Peregrine motor design and verify it with up to three test flights, for subsequent release to industry.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, the Heliophysics Research program anticipates achieving unprecedented science results from analysis of the record number of 19 active space missions of the Heliophysics System Observatory with its 33 individual spacecraft. These include ACE, Aeronomy of Ice in the Mesosphere (AIM), Cluster II (4 spacecraft), Coupled Ion Neutral Dynamic Investigation (CINDI), Geotail, Hinode, Interstellar Boundary Explorer (IBEX), IRIS, Magnetospheric MultiScale (MMS 4 spacecraft), RHESSI, SDO, SET, SOHO, STEREO (2 spacecraft), TIMED, THEMIS (5 spacecraft), TWINS (2 spacecraft), Van Allen (2 spacecraft), Voyager (2 spacecraft), and Wind. The anticipated awards of small research investigations will continue the science advancements.

In FY 2015, the Voyager 2 spacecraft may pass the heliopause and provide us for the first time with direct interstellar plasma observations. This unique achievement would not be possible with the faster Voyager 1 due to the loss of its plasma sensor more than 20 years ago.

In addition to operating mission data, the budget request supports a flight program of 16 to 20 sounding rocket flights, with one to two campaign deployments that involve Heliophysics payloads. Poker Flat, Norway, and/or Australia are potential locations for the deployments.

## Program Elements

### RESEARCH RANGE

The Research Range Services (RRS) project provides operations support, maintenance, and engineering for the Wallops Launch Range and instrumentation. The range and instrumentation support suborbital, orbital, and aircraft missions conducted on behalf of NASA and the Department of Defense at the Wallops Flight Facility and at remote sites around the world. New work includes support for Commercial Resupply Services missions, NASA technology missions, unmanned aerial vehicle flights, and commercial launch and flight projects.

The range instrumentation includes meteorological, telemetry, radar, command, launch and range control centers, and optical systems. RRS mobile assets provide range services at other ranges and remote locations around the world.

### SOUNDING ROCKETS

The Sounding Rockets project provides low-cost, sub-orbital access to space in support of space and Earth sciences research and technology development sponsored by NASA and other users by providing payload development, launch vehicles, and mission engineering services.

## HELIOPHYSICS RESEARCH

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### HELIOPHYSICS RESEARCH AND ANALYSIS

This project supports basic research, solicited through NASA's annual ROSES announcements. NASA solicits investigations relevant to Heliophysics in several broad areas that include:

- Understanding the changing flow of energy and matter throughout the Sun, heliosphere, and planetary environments;
- Exploring the fundamental physical processes of space plasma systems; and
- Improving our ability to predict space weather and its effects.

Heliophysics, which includes the sub-disciplines of Solar, Heliosphere, Magnetospheres, Ionospheres and upper Atmosphere, solicits basic theory investigations needed to interpret data from NASA's heliophysics missions, and to develop the scientific basis for future missions.

Other research elements include Heliophysics Technology and Instrument Development for Science program and Heliophysics Guest Investigators.

NASA occasionally releases special solicitations to take advantage of research opportunities that arise from recent launches or other significant opportunities. Heliophysics Research and Analysis funds scientific investigations on suborbital platforms such as balloons or sounding rockets.

### **Program Schedule**

NASA implements the Heliophysics Research program via competitively selected research. NASA releases research solicitations each year in the ROSES NRA, typically aiming to initiate research for about one-third of the program, given the selected projects are typically three-year awards. Therefore, NASA will allocate FY 2014 funds to first year projects from ROSES-2013 selections, second year of projects from ROSES-2012 selections, and third year of projects from ROSES-2011 selections.

Date	Significant Event
Q2 FY 2014	ROSES-2014 solicitation - February 2014
Q3 FY 2014	Review of all Proposals Submitted to Heliophysics ROSES Elements
Q4 FY 2014	Data Archive Review
Q3 FY 2015	Senior Review of All Operating Missions

## HELIOPHYSICS RESEARCH

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### Program Management & Commitments

Program Element	Provider
Research and Analysis	Provider: HQ Lead Center: HQ Performing Centers: Goddard Space Flight Center (GSFC), Marshall Space Flight Center (MSFC), Jet Propulsion Laboratory (JPL), Langley Research Center (LaRC), Johnson Space Center (JSC) Cost Share Partners: None
Sounding Rockets and Research Range	Provider: GSFC Lead Center: HQ Performing Center: GSFC Cost Share Partners: None
Heliophysics Operating Missions	Provider: GSFC, JPL, MSFC Lead Center: HQ Performing Center: GSFC, JPL, MSFC Cost Share Partners: None

### Acquisition Strategy

NASA fully and openly competes all new acquisitions. Proposals are peer-reviewed and selected from the annual ROSES announcement. Universities, government research laboratories, and industry partners throughout the United States participate in research and analysis projects. NASA previously selected the Heliophysics operating missions and instrument teams via NASA Announcements of Opportunity. NASA evaluates the allocation of funding among the operating missions bi-annually through the Heliophysics Senior Review. Universities, government research labs, and industry partners throughout the United States participate in science data and computing technology research projects.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Sounding Rocket Operations	Orbital Sciences Corp., Dulles VA	Various

## HELIOPHYSICS RESEARCH

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### INDEPENDENT REVIEWS

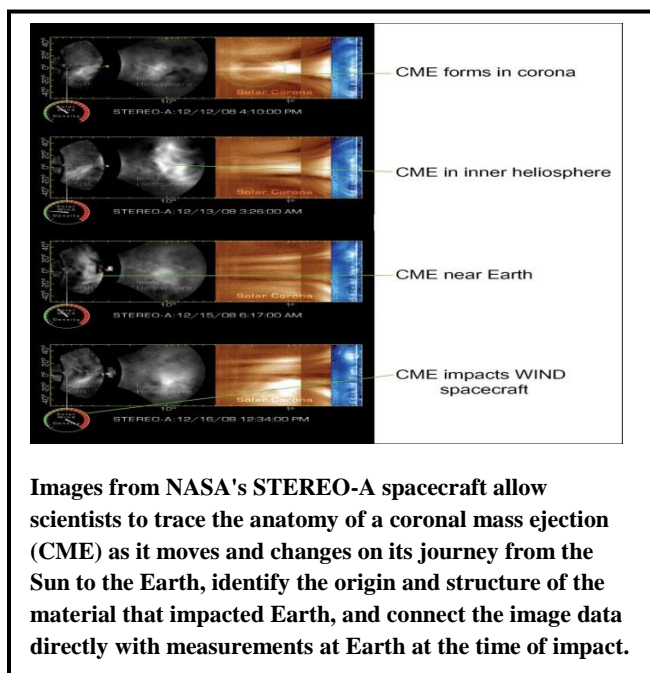
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Mission Senior Review Panel	Apr 2013	A comparative evaluation of Heliophysics operating missions	Report released in July 2013. Assessed missions singly, and as part of a greater whole	Apr 2015

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Science Planning and Research Support	5.5	--	6.5	6.6	6.7	6.8	6.8
Directed Research & Technology	11.1	--	48.5	5.6	10.0	11.9	12.2
CubeSat	0.0	--	5.0	5.0	5.0	5.0	5.0
SOLAR Data Center	1.0	--	1.0	1.0	1.0	1.0	1.0
Data & Modeling Services	3.5	--	3.2	3.0	3.0	3.0	3.0
Space Physics Data Archive	2.0	--	2.0	2.0	2.0	2.0	2.0
Guest Investigator Program	10.6	--	7.2	8.0	8.0	8.0	8.0
Community Coordinated Modeling Center	1.7	--	2.0	2.0	2.0	2.0	2.0
Space Science Mission Ops Services	7.5	--	11.3	11.5	11.5	11.5	11.6
Space Weather Research to Operations	0.3	--	0.0	0.0	0.0	0.0	0.0
Voyager	5.3	--	5.4	5.5	5.5	5.5	5.5
SOHO	2.1	--	2.1	2.1	2.1	2.1	2.1
WIND	2.1	--	2.0	2.0	2.0	2.0	2.0
GEOTAIL	0.5	--	0.2	0.2	0.2	0.2	0.2
CLUSTER-II	0.4	--	0.2	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>53.5</b>	<b>--</b>	<b>96.7</b>	<b>54.6</b>	<b>59.1</b>	<b>61.1</b>	<b>61.4</b>



*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

NASA accumulates, archives, and distributes data collected by the Heliophysics System Observatory, a fleet of operating spacecraft. Combining the measurements from all of these observing platforms enables interdisciplinary science across the vast spatial scales of our solar system. This collective asset enables the data, expertise, and research results to contribute directly to fundamental research on solar and space plasma physics and to the national goal of real-time space weather prediction. NASA teams support day-to-day mission operations, and a guest

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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investigator program for data analysis to advance the state of space science and space weather. NASA conducts community-based projects to provide evaluations of the ability of research models to forecast weather disturbance information of value to industry and government agencies, in preparation for transition to operations. Heliophysics data centers archive and distribute the collected science data from operating missions in the Living with a Star (LWS), Solar Terrestrial Probes (STP), Research, and Explorers programs.

NASA funds projects that facilitate a smooth data flow: the Solar Data Center, Sun-Earth Connection Data and Modeling Services, the Space Physics Data Archive, and Space Science Mission Operations Services. These projects undergo a competitive senior review process with the level of support adjusted regularly, according to the anticipated scientific productivity and mission maintenance requirements.

For more information, go to <http://science.nasa.gov/about-us/smd-programs/heliophysics-research/>.

## **Mission Planning and Other Projects**

### **SCIENCE PLANNING AND RESEARCH SUPPORT**

This project supports NASA's participation in proposal peer review panels, decadal surveys and National Research Council studies.

### **DIRECTED RESEARCH AND TECHNOLOGY**

This project funds the civil service staff that work on emerging flight projects, instruments, and research.

### **CUBESAT**

The CubeSat project offers a low-cost option for enabling scientific discovery across the various themes and disciplines in the Science Mission Directorate. CubeSats are very small spacecraft, as small as a few inches square, which can launch as secondary ("tag-along") payloads, on either orbital or sub-orbital rockets. At costs that can be less than \$1 to \$2 million per satellite and with rapid development cycles, CubeSats are now a viable frequent flight opportunity for rapid innovation in science and technology. CubeSats will address space technology and exploration systems development needs and will leverage exploratory and systematic science observations at a minimal cost. CubeSats have the potential to reduce risk by testing new technologies before using them in missions that are more expensive. NASA plans to select multiple CubeSat investigations in FY 2014. NASA expects delivery of the CubeSats approximately 24 months after award, and at least one CubeSat may launch by 2016.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### SOLAR DATA CENTER

The Solar Data Center provides mission and instrument expertise to enable high-quality analysis of solar physics mission data. It provides leadership for community-based, distributed development efforts to facilitate identifying and accessing solar physics data, including ground-based coordinated observations residing in the Virtual Solar Observatory (VSO). The center also provides a repository for software used to analyze these data. The VSO is a software system linking together distributed archives of solar data into a unified whole, along with data search and analysis tools.

### DATA & MODELING SERVICES

This project supports missions in extended operations, and missions transitioning to decommissioning, to prepare their data holdings for long-term archival curation. This project also provides for the creation of higher-level data products, which are of significant use to the science community and not funded during the prime mission. Higher-level data products are data that combine results of multiple missions and/or instruments. This project is competed through the annual ROSES competitive announcement.

### SPACE PHYSICS DATA ARCHIVE

The Space Physics Data Facility (SPDF) ensures long-term data preservation and online access to non-solar heliophysics science data. It operates key infrastructure components for the Heliophysics Data Environment including inventory and web service interfaces to systems and data. It also provides unique enabling science data services. Notable is recent progress in assuring data from the Van Allen Probes and MMS will be in the standard format for delivery to the SPDF during the operations, and at the end of these missions.

### GUEST INVESTIGATOR PROGRAM

The Guest Investigator program maximizes the return from currently operating Heliophysics missions by supporting studies of the current science goals of these missions. These highly competitive research investigations use data from multiple spacecraft, as appropriate, and investigations addressing global system problems are strongly encouraged, as Heliophysics is, by its nature, the investigation of a large-scale, complex, connected system.

### COMMUNITY COORDINATED MODELING CENTER (CCMC)

The Community Coordinated Modeling Center is a multi-agency partnership to enable and perform the research and development for next-generation heliophysics and space weather models. The center provides the United States and international research community access to up to date simulations to enable “runs on demand,” using models to study solar events in near-real time. This allows the comparison of observational data and model parameters during or shortly after solar activity, thereby making the models more accurate.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### SPACE SCIENCE MISSION OPERATIONS SERVICES

Space Science Mission Operations Services manages the on-orbit operations of GSFC Space Science missions'. Services include consistent processes for missions operated at GSFC, Johns Hopkins University Applied Physics Laboratory (JHU-APL), Orbital Sciences Corporation, Pennsylvania State University, and University of California at Berkeley. Space Science Mission Operations Services also sustains an operational infrastructure for current and future missions.

### Operating Missions

#### VOYAGER

The Voyager Interstellar Mission is exploring the interaction of the heliosphere with the local interstellar medium. The Voyager Interstellar mission is making the first in situ observations of the region outside the heliosphere. Voyager 1 is about 123 astronomical units (AU), or 123 times Earth's distance from the Sun, and traveling at a speed of 3.6 AU per year. Voyager 2 is about 100 AU from the Sun and traveling at a speed of about 3.3 AU per year. Spacecraft power should be adequate for currently operating instruments through 2020; a subset of those instruments could operate through 2025.

#### Recent Achievements

Thirty-five years after launch, Voyager 1, at a distance of more than 11 billion miles from the sun, has now become the first human-made object to cross the heliopause – the boundary of the bubble inflated by the continuous stream of charged particles from the Sun known as the solar wind. When a CME that had left the sun in March 2012 arrived at Voyager 1 thirteen months later in April 2013, the Plasma Wave Instrument recorded vibrations in the surrounding plasma cloud, which allowed scientists to determine the density of the plasma. The plasma was 40 times denser than that measured in the outer layer of the heliopause, matching all expectations of the plasma density of interstellar space.

### SOLAR AND HELIOSPHERIC OBSERVATORY (SOHO)

SOHO combines remote sensing of the Sun and the consequences of solar activity with measurements of the space environment near the L1 Lagrangian point, about a million miles from Earth toward the Sun. SOHO is the main source of near-real time solar data for space weather predictions. The Large Angle and Spectrometric Coronagraph on SOHO is a unique instrument resource on the Sun-Earth line that is critically important to the Nation's space weather architecture. This instrument helps scientists understand coronal mass ejections, which are large bursts of plasma from the Sun that can collide with Earth, and their effect on interplanetary space.

#### Recent Achievements

Recent observations from SOHO help scientists understand the origins of the solar wind and acceleration mechanisms. Understanding the solar wind has implications both as a fundamental physical process and



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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for its impacts on Earth's space environment. The findings show that during most of the solar minimum period, the solar wind in the polar coronal holes fills the void left by those parts of the corona that do not emit solar wind. The effect disappears when the polar coronal holes recede during the rising phase of the solar cycle. Furthermore, the observed outflow speeds near the sun are only half the speed of the solar wind at Earth, which suggests that there is additional acceleration in the extended corona before the solar wind reaches its ultimate speeds.

### WIND

The Wind spacecraft studies the solar wind and its impact on the near Earth environment. It addresses wave-particle interaction processes in the space environment, the evolution of solar transients in the heliosphere, and the geomagnetic impact of solar activity. Wind performs in situ studies using unique capabilities, such as three-dimensional particle distributions over a wide range of energies, and delivery at higher time resolution than available from any other mission.

### Recent Achievements

A recent study using the stable and long duration Wind solar wind measurements demonstrated that a very specific ion heating mechanism is acting in the corona and the solar wind. These plasma waves move in opposite directions to accelerate particles. In the same way, two walls that approach each other would accelerate a bouncing ball between them. Wind provided the crucial, but rare measurements out of its unique long-term data set of millions of independent solar wind observations. While this Wind result established that ion-cyclotron resonance is an active process in the heliosphere, Solar Probe Plus (SPP) measurements will be necessary to determine its relative importance as a function of heliocentric distance. Thus, Wind has helped to frame one of the measurement objectives of SPP.

### GEOTAIL

Geotail enables scientists to assess data on the interaction of the solar wind and the magnetosphere. July 24, 2012 marked the 20th anniversary of the launch of Geotail, and its instruments continue to function, sending back crucial information about how aurora form, how energy from the Sun funnels through near Earth space, and the ways in which magnetic field lines move and rebound creating explosive bursts that rearrange the very shape of our magnetic environment. The Geotail mission is a collaborative project undertaken by the Japanese Institute of Space and Astronautical Science and NASA.

### CLUSTER-II

Cluster uses four spacecraft to make direct measurements of the particles trapped in Earth's magnetic field. By varying spacecraft separations during repeated visits to regions, Cluster can measure the small-scale fluctuations in interplanetary space. One of the interactions studied is the acceleration of plasma in the magnetotail during substorms. The magnetotail is a large reservoir of both solar wind and ionospheric particles that, under some circumstances, releases a large quantity of particles towards Earth. Both mechanisms—particles entering the polar cusps and the substorms—produce an aurora when the

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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participating particles, electrons and ions, hit the neutral gas of the atmosphere. When these particles are particularly energetic, they can have a dramatic effect on human activities, disrupting electrical power and telecommunications or causing serious anomalies in the operation of satellites, especially those in geostationary orbit.

Cluster is a joint European Space Agency (ESA) and NASA project, part of ESA's Horizons 2000 program.

### Recent Achievements

The ESA-NASA Cluster mission continues to advance science. Cluster recently discovered a steady leak in Earth's plasmasphere, the torus of plasma that surrounds our planet's atmosphere. The outflow amounts to almost 90 tons a day. Predicted by theory two decades ago, this is one of the main mechanisms that replenishes Earth's magnetosphere with fresh plasma. In addition, a new study using Cluster data has shown improved precision in determining the source of a radio emission produced by the Earth. The experiment involved tilting one of the four identical Cluster spacecraft to measure the electric field of this emission in three dimensions for the first time.

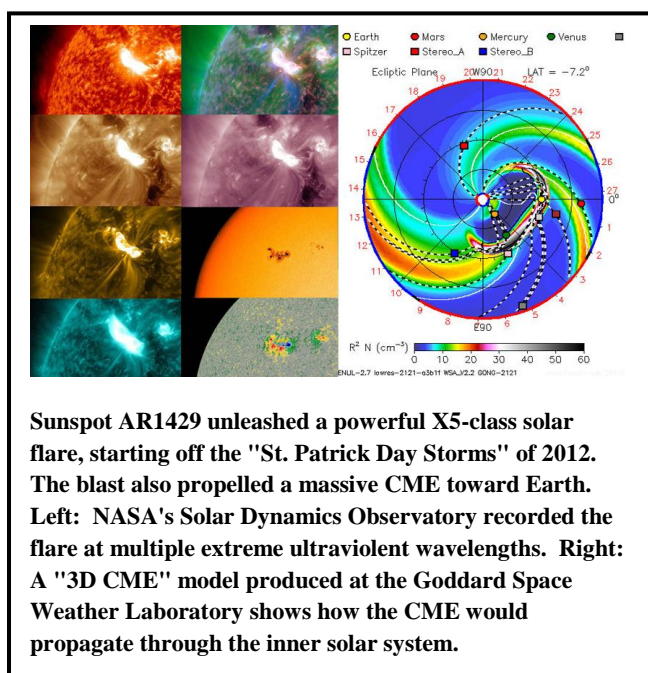
## LIVING WITH A STAR

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Solar Probe Plus	108.2	104.8	145.6	219.2	212.3	345.1	180.4
Solar Orbiter Collaboration	19.1	--	76.5	88.8	117.8	6.7	35.4
Other Missions and Data Analysis	47.6	--	44.3	47.8	48.2	47.0	66.8
<b>Total Budget</b>	<b>174.9</b>	<b>--</b>	<b>266.4</b>	<b>355.8</b>	<b>378.2</b>	<b>398.9</b>	<b>282.7</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The LWS program targets specific aspects of the Sun-Earth-planetary system that affect life and society. LWS provides a predictive understanding of the Sun-Earth system, the linkages among the interconnected systems, and specifically of the space weather conditions at Earth and the interplanetary medium. LWS products measure and therefore may mitigate impacts to technology associated with space systems, communications and navigation, and ground systems such as power grids. Its products improve understanding of ionizing radiation, which has human health implications on the International Space Station and high-altitude aircraft flight, as well as operations of future space exploration with and without human presence. Its products improve the definition of solar radiation for global climate change, surface warming, and ozone depletion and recovery.

For more information, go to <http://science.nasa.gov/about-us/smd-programs/living-with-a-star/>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

ESA changed the delivery date for the two Solar Orbiter Collaboration instruments, HIS and SoloHI, from January 2015 to July 2015, allowing NASA to defer some of the launch vehicle funding and make it available to the Solar Probe Plus mission.

## SOLAR PROBE PLUS (SPP)

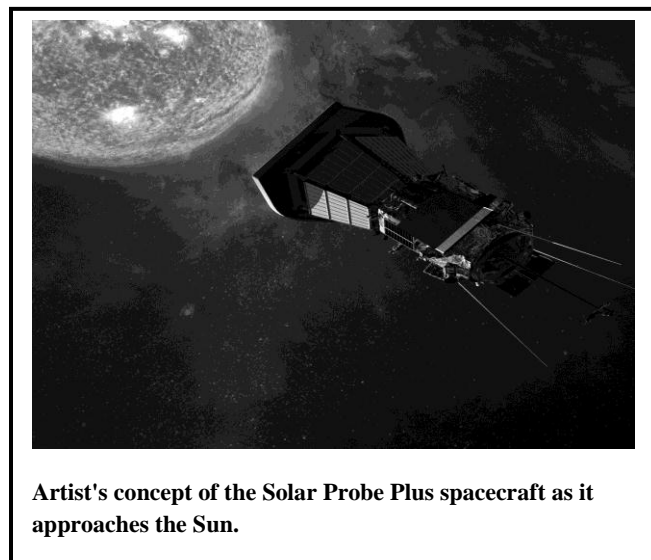
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>108.2</b>	<b>104.8</b>	<b>145.6</b>	<b>219.2</b>	<b>212.3</b>	<b>345.1</b>	<b>180.4</b>
Change from FY 2014			<b>40.8</b>				
Percentage change from FY 2014			<b>38.9%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



### PROJECT PURPOSE

SPP will explore the Sun's outer atmosphere, or corona, as it extends out into space. At a distance of less than 5 times the Sun's diameter from its surface, closer than any other spacecraft, SPP will repeatedly obtain direct in situ coronal magnetic field and plasma observations and white-light remote sensing observations in the region of the Sun that carries the solar wind and creates space weather. SPP's findings will revolutionize knowledge and understanding of coronal heating and of the origin and evolution of the solar wind, answering critical questions posed in the last heliophysics decadal survey.

Its seven-year prime mission lifetime will permit observations over a significant portion of a solar cycle. SPP will enable direct sampling of plasma, enabling observations that otherwise are impossible. These observations will allow heliophysicists to verify and discriminate between a broad range of theory and models that describe the Sun's coronal magnetic field and the heating and acceleration of the solar wind. SPP will enable NASA to characterize and forecast the radiation environment in which future space explorers will work and live.

For more information about SPP, go to <http://nasascience.nasa.gov/missions/solar-probe>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA has increased the budget request for FY 2015, to keep SPP on track for a July 2018 launch.

## **SOLAR PROBE PLUS (SPP)**

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Formulation	Development	Operations
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### **PROJECT PRELIMINARY PARAMETERS**

SPP's first closest approach to the Sun occurs three months after launch, at a heliocentric distance of 35 solar radii. Over the next several years, successive Venus gravitational assists will gradually lower the spacecraft's closest approach to the Sun to less than 10 solar radii. After launch, SPP will orbit the Sun 24 times, gradually "walking in" toward the Sun with each pass. The closest points of each orbit come well within the path of Mercury, the closest planet to the Sun. On the final three orbits, SPP will fly within 3.7 million miles, less than 5 solar diameters, of the Sun's surface. That is about seven times closer than the Helios spacecraft, the current record holder for a close solar pass. SPP will sample changes in the solar wind with increasing solar activity.

### **ACHIEVEMENTS IN FY 2013**

The project developed requirements for the mission, instruments, and spacecraft, and completed system and sub-system design reviews during FY 2013.

The project designed and fabricated hardware to demonstrate technical readiness level (TRL)-6 (system/subsystem model or prototype demonstration in a relevant environment) for all new technology items, including the thermal protection system and its support structure, the solar array cooling system, the high temperature portion of the solar array, and the solar limb sensors.

### **WORK IN PROGRESS IN FY 2014**

In FY 2014, SPP has already completed a static firing of the STAR48GXV motor. This motor is a new development for the upper stage of the launch vehicle. The static firing demonstrated the motor concept and provided the engineering data necessary for follow-on work to develop the motor.

SPP has completed TRL-6 testing and analysis for all enabling technologies, including the Thermal Protection System (TPS), the high temperature solar array, and its cooling system. A series of subsystem-level preliminary design reviews followed these TRL-6 demonstrations. In January 2014, the SPP project completed its mission-level Preliminary Design Review (PDR) in preparation for mission confirmation (KDP-C). In March 2014, at the successful conclusion of the KDP-C process, SPP will start its implementation phase.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015, the project will conduct peer level critical design reviews for system and subsystems, leading up to the mission level Critical Design Review (CDR). Upon completion of the CDR, the project will initiate the build of flight hardware and begin the launch vehicle procurement process.

## SOLAR PROBE PLUS (SPP)

Formulation	Development	Operations
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### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	Dec 2009	Dec 2009
KDP-B	Feb 2012	Feb 2012
KDP-C	Jul 2014	Mar 2014
KDP-D	Mar 2016	Mar 2016
Launch	Jul 2018	Jul 2018

### Formulation Estimated Life Cycle Cost Range and Schedule Range Summary

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Jan 2012	1,233-1,439	Launch Readiness	Jul 2018

### Project Management & Commitments

GSFC provides program management. JHU-APL manages the project.

Element	Description	Provider Details	Change from Formulation Agreement
Expendable Launch Vehicle	Deliver the spacecraft to operational orbit	Provider: TBD Lead Center: GSFC Participating Centers: KSC Cost Share Partners: N/A	
Ground Systems	Receive science and telemetry data from spacecraft, command spacecraft, and distribute science data to investigator teams	Provider: JHU-APL Lead Center: GSFC Participating Centers: N/A Cost Share Partners: N/A	

## SOLAR PROBE PLUS (SPP)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Spacecraft	Transport instruments to science destination, operate instruments, and modify orbit, including several Venus gravity assists	Provider: JHU-APL Lead Center: GSFC Participating Centers: N/A Cost Share Partners: N/A	
Instruments	Provide in situ measurements and remote observations of the Sun	Provider: NASA funded investigators Lead Center: GSFC Participating Centers: N/A Cost Share Partners: N/A	

### Project Risks

Risk Statement	Mitigation
If: The TPS design does not meet launch load requirements, Then: the mass may increase to accommodate loads, or a different design option may be required.	Using the prototype TPS, the SPP project demonstrated that the design can survive mission launch loads. The project will conduct batch uniformity, high temperature fatigue, and other tests in order to quantify the structural capability of the TPS system. Management will consider the risk mitigated after these tests are complete.
If: The NASA budget profile is not better aligned with the development and execution needs of the SPP Project, Then: the Project may have to cut short development and test activities thus raising the technical risk level of the Project.	NASA is reevaluating the outyear profile for SPP to determine whether rephasing of resources in future years is needed. The total budget for SPP remains unchanged.

### Acquisition Strategy

PIs selected through the announcement of opportunity will build science instruments. JHU-APL will build the spacecraft, and will competitively procure the spacecraft subassemblies, components, and parts. The project will define the ground system components and requirements during the formulation phase. GSFC will manage the operations contracts.

## SOLAR PROBE PLUS (SPP)

Formulation	Development	Operations
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### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Prime Contract & Mission Mgt	JHU-APL	Laurel, MD
FIELDS magnetometers & plasma wave instrument	University of California, Berkeley	Berkeley, CA
ISIS energetic particle instruments	Southwest Research Institute	San Antonio, TX
SWEAP plasma instruments	Smithsonian Astrophysical Observatory	Cambridge, MA
WISPR heliospheric imager	Naval Research Laboratory	Washington, DC
Helio Origins Investigation	JPL	Pasadena, CA

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Mission Definition Review (MDR)	SRB	Nov 2011	Gate Review for KDP-B	Successful, project moved to early design	Jan 2014
Preliminary Design Review (PDR)	SRB	Jan 2014	Gate Review for KDP-C	Successful, project ready to proceed to development	Mar 2015



## SOLAR ORBITER COLLABORATION (SOC)

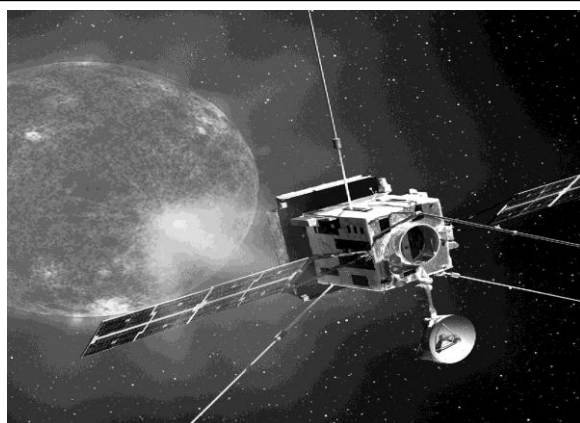
Formulation	Development		Operations	
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	40.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.5
Development/Implementation	0.0	18.1	39.4	76.5	88.8	116.3	4.6	32.8	0.0	376.5
Operations/Close-out	0.0	0.0	0.0	0.0	0.0	1.5	2.1	2.6	11.3	17.5
<b>2014 MPAR LCC Estimate</b>	<b>40.6</b>	<b>19.0</b>	<b>39.4</b>	<b>76.5</b>	<b>88.8</b>	<b>117.8</b>	<b>6.7</b>	<b>35.4</b>	<b>11.3</b>	<b>435.5</b>
<b>Total Budget</b>	<b>40.6</b>	<b>19.1</b>	<b>--</b>	<b>76.5</b>	<b>88.8</b>	<b>117.8</b>	<b>6.7</b>	<b>35.4</b>	<b>11.3</b>	<b>451.7</b>
Change from FY 2014				21.0						
Percentage change from FY 2014				37.8%						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**This ESA-led mission will explore the inner solar system to improve the understanding of how the Sun determines the environment of the inner solar system and how fundamental plasma physical processes operate near the Sun.**

### PROJECT PURPOSE

The NASA and ESA SOC mission will provide measurements that will give NASA better insight on the evolution of sunspots, active regions, coronal holes, and other solar features and phenomena. The instruments will explore the near Sun environment to improve the understanding of the origins of the solar wind streams and the heliospheric magnetic field, the sources, and acceleration mechanisms, and transport processes of solar energetic particles, and the evolution of CMEs in the inner heliosphere. To achieve these objectives, SOC will make in situ measurements of the solar wind plasma, fields, waves, and energetic particles and imaging/spectroscopic observations close enough to the Sun such that they are still relatively unprocessed. SOC will

provide close-up views of the Sun's polar regions and its far side. SOC will tune its orbit to the direction of the Sun's rotation to allow the spacecraft to observe one specific area for much longer than currently possible.

## **SOLAR ORBITER COLLABORATION (SOC)**

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Formulation	Development	Operations
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ESA provides the spacecraft and operations, the ESA member states provide the majority of the instruments, and NASA provides the launch vehicle and two science investigations/instruments: Solar and Heliospheric Imager and the Heavy Ion Sensor. In return for its contributions, NASA will have access to the entire science mission data set.

For more information about SOC, go to: <http://nasascience.nasa.gov/missions/solar-orbiter>.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

ESA changed the delivery date for the two Solar Orbiter Collaboration instruments, HIS and SoloHI, from January 2015 to July 2015, allowing NASA to defer some of the launch vehicle funding and make it available to the Solar Probe Plus mission.

### **PROJECT PARAMETERS**

A NASA-provided launch vehicle will place the ESA-provided SOC spacecraft into an inner heliospheric orbit around the Sun, with its closest approach ranging from 0.23 to 0.38 astronomical units and the farthest distance from 0.73 to 0.88 astronomical units. In the first phase of mission operations, SOC will orbit around the Sun's equator at about the same rate as the Sun's rotation. In the second phase, it will perform a Venus gravity assist between each rotation around the Sun. Each gravity assist will increase the SOC inclination with respect to the Sun's equator so that the inclination will reach 27.5 degrees by the end of prime mission operations. This will enable the instruments to image the polar regions of the Sun clearly for the first time and make key measurements that will advance our understanding of the solar dynamo and the polarity reversal of the global magnetic field. The inclination will increase to 34 degrees by the end of the three-year extended mission allowing better insight into the polar regions.

### **ACHIEVEMENTS IN FY 2013**

NASA approved SOC to proceed into implementation phase in March 2013. The Solar-Heliospheric Imager instrument completed its CDR in October 2013.

### **WORK IN PROGRESS IN FY 2014**

NASA will deliver the Structural Thermal models and continue constructing the flight hardware for both the Solar-Heliospheric Imager science instrument and the Heavy Ion Sensor.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA will perform environmental testing of both the Solar-Heliospheric Imager and the Heavy Ion Sensor in FY 2015.

## SOLAR ORBITER COLLABORATION (SOC)

Formulation	Development	Operations
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### SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	Mar 2013	Mar 2013
SoloHI Instrument CDR	Jun 2013	Oct 2013
HIS Instrument CDR	Feb 2014	Mar 2014
Pre-ship review	Jan 2015	Jun 2015
Launch	Oct 2018	Oct 2018
Begin Phase E	Oct 2018	Jan 2019
End of Prime Mission	Nov 2026	Dec 2025

### Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	\$376.9	70%	2014	\$376.6	0	Launch Readiness Date (LRD)	Oct 2018	Oct 2018	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Two instruments are below the \$250M LCC threshold for JCL. Independent cost and schedule estimates completed by Aerospace and GSFC RAO with each instrument had confidence levels for cost and schedule that were 70 percent when the start of development was approved (at KDP-C).*

## SOLAR ORBITER COLLABORATION (SOC)

Formulation	Development	Operations
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### Development Cost Details

NASA confirmed Solar Orbiter to proceed into implementation phase in March 2013.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>376.9</b>	<b>376.6</b>	<b>-0.3</b>
Aircraft/Spacecraft	0	0	0
Payloads	23.7	29.3	5.6
Systems I&T	0	0	0
Launch Vehicle	250.0	229.0	-21.0
Ground Systems	N/A	N/A	N/A
Science/Technology	1.3	1.5	0.2
Other Direct Project Costs	101.9	116.8	14.9

### Project Management & Commitments

GSFC has program management responsibility for the LWS program and the SOC project. NASA procured all instruments provided by the United States through a competitive Announcement of Opportunity.

Element	Description	Provider Details	Change from Baseline
Solar Orbiter Heliospheric Imager (SoloHi)	Measures the solar wind formations, shock disturbance, and turbulence	Provider: Naval Research Lab Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A
Heavy Ion Sensor (HIS)	Measures the range of heavy ion energies, charge states, masses, and elevation angles as part of the United Kingdom-provided Solar Wind Analyzer instrument suite	Provider: Southwest Research Institute Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A

## SOLAR ORBITER COLLABORATION (SOC)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Expendable Launch Vehicle	Launch vehicle	Provider: TBD Lead Center: N/A Performing Center(s): KSC Cost Share Partner(s): N/A	N/A

### Project Risks

Risk Statement	Mitigation
If: Aggressive instrument delivery schedule is maintained by ESA, Then: NASA will not meet the planned delivery schedule.	NASA will negotiate new instrument delivery and integration dates with ESA, and use project risk resources to cover the period of delay.
If: ESA hardware delivery for launch is delayed, Then: NASA launch vehicle and development costs will increase.	Monitor ESA's progress during its hardware development and plan to cover ESA schedule overruns.

### Acquisition Strategy

NASA selected the instruments and science investigations from a competed Announcement of Opportunity. NASA is competitively selecting the launch vehicle through the NLS-2 contract.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
SoloHI	Naval Research Lab	Washington, DC
Heavy Ion Sensor	Southwest Research Institute	San Antonio, TX

## SOLAR ORBITER COLLABORATION (SOC)

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Formulation	Development	Operations
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### INDEPENDENT REVIEWS

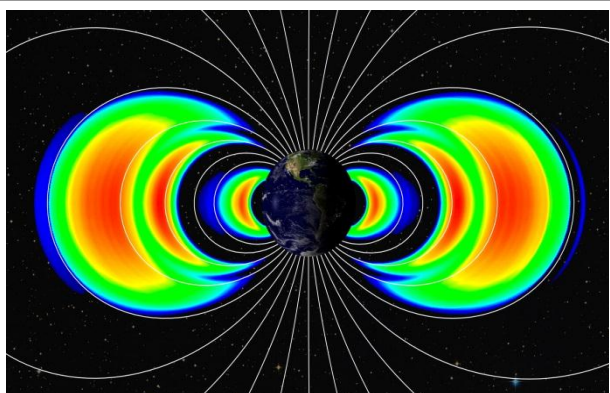
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
All	SRB	Dec 2011	Assess readiness for KDP-B	Successful	N/A
All	SRB	Dec 2012	Assess readiness for PDR	Successful	N/A
SoloHI Instrument	SRB	Oct 2013	Assess readiness for CDR	Successful	Apr 2015
HIS Instrument	SRB	Mar 2014	Assess readiness for CDR		Apr 2015

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Balloon Array for Radiation-Belt Relativ	1.9	--	0.3	0.0	0.0	0.0	0.0
LWS Space Environment Testbeds	0.4	--	0.6	0.4	0.0	0.0	0.0
LWS Science	20.0	--	17.5	17.5	17.5	17.5	17.5
LWS Program Management and Future Missions	6.1	--	5.8	13.1	17.6	20.0	39.7
Van Allen Probes (RBSP)	7.7	--	9.9	6.5	2.5	0.0	0.0
Solar Dynamics Observatory (SDO)	11.6	--	10.2	10.2	10.5	9.5	9.5
<b>Total Budget</b>	<b>47.6</b>	<b>--</b>	<b>44.3</b>	<b>47.8</b>	<b>48.2</b>	<b>47.0</b>	<b>66.8</b>



The Earth's Van Allen radiation belts consist of donut-shaped distinct zones of trapped, highly energetic charged particles. The spatially separated inner zone is primarily comprised of very energetic positive protons and is stable over years to decades. Novel in situ energy-specific observations from NASA's Van Allen probes show a remarkable and unexpected structure of the outer region: an isolated third ring on the inner edge composed of extremely high-energy electrons that persisted largely unchanged for over four weeks before being virtually annihilated by a powerful interplanetary shock wave passage. The outer zone is comprised predominantly of mega-electron volt electrons that wax and wane in intensity on time scales ranging from hours to days depending primarily on external forcing by the solar wind.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

The Living with a Star Other Missions and Data Analysis budget includes operating LWS missions, a science research program, program management, and limited funding for missions to be launched in the next decade.

The National Academies' Heliophysics Decadal Surveys strategically define and prioritize Future LWS missions, most recently in August 2012.

For more information, go to the LWS program at: <http://lws.gsfc.nasa.gov/>.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Mission Planning and Other Projects

#### **THE BALLOON ARRAY FOR RBSP RELATIVISTIC ELECTRON LOSSES (BARREL)**

BARREL is a balloon-based mission of opportunity to augment the measurements of the Van Allen Probes, formerly Radiation Belt Storm Probes, or RBSP, mission. The balloon array made its observations in conjunction with the Van Allen spacecraft, to enable direct comparisons of data. There are two campaigns of five to eight long-duration balloons aloft simultaneously (over one month) to provide measurements of the spatial extent of relativistic electron precipitation and to allow an estimate of the total electron loss from the radiation belts. The first campaign ran successfully in January thru February 2013. Campaign 2 began in December 2013 and was successfully completed in February 2014.

##### **Recent Achievements**

Campaign 1 ran smoothly with five or more balloons aloft simultaneously for almost the entire campaign. Scientists submitted two BARREL science papers to a special issue of Geophysical Review Letters for publication in January 2015: one quantifying rapid and significant loss of high-energy electrons from the radiation belts, and one detailing precipitation of lower energy electrons occurring over a range of time scales.

Campaign 2 launched an additional 20 balloons between Dec 2013 and early February 2014. Once launched, each balloon travelled in a wide circle around the South Pole for up to three weeks, so that a handful of balloons were up at all times. NASA enhanced coordination with NASA's Van Allen Probes for campaign 2 building on experience from campaign 1. Science results will emerge over the next year as experimenters examine data during solar active times.

#### **LWS SPACE ENVIRONMENT TESTBEDS**

The Space Environment Testbeds (SET) project seeks to improve the accommodation and/or mitigation of the effects of solar variability on the environment in the presence of a spacecraft, i.e. the induced environment. It addresses the identification and understanding of the mechanisms of the space environment interactions, modeling of the interactions, and developing and validating ground test protocols to qualify technologies for space. As the complexity of the technologies increases, models derived from the physics-based understanding of the effects are required, and the SET mission responds to these needs. The SET mission will get to Medium Earth Orbit as a piggyback payload on the Air Force Research Laboratory's Demonstration and Space Experiments, with the launch expected in August 2015 on the first flight of the SpaceX Falcon 9 Heavy launch vehicle.

##### **Recent Achievements**

The Demonstration and Space Experiments spacecraft remains in storage with monthly battery charges, abbreviated functional tests, and minor hardware modifications.



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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All SET experiment teams are continuing research on code development designed to supplement SET experiments. NASA is funding a GSFC proposal to model the effects of space weather on operational flight electronic systems. In collaboration with JSC and MSFC, the project developed an updated database of solar particle events (coronal mass ejections and solar flares), and will distribute it via the SET web site.

### LWS SCIENCE

Understanding space weather and improving the capability to address problems, such as predicting geomagnetic storms, pose two major challenges for the research community. First, research must couple traditionally separate disciplines in NASA's Heliophysics division, such as solar-heliospheric and geospace physics. Second, to be truly successful, research must also demonstrate how results would enable an operational capability, such as the generation of forecasts for geomagnetic storms. LWS Science addresses these challenges. A community-based steering committee provides advice on priorities for future LWS Science investigations, and focus teams comprised of selected investigators in particular areas have been set up. The LWS Science team addresses these challenges through three main approaches:

It builds infrastructure: The infrastructure component includes funding to train the next generation of heliophysics experts, to conduct a heliophysics graduate-level summer school, to develop graduate course content, and to support a limited number of space weather postdoctoral positions at universities and government laboratories.

It addresses scientific needs: Funds permit the LWS program to tackle large-scale problems that cross discipline and technique boundaries (e.g., data analysis, theory, modeling, etc.); and identify how this new understanding will have a direct impact on life and society. The aforementioned community-based steering committee provides advice on which areas NASA should prioritize each year. NASA assembles teams from peer-reviewed proposals that individually address pieces of the problem but collectively, as a team, tackle the entire scientific need.

It develops strategic capabilities--Funds allow areas of science focus that have reached level of maturity to be integrated into scientific and operational deliverables (e.g. models or tools) broadly useful to the larger community in universities, government laboratories, industry and the military.

### Recent Achievements

In recent years, there has been an effort to develop accurate solar cycle predictions, leading to nearly a hundred widely spread predictions for the amplitude of the current solar cycle. LWS Science-funded researchers have shown that cycle predictions are better if performed separately for each hemisphere, taking advantage of information about both the dipolar and quadrupolar moments of the solar magnetic field during minimum. This work paves the way for a new generation of precursor methods where the objective is no longer to find which variable yields the most accurate predictions, but rather how to make predictions better.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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LWS Science-funded researchers observed significant changes in the average solar wind composition and plasma properties on the timescale of a solar cycle. We now know that the interplanetary magnetic field decreased by 30 percent between the last two solar minima, and that average ionic charge states of oxygen, from which researchers infer temperatures in the solar corona, have also decreased. There is thus a coherent decrease in small-scale magnetic activity on our sun, simultaneous with the decrease in large-scale magnetic activity (low sunspot numbers).

Interdisciplinary science teams such as those set up from LWS Focus teams are ripe for cross-fertilization and new ideas. Bringing together solar and ionospheric scientists who work on plasma-neutral coupling has resulted in a new state-of-the-art code for use in ionospheric global circulation models, improving forecasting for extreme geomagnetic storms and other space weather phenomena.

### LWS PROGRAM MANAGEMENT AND FUTURE MISSIONS

Program Management and Future Missions provide the resources required to manage the planning, formulation, and implementation of all LWS missions. The office resolves technical and programmatic issues and risks, monitors and reports on progress, and is responsible for achieving overall LWS cost and schedule goals. Additionally, Future Missions supports the program's strategic planning for addressing the recommendations of the heliophysics decadal survey, and the pre-formulation activities for missions that are still merely concepts.

### Operating Missions

#### VAN ALLEN PROBES (FORMERLY RADIATION BELT STORM PROBES)

The Van Allen Probes mission will help scientists understand the Sun's influence on Earth and near Earth space by studying Earth's radiation belts on various scales of space and time. The mission observes the processes that energize and transport radiation belt electrons and ions in Earth's inner magnetosphere, the area in and around Earth's radiation belts. These observations will provide new knowledge on the dynamics and extremes of the radiation belts that are important to all technological systems that fly in and through geospace. The mission will enable an understanding, ideally to the point of predictability, of how populations of relativistic electrons and penetrating ions in space form or change in response to variable inputs of energy from the Sun.

#### Recent Achievements

The twin spacecraft launched in August 2012 and within days had discovered a third radiation belt, a long-lived relativistic electron storage ring embedded in Earth's outer Van Allen belt. Researchers have developed models to explain the new storage belt, involving whistler waves called hiss that can scatter high-energy particles only over very long time scales. Researchers published, or are in the process of publishing, nearly thirty other science papers. There was a fundamental unanswered question about how

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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electrons can accelerate to such high energies; several papers on this topic show evidence of local acceleration in the heart of the radiation belts and wave processes that act like a geophysical synchrotron.

### SOLAR DYNAMICS OBSERVATORY (SDO)

Launched on February 11, 2010, the SDO seeks to understand the Sun's influence on Earth and near Earth space by studying the solar atmosphere on small scales of space and time and in many wavelengths simultaneously. The observatory enables scientists to determine how the Sun's magnetic field is generated and structured and how stored magnetic energy is converted and released in the form of solar wind, energetic particles, and variations in the solar irradiance. It collects data to help elucidate the creation of solar activity, and how space weather emerges as a product of that activity. Measurements of the interior of the Sun, the Sun's magnetic field, the hot plasma of the solar corona, and the irradiance that creates Earth's ionosphere are the primary data products. Currently in its prime operations phase, SDO's images and spectra are key sources of data at solar science conferences and further advance knowledge of the Sun.

#### Recent Achievements

Using an instrument on NASA's Solar Dynamics Observatory, called the Helioseismic and Magnetic Imager, or HMI, scientists have overturned previous notions of how the sun's writhing insides move from equator to pole and back again, a key part of understanding how the dynamo works. The team's recent results, based on an analysis of two full years of continuous SDO operation, show that, instead of a simple cycle of flow moving toward the poles near the sun's surface and then back to the equator, the material inside the sun shows a double layer of circulation, with two such loops on top of each other. This has important consequences for modeling the solar dynamo, and these results on the sun's interior flow will provide a new opportunity to study the generation of solar magnetism and solar cycles.

Another novel application came from observing comets that pass very close to the sun, called (aptly) sun-grazers. When such comets sweep right through the sun's corona, with their long tails streaming behind them, SDO sends back pictures of systems around the sun buffeting the tails. Such comet tails move in response to the sun's otherwise invisible magnetic field, so they can also act as tracers of the complex magnetic field higher up in the corona, offering scientists a unique way of observing movement there. Observations of the comet's long trail of water vapor and the material it has lost, as well as how it vaporizes in the intense radiation of the sun could enable study of atomic material and their ratios in the corona.

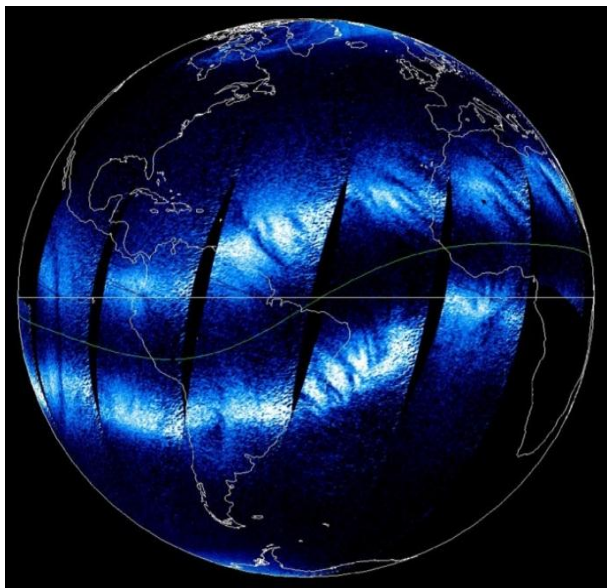
## SOLAR TERRESTRIAL PROBES

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Magnetospheric Multiscale (MMS)	183.3	120.9	39.5	20.2	12.3	2.7	0.0
Other Missions and Data Analysis	20.6	--	21.9	21.3	29.8	27.8	129.4
<b>Total Budget</b>	<b>203.9</b>	<b>--</b>	<b>61.4</b>	<b>41.5</b>	<b>42.1</b>	<b>30.5</b>	<b>129.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Earth's night-time ionosphere displaying spatial structures of various scales (caused by small and large-scale waves emanating upward from the troposphere). Such plasma bubbles and dropouts greatly affect communication and navigation. This program continues to make important contributions to the understanding of many of the processes that link the Earth's upper atmosphere and ionosphere system.

STP focuses on understanding the fundamental physics of the space environment, from the Sun to Earth, other planets, and beyond to the interstellar medium. STP provides insight into the fundamental processes of plasmas (fluid of charged particles) inherent in all astrophysical systems. STP missions focus on processes such as the variability of the Sun, the responses of the planets to those variations, and the interaction of the Sun and solar system. NASA defines STP missions strategically and selects investigations competitively. These missions allow the science community an opportunity to address important research focus areas and make significant progress in understanding fundamental physics.

For more information, go to the STP program at: <http://stp.gsfc.nasa.gov>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

There are no programmatic changes. The decrease in FY 2015 from the FY 2014 budget request reflects the anticipated launch of the Magnetospheric MultiScale (MMS) mission.

## MAGNETOSPHERIC MULTISCALE (MMS)

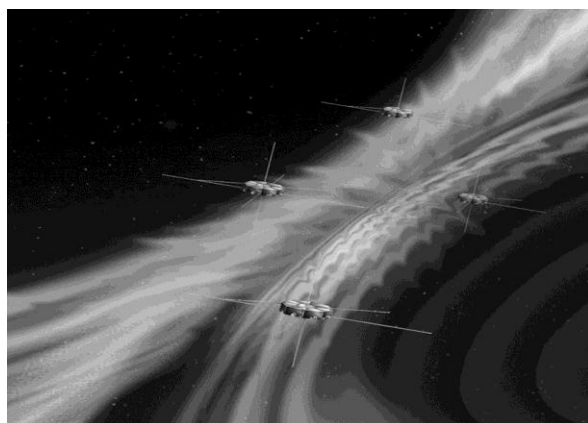
Formulation	Development		Operations	
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	172.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	172.9
Development/Implementation	529.3	183.3	120.9	23.2	0.0	0.0	0.0	0.0	0.0	856.7
Operations/Close-out	0.0	0.0	0.0	16.3	20.2	12.3	2.7	0.0	0.0	51.5
<b>2014 MPAR LCC Estimate</b>	<b>702.2</b>	<b>183.3</b>	<b>120.9</b>	<b>39.5</b>	<b>20.2</b>	<b>12.3</b>	<b>2.7</b>	<b>0.0</b>	<b>0.0</b>	<b>1081.1</b>
<b>Total Budget</b>	<b>702.2</b>	<b>183.3</b>	<b>120.9</b>	<b>39.5</b>	<b>20.2</b>	<b>12.3</b>	<b>2.7</b>	<b>0.0</b>	<b>0.0</b>	<b>1081.1</b>
Change from FY 2014				-81.4						
Percentage change from FY 2014				-67.3%						

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Artist's concept of four identical Magnetospheric Multiscale (MMS) spacecraft variably spaced in Earth orbit.

### PROJECT PURPOSE

The MMS mission investigates how the Sun's and the Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other. This "magnetic reconnection" process occurs throughout the universe. MMS will use Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection, a fundamental plasma-physical process that converts magnetic energy into heat and the kinetic energy of charged particles. In addition to seeking to solve the mystery of the small-scale physics of the reconnection process, MMS will also investigate how the energy conversion that occurs in magnetic reconnection accelerates particles to high energies and what role plasma turbulence plays in reconnection

events. Magnetic reconnection, particle acceleration, and turbulence occur in all astrophysical plasma systems, but researchers can only study them in situ in the solar system, and most efficiently in Earth's magnetosphere, where these processes control the dynamics of the geospace environment and play an important role in the phenomena known as space weather.

For more information about MMS, go to <http://science.nasa.gov/missions/mms/>.

## MAGNETOSPHERIC MULTISCALE (MMS)

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Formulation	Development	Operations
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### EXPLANATION OF MAJOR CHANGES IN FY 2015

The decrease in FY 2015 from the FY 2014 budget request reflects the anticipated launch of the mission, scheduled for March 2015.

### PROJECT PARAMETERS

The MMS mission comprises four identically instrumented spacecraft that measure particles, fields, and plasmas. The MMS instrument payload will measure electric and magnetic fields and the plasmas found in the regions where magnetic reconnection occurs. Fast, multi-point measurements will enable dramatically revealing direct observations of these physical processes. A near-equatorial orbit will explore how Sun-Earth magnetic fields reconnect in Earth's neighborhood. The four spacecraft will fly in a tetrahedron formation that allows them to observe the 3-D structure of magnetic reconnection. The separation between the observatories will be adjustable over a range of six to 250 miles during science operations in the area of interest. The mission design life is two years.

### ACHIEVEMENTS IN FY 2013

The project completed fabrication of spacecraft and instruments and began the integration & testing process.

### WORK IN PROGRESS IN FY 2014

The project will complete environmental testing of all four observatories and conduct vibration testing of a stack of all four observatories. The project will pack and ship all four observatories to the Kennedy Space Center and start launch processing by the end of FY 2014.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

NASA will launch MMS and begin mission operation in FY 2015.

### SCHEDULE COMMITMENTS/KEY MILESTONES

The MMS mission will launch on the Atlas V 421 vehicle from Cape Canaveral Air Force Station in Florida no later than March 2015.

Milestone	Confirmation Baseline Date	FY 2015 PB Request
KDP-C	Jun 2009	Jun 2009
CDR	Aug 2010	Aug 2010
SIR	Jan 2012	Aug 2012

## MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations
Milestone	Confirmation Baseline Date	FY 2015 PB Request
Launch	Mar 2015	Mar 2015
Start of Phase E	Jul 2015	Jul 2015
End of Prime Mission	Jul 2017	Jul 2017

### Development Cost and Schedule

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2010	857.3	70	2014	856.7	0	LRD	Mar 2015	Mar 2015	0

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

### Development Cost Details

Spacecraft costs increased due to increased requirements for personnel, increased parts costs, increased environmental test costs and the requirement for a clean room when the planned facilities were not available. Payloads increased due to a foreign partner decreasing its contribution to the Spin-plane Double Probe electric field instrument, fluctuation in foreign exchange rate for purchase of a major instrument component, and cost growth for Fast Plasma Investigation, Hot Plasma Composition Analyzer, and Central Instrument Data Processor. NASA realized some savings due to reduced launch costs. The United Launch Alliance (ULA) team was able to reduce the cost of mission unique engineering by using fleet-wide system upgrades for MMS. Integration and Test (I&T) costs have been reduced by increasing the testing performed at the system and subsystem level prior to delivery to the Observatory and Constellation I&T activity.

## MAGNETOSPHERIC MULTISCALE (MMS)

Formulation		Development		Operations
Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)	
<b>TOTAL:</b>	<b>857.4</b>	<b>856.7</b>	<b>-0.7</b>	
Aircraft/Spacecraft	169.0	251.8	82.8	
Payloads	131.9	214.9	83.0	
Systems I&T	55.3	48.8	-6.5	
Launch Vehicle	194.2	184.4	-9.8	
Ground Systems	19.1	33.4	14.3	
Science/Technology	19.9	23.3	3.4	
Other Direct Project Costs	268.0	99.9	-168.1	

## Project Management & Commitments

Element	Description	Provider Details	Change from Baseline
Electric fields instrument	Provide measurements of electric fields (time resolution 1ms) and magnetic fields (time resolution 10ms)	Provider: University of New Hampshire Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): Austria	
Fast Plasma Investigation	Provide high temporal resolution measurements of the 3D distributions of hot electrons and ions (30 ms electrons, 150 ms ions)	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): Japan	
Energetic Particle Detectors	Provide high-resolution measurement of energetic particles	Provider: JHU-APL Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): None	
Hot Plasma Composition Analyzers	Three-dimensional measurements of hot plasma composition (time resolution 10 seconds)	Provider: SwRI Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): None	



## MAGNETOSPHERIC MULTISCALE (MMS)

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Launch Vehicle	Deliver approximately 4,000kg payload consisting of four observatories to a highly elliptical Earth orbit	Provider: ULA Lead Center: N/A Performing Center(s): KSC Cost Share Partner(s): None	
Ground Systems	Provide during operations minimum science data payback of four gigabits of data per observatory each day.	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): None	
Four Spacecraft	Deliver high-rate data from instruments to ground station with a high accuracy for two years	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): None	
Science Operations	Provide science data to the community and archive	Provider: University of Colorado, Laboratory for Atmospheric and Space Physics Lead Center: GSFC Performing Centers: GSFC Cost Share Partners: None	
Four Instrument Suites	Provide measurements of electric fields, plasma waves, energetic particles, and hot plasma	Provider: SwRI Lead Center: GSFC Performing Centers: GSFC Cost Share Partners: Austria, France, Japan	

### Project Risks

Risk Statement	Mitigation
If: Manifesting problems prevent a March 2015 launch of MMS, Then: the program will have to continue operating and may deplete remaining funding.	Hold present development schedule, maintain dialog with Launch Services to push for priority into the desired time slot.

## MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations
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### Acquisition Strategy

A combination of civil servants and local contractors are developing and testing the MMS spacecraft in-house at GSFC. The acquisition of subcontracted spacecraft sub-assemblies, components, and parts is through procurement contracts issued by the MMS procurement office.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Launch Vehicle	United Launch Alliance (ULA)	KSC, FL
Instrument Suite	SwRI	San Antonio, TX

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
All	SRB	Jul 2014	Operations Readiness Review (ORR)	TBD	N/A
All	SRB	Aug 2012	Systems Integration Review (SIR)	Successful	N/A

## OTHER MISSIONS AND DATA ANALYSIS

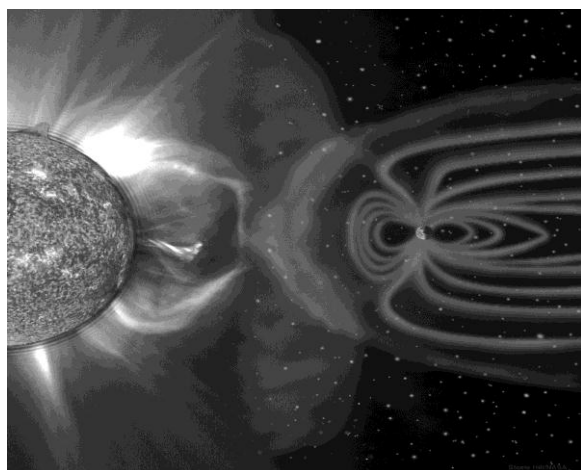
Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
STP Program Management and Future Missions	1.1	--	2.2	1.9	10.7	8.8	110.5
Solar Terrestrial Relations Observatory (STEREO)	8.5	--	9.5	9.5	9.5	9.5	9.5
Hinode (Solar B)	8.2	--	7.5	7.3	7.0	7.0	7.0
TIMED	2.8	--	2.7	2.7	2.6	2.5	2.5
<b>Total Budget</b>	<b>20.6</b>	<b>--</b>	<b>21.9</b>	<b>21.3</b>	<b>29.8</b>	<b>27.8</b>	<b>129.4</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



STP studies the interaction of the Sun's wind with the Earth's magnetic field as shown in the graphic above.

The STP Other Missions and Data Analysis budget includes operating STP missions, program management, and limited funding for future missions launching in the next decade.

For more information, go to the STP program at: <http://stp.gsfc.nasa.gov>.

### Mission Planning and Other Projects

#### PROGRAM MANAGEMENT AND FUTURE MISSIONS

Program Management and Future Missions provide the resources required to manage the planning, formulation, and implementation of all STP missions. The program office ensures successful achievement of STP program cost and schedule goals, while managing cross-project dependencies, risks, issues, and requirements as projects progress through formal key decision points. Additionally, Future Missions supports the STP program strategic planning for addressing the recommendations of the Heliophysics decadal survey and the pre-formulation activities for STP missions not yet approved as projects.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Operating Missions

#### **SOLAR TERRESTRIAL RELATIONS OBSERVATORY (STEREO)**

STEREO enables studies of the origin of the Sun's coronal mass ejections and their consequences for Earth. The mission consists of two spacecraft, one leading and the other lagging Earth in its orbit. STEREO's instrumentation targets the fundamental process of energetic particle acceleration in the low solar corona and in interplanetary space. The mission can image the structure and evolution of solar storms as they leave the Sun and move through space toward Earth. The mission also provides the foundation for understanding space weather and developing predictive models. The models in turn will help identify and mitigate the risks associated with space weather events. Additionally, it will improve our space weather situational awareness not only for Earth and in low earth orbit, but also throughout the solar system.

#### **Recent Achievements**

On July 23, 2012 a solar active region that space weather scientists had been monitoring and that had already produced four fairly fast Coronal Mass Ejections (CME's) in the direction of Earth, released one of the fastest CME's on record, fortunately in the direction of the STEREO A, well away from Earth. This CME had speeds that exceeded 1200 miles per second, comparable with the so-called Carrington event of 1859. Had the Earth been at the location of STEREO A, the large southward-oriented magnetic field component in the event, combined with its high speed, would have produced a record geomagnetic storm comparable to that of 1859. The CME was accompanied by an unusually intense solar energetic particle event which could have caused havoc at Earth had we received the direct impact. Instead, Earth was near the edge of the solar energetic particle cloud and experienced a modest solar energetic particle storm. This event shows that the sun can produce extreme events even during a relatively modest solar cycle and improves our estimates of the probability of such extreme events occurring.

#### **Hinode**

Hinode is a Japanese Institute of Space and Astronautical Science mission operating as a follow-on to the highly successful Japan, U.S., U.K. Yohkoh (Solar-A) collaboration. The mission consists of a coordinated set of optical, Extreme Ultraviolet and x-ray instruments that are studying the basic heating mechanisms and dynamics of the active solar corona. By investigating the fundamental processes that connect the Sun's magnetic field and the solar corona, Hinode is discovering how the Sun generates magnetic disturbances and the high-energy particle storms that propagate from the Sun to Earth.

#### **Recent Achievements**

High-resolution observations of the Sun's corona by Hinode and SDO in extreme ultraviolet and soft X-rays have revealed a new world of complexity in the sheet-like structures connecting CMEs to the post-eruption flare loops. These findings demonstrate that turbulent effects are present in or very near the current sheets in CME-associated eruptive flares. This turbulence very likely has significant effects on the

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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magnetic field, and possibly on the current sheets. The resulting conditions are likely to have profound effects on the rate of magnetic reconnection.

### THERMOSPHERE, IONOSPHERE, MESOSPHERE ENERGETICS AND DYNAMICS (TIMED)

The TIMED mission characterizes and studies the physics, dynamics, energetics, thermal structure, and composition of the least explored and understood region of Earth's atmosphere, the mesosphere-lower thermosphere-ionosphere (MLTI). This region of interest, located between altitudes of approximately 35 to 100 miles above the surface of Earth, helps protect Earth from harmful solar radiation. It is a gateway between Earth's environment and space, where the Sun's energy first affects Earth's environment.

#### Recent Achievements

Using observations of the STS-135 Shuttle launch vapor trail, one can observe the transport of water on a global scale, and Polar Mesospheric Cloud (PMC) formation at high latitudes. These observations present a unique opportunity to test our understanding of the dynamics affecting the global distribution of the constituents of the Earth's atmosphere by using water as a proxy measurement.

TIMED observations also contribute to understanding the seasonal and solar cycle variations in the composition of the thermosphere, and their linkage to changes in gravity wave activity. Recently, TIMED observed significant thermospheric changes driven by a geomagnetic storm that established the important role of mixing of Oxygen and molecular Nitrogen. Further, the measurement of the relative ratios of these two elements was determined to be a good diagnostic for understanding thermospheric storm time dynamics.

## HELIOPHYSICS EXPLORER PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
ICON	18.2	--	78.2	49.8	41.0	7.5	1.0
Other Missions and Data Analysis	40.9	--	45.4	42.2	47.7	66.8	92.4
<b>Total Budget</b>	<b>59.1</b>	<b>95.2</b>	<b>123.6</b>	<b>91.9</b>	<b>88.7</b>	<b>74.3</b>	<b>93.4</b>
Change from FY 2014			28.4				
Percentage change from FY 2014			29.8%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Explorers Program is the oldest continuous program in NASA. It is comprised of a long-standing series of space science missions that are independent, but share a common NASA oversight/insight management structure. The Heliophysics Explorers Program provides frequent flight opportunities for world-class scientific investigations from space, accomplished within NASA Heliophysics space science goals using efficient management approaches. The Heliophysics Explorers Program provides a vital and effective means of timely achieving urgent strategic goals.

The Heliophysics Explorers Program provides frequent flight opportunities for world-class scientific investigations on focused and timely science topics. Explorers use a suite of smaller, fully competed missions that address these topics to complement the science of strategic missions of the Living with a Star and Solar Terrestrial Probes (STP) programs. Highly competitive selection ensures accomplishment of the most current and best strategic science.

Full missions include Medium Explorers, Explorers, and Small Explorers. Missions of Opportunity are typically instruments flown as part of a non-NASA space mission.

NASA introduced Explorer missions within the 2011 Announcement of Opportunity, in response to the currently available expendable launch vehicles. In September 2011, NASA selected three heliophysics Explorer missions and three Missions of Opportunity for initial study.

Other Missions and Data Analysis supports numerous operating Heliophysics Explorer

missions, as well as program management functions and funding for future mission selections.

For more information on Explorer missions, go to <http://explorers.gsfc.nasa.gov/missions.html>.

## HELIOPHYSICS EXPLORER PROGRAM

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### EXPLANATION OF MAJOR CHANGES IN FY 2015

There are no programmatic changes.

### ACHIEVEMENTS IN FY 2013

In spring 2013, NASA selected two missions for implementation: the Ionospheric CONnection Explorer (ICON) is a full mission, and the Global-scale Observations of the Lamb Disk (GOLD) is a mission of opportunity. IRIS, a mission to understand what energizes the solar atmosphere, launched in June. Senior Review of operating missions occurred in April.

### WORK IN PROGRESS IN FY 2014

Planning of the Program Implementation Review in September.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Senior Review of Operating Missions

### Program Elements

None.

### Program Schedule

NASA implements the Heliophysics Explorers program via competitively selected Announcements of Opportunity (AO). NASA releases mission solicitations based on available funding, with the expectation of a three-year cadence. Based on current funding projections, NASA can release the next Explorers AO no earlier than FY 2016.

Date	Significant Event
Apr 2015	Senior Review of Operating Missions

## HELIOPHYSICS EXPLORER PROGRAM

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### **Program Management & Commitments**

GSFC provides program management.

Program Element	Provider
ICON	Provider: University of California, Berkeley Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): none
Explorer Operating Missions	Provider: GSFC Lead Center: HQ Performing Center(s): GSFC, ARC Cost Share Partner(s): None

### **Acquisition Strategy**

The Explorer program competes new missions via the Announcement of Opportunity (AO) process with a plan for a three year cadence.

### **MAJOR CONTRACTS/AWARDS**

None.

### **INDEPENDENT REVIEWS**

None.



# IONOSPHERIC CONNECTION EXPLORER (ICON)

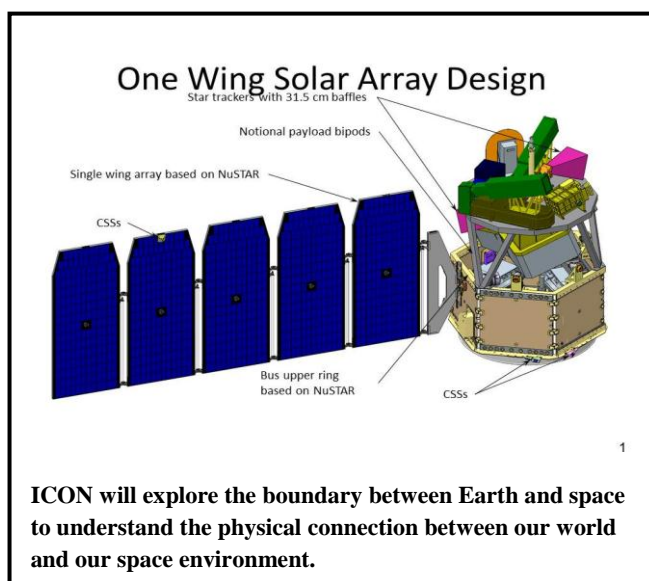
Formulation	Development	Operations
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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	18.2	--	78.2	49.8	41.0	7.5	1.0

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



## PROJECT PURPOSE

The Ionospheric CONnection Explorer (ICON) is a single spacecraft mission dedicated to understanding neutral-ion coupling in the Earth's upper atmosphere (thermosphere). It will resolve both long-standing and newly emerging questions about the mechanisms that control the daily development of plasma in Earth's space environment.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

There are no changes on this newly selected mission.

## PROJECT PRELIMINARY PARAMETERS

ICON will simultaneously measure altitude profiles of the thermosphere and ionosphere's neutral winds, composition, density, temperature, and ion density. At the same time, it will make in-situ plasma measurements. Three institutions with a successful record of accomplishment of previous space missions and strong schedule, cost, and engineering management structures will build the four high-heritage scientific instruments of ICON. The payload will fly on an Orbital Sciences Inc. LEOStar-2 with heritage from Solar Radiation and Climate Experiment (SORCE), AIM, Orbital Carbon Observatory (OCO), Glory, Nuclear Spectroscopic Telescope Array (NuSTAR), and Gravity and Extreme Magnetism (GEMS). ICON will provide the data to "understand how neutral winds control ionospheric variability," which is a stated goal of the 2010 Science Plan for NASA's Science Mission Directorate.

## IONOSPHERIC CONNECTION EXPLORER (ICON)

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Formulation	Development	Operations
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### ACHIEVEMENTS IN FY 2013

NASA selected ICON as a new mission in April 2013.

### WORK IN PROGRESS IN FY 2014

Completed the System Requirements Review and signed the Phase B-F contract. Preparing for the PDR and KDP-C.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The Project will complete the KDP-C and the Critical Design Review.

### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	Apr 12, 2013	Apr 12, 2013
PDR	Apr 2014	May 2014
KDP-C	May 2014	Jun 2014
CDR	Feb 2015	Feb 2015
Launch	Feb 2017	Feb 2017

### Formulation Estimated Life Cycle Cost Range and Schedule Range Summary

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Mar 28, 2013	\$225 - \$257	LRD	Feb 2017

# IONOSPHERIC CONNECTION EXPLORER (ICON)

Formulation	Development	Operations
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## Project Management & Commitments

Element	Description	Provider Details	Change from Formulation Agreement
Expendable Launch Vehicle	Deliver the spacecraft to operational orbit	Provider: TBD Lead Center: Performing Center(s): KSC Cost Share Partner(s):	
Spacecraft	Transport instruments to science destination	Provider: Orbital Sciences Corp. Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):	
MIGHTI	High resolution imager instrument	Provider: NRL Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):	
EUV	Extreme UV instrument	Provider: Univ. of Calif., Berkeley Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):	
FUV	Far UV instrument	Provider: UCB Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):	
IVM	Ion velocity meter instrument	Provider: Univ. of Texas, Dallas Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):	

## Project Risks

Risk Statement	Mitigation
If: Problems occur in the flight unit build/test or software, Then: Flight MAU delivery will be delayed.	Utilize the Explorer Master Avionics Unit test program to meet ICON requirements

# IONOSPHERIC CONNECTION EXPLORER (ICON)

Formulation	Development	Operations
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## Acquisition Strategy

PIs selected through the announcement of opportunity will build science instruments. The University of California, Berkeley will build instruments and provide project management. Orbital Sciences Corporation will build the spacecraft. The project will define the ground system components and requirements during the formulation phase. GSFC will manage the operations contracts and provide program management.

## MAJOR CONTRACTS/AWARDS

The Phase B contract with options for Phases C-E was awarded to the University of California at Berkeley for the PI controlled mission.

## INDEPENDENT REVIEWS

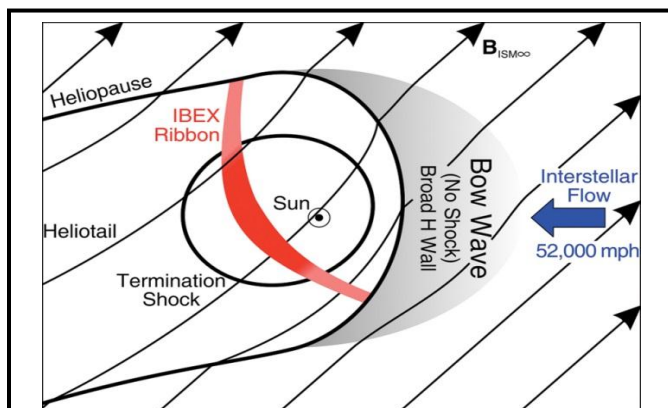
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
SRR	SRB	Dec 2013	Evaluate ICON requirements	Successful	May 2014
PDR	SRB	May 2014	Preliminary Design Review		
KDP-C	DPMC	Jun 2014	Confirmation		
CDR	SRB	Feb 2015	Design Review		
SIR	SRB	Mar 2016	Systems integration		
PER	SRB	May 2016	Environmental testing		
KDP-D	DPMC	Nov 2016	Mission launch readiness		

## OTHER MISSIONS AND DATA ANALYSIS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Global-scale Observations of the Limb and Disk (GOLD)	2.8	--	22.1	18.2	15.1	6.2	2.9
Heliophysics Explorer Future Missions	0.1	--	0.0	0.0	8.9	39.4	64.5
Heliophysics Explorer Program Management	4.8	--	4.1	6.8	7.1	4.7	8.5
Interface Region Imaging Spectogr (IRIS)	15.1	--	1.0	0.0	0.0	0.0	0.0
Interstellar Boundary Explorer (IBEX)	4.0	--	3.4	3.4	3.4	3.4	3.4
TWINS	1.0	--	0.6	0.6	0.6	0.6	0.6
CINDI	0.9	--	0.9	0.6	0.3	0.2	0.2
Aeronomy of Ice in Mesosphere (SMEX-9)	3.0	--	3.0	3.0	3.0	3.0	3.0
THEMIS	4.4	--	5.4	4.6	4.5	4.5	4.5
ACE	3.0	--	3.0	3.0	3.0	3.0	3.0
RHESSI	2.0	--	1.9	1.9	1.9	1.9	1.9
<b>Total Budget</b>	<b>40.9</b>	<b>--</b>	<b>45.4</b>	<b>42.2</b>	<b>47.7</b>	<b>66.8</b>	<b>92.4</b>



IBEX provided unprecedented measurements of the interstellar flow speed and direction. The revised speeds indicate that the heliosphere, the bubble surrounding the sun and solar system with solar wind, does not drive a bow shock. Instead, a bow wave is now assumed to precede the heliosphere in its motion through the interstellar medium. The figure shows a schematic of the elongated heliosphere with its three boundaries, the Termination Shock, the Heliopause, and the Bow Wave (McComas et al., Science, 2012).

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*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

The Heliophysics Explorers Other Missions and Data Analysis budget includes operating Explorer missions, program management, and funding for the mission currently in the competitive principal investigator-led mission procurement cycle.

For more information, go to the Explorer program at: <http://explorer.gsfc.nasa.gov/>.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Mission Planning and Other Projects

#### **GLOBAL-SCALE OBSERVATIONS OF THE LIMB AND DISK (GOLD)**

The GOLD mission will perform unprecedented imaging of the Earth's thermosphere and ionosphere. For the first time in history, GOLD will answer fundamental scientific questions about how the thermosphere / ionosphere system responds to geomagnetic storms, solar radiation, and upward propagating waves and tides.

##### **Recent Achievements**

NASA and the GOLD project signed Phase B-E contract. GOLD completed System Requirements Review. GOLD is now preparing for the Key Decision Point (KDP-C).

#### **EXPLORER FUTURE MISSIONS**

Explorer Future Missions provides the resources required to manage the planning, formulation, and implementation of all Explorer missions. The program office ensures successful achievement of Explorer program cost and schedule goals, while managing cross-project dependencies, risks, issues, and requirements as projects progress through formal key decision points. Additionally, Future Missions supports the Explorer procurement activities, including the pre-formulation activities for missions not yet approved as projects.

##### **Recent Achievements**

The Explorer program selected one full mission (ICON) and one mission of opportunity (GOLD) in April 2013 to proceed toward flight with launches potentially in 2017 for both missions.

#### **EXPLORER PROGRAM MANAGEMENT**

Explorer Program Management encompasses the program office resources required to manage the formulation and implementation of all Explorer projects. The program office is responsible for providing support and guidance to projects in resolving technical and programmatic issues and risks, for monitoring and reporting technical and programmatic progress of the projects and for achieving Explorer cost, schedule and technical goals and requirements.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Operating Missions

#### INTERFACE REGION IMAGING SPECTROGRAPH (IRIS)

The Interface Region Imaging Spectrograph (IRIS) explorer is a Small Explorers mission selected in June 2009 and launched on June 27, 2013. IRIS joined a network of solar spacecraft and ground-based observatories to provide unprecedented insight into a little understood region of the sun called the interface region. IRIS will enable scientists to understand what energizes the solar atmosphere. IRIS will provide significant new information to increase our understanding of energy transport into the corona and solar wind and provide an archetype for all stellar atmospheres. The mission will extend the scientific output of existing heliophysics spacecraft that follow the effects of energy release processes from the Sun to Earth. IRIS will provide key insights into all these processes, and thereby advance our understanding of the solar drivers of space weather from the corona to the far heliosphere, by combining high-resolution imaging and spectroscopy for the entire chromosphere and adjacent regions.

IRIS is a sun-pointed mission that studies the chromosphere in the far ultraviolet and near ultraviolet. This two-year mission fills a critical observational data gap by providing simultaneous, co-spatial, and comprehensive coverage from photosphere up to corona. IRIS consists of a 20-centimeter aperture telescope assembly that feeds an imaging spectrograph and a separate imaging camera system with wavelengths in the far ultraviolet and near ultraviolet.

#### Recent Achievements

IRIS completed its 30-day commissioning period, began science operations, and fully released observational data to the public. Over its first six months, IRIS thrilled scientists with detailed images of the interface region, finding even more turbulence and complexity than expected. For the first time, IRIS is making it possible to study the explosive phenomena in the interface region in sufficient detail to determine their role in heating the outer solar atmosphere. The mission's observations also open a new window into the dynamics of the low solar atmosphere that play a pivotal role in accelerating the solar wind and driving solar eruptive events. Initial observations of solar prominences and spicules show dynamics and flows, far more complex than what existing theoretical models predicted.

#### INTERSTELLAR BOUNDARY EXPLORER (IBEX)

The Interstellar Boundary Explorer is the first mission designed to image the edge of the solar system. As the solar wind from the Sun flows out beyond Pluto, it collides with the material between the stars, forming several boundaries. These interactions create energetic neutral atoms, particles with no charge that move very quickly. This region emits no light that conventional telescopes can see, so IBEX measures the particles that happen to be traveling inward from the boundary instead. IBEX contains two detectors designed to collect and measure energetic neutral atoms, providing data about the mass, direction of origin, and energy of these particles. From this data, researchers create maps of the boundary. The mission's focused science objective is to discover the nature of the interactions between the solar wind and the interstellar medium at the edge of the solar system. This region is important because it shields a large percentage of harmful galactic cosmic rays from Earth and the inner solar system.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### Recent Achievements

IBEX has measured faint signals in the form of energetic neutral atoms from the trailing edge of the heliosphere. These observations have enabled researchers to determine the direction and shape of the tail of the heliosphere. It turns out that the heliotail is much flatter and larger than expected, and the interstellar magnetic field surrounding our star's heliosphere deflects it. Combining four decades worth of observations from IBEX with Ulysses, ACE, and STEREO observations and from other historical databases, scientists have discovered that the interstellar gas breezing through the solar system has shifted in direction by 6 degrees. This finding provides evidence that the sun and the solar system live in a surprisingly complex and dynamic part of the Milky Way galactic environment that evolves on much shorter timescales than previously believed.

### TWO WIDE-ANGLE IMAGING NEUTRAL ATOM SPECTROMETERS (TWINS)

TWINS provides stereo imaging of Earth's magnetosphere, the region surrounding the planet controlled by its magnetic field and containing the Van Allen radiation belts and other energetic charged particles. TWINS gives a three-dimensional global visualization of this region, which has led to a greatly enhanced understanding of the connections between different regions of the magnetosphere and their relation to solar variability. TWINS is a NASA-sponsored mission of opportunity that has been operational since 2008 and approved for extended operations until September 2016.

### Recent Achievements

The TWINS mission has imagers to capture two key components of the Earth's extended upper atmosphere, the neutral hydrogen exosphere, and the ionized oxygen in the terrestrial ring current. TWINS Lyman-alpha imaging, which detects the ultraviolet glow from the neutral hydrogen exosphere, has characterized new dependences of this region. The neutral exosphere exhibits major reconfigurations with the change of seasons, and the exospheric density increases by 5 to 15 percent during geomagnetic storms. Another key component of TWINS science analysis is oxygen ion imaging, achieved by post-processing of energetic neutral atom images. The TWINS oxygen images extend to lower energy than has previously been observed, which is an advantage for understanding how low-energy ionospheric oxygen enriches the ring current. Lower-energy oxygen enrichment occurs during the main phases of storms, at a rate of increase that is much faster and more pronounced than predicted by empirical models. Comparison of oxygen energetic neutral atom images with self-consistent models, both to improve the models and to elucidate physical processes, has shown how oxygen enrichment of the ring current can profoundly affect the strength and duration of storms.

### THE COUPLED ION-NEUTRAL DYNAMICS INVESTIGATIONS (CINDI)

CINDI is a mission to understand the dynamics of Earth's ionosphere. This mission studies the behavior of equatorial ionospheric irregularities, which can cause significant service interrupts for communications and navigation systems. CINDI data incorporated into state-of-the-art physics models is leading to advances in specification and prediction of space weather. CINDI is in extended phase until September



## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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2016. The mission consists of two instruments on the Communication/Navigation Outage Forecast System satellite, a project of the US Air Force.

### Recent Achievements

Continuous operation of the CINDI instruments over a period of low solar activity and into a period of more moderate levels of solar activity has afforded the opportunity to study both short term and long-term variations in the topside ionosphere and their relationships to the solar flux.

Researchers also discovered that the magnetic inclination and the offset between the magnetic and geographic equators produce important differences in the production and loss rates in each hemisphere. These factors also appear in the systematic variations in field-aligned plasma motions.

## AERONOMY OF ICE IN THE MESOSPHERE (AIM)

The Aeronomy of Ice in the Mesosphere is a mission to determine why polar mesospheric clouds form, and why they vary. Polar mesospheric clouds, Earth's highest-altitude clouds, form each summer in the coldest part of the atmosphere about 50 miles above Polar Regions. These clouds are of particular interest, as the number of clouds in the middle atmosphere, or mesosphere, over Earth's poles has been increasing over recent years, possibly related to climate change. The spacecraft launched on April 25, 2007, completed its prime mission in FY 2009, and is currently in extended phase until September 2016.

### Recent Achievements

Solar Occultation For ICE Experiment (SOFIE) meteoric smoke observations show a steadily decreasing trend in the annual minimum suggesting a changing atmospheric circulation. The Polar Mesospheric Cloud season onset is highly correlated with the meteoric smoke minimum suggesting a strong dynamics connection. AIM observations have quantified and explained variations in Polar Mesospheric Cloud season length and latitudinal extent, which are sensitive indicators of the prevailing meteorological conditions.

## TIME HISTORY OF EVENTS AND MACROSCALE INTERACTIONS DURING SUBSTORMS (THEMIS)

THEMIS is a Medium Class Explorers mission that launched on February 17, 2007, and is currently operating in extended phase until September 2016. Starting as a five-spacecraft mission, the three inner probes of THEMIS now focus on collecting data related to the onset and evolution of magnetospheric substorms, while the two outer probes (now referred to as ARTEMIS) have been repositioned into lunar orbits). Magnetospheric substorms are the explosive release of stored energy within the near Earth space environment leading to important space weather effects. The two ARTEMIS probes orbit the Moon's surface at approximately one hundred miles altitude and provide new information about the Moon's internal structure and its atmosphere. ARTEMIS provides two-point observations essential to characterizing the Moon's plasma environment and hazardous lunar radiation. THEMIS and ARTEMIS,

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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among others in the heliophysics portfolio, are examples of missions offering important dynamics knowledge useful for future human spaceflight.

### Recent Achievements

Scientists have recently provided their most complete picture yet of the locales of intense energy interactions between the sun and Earth. The THEMIS probes enabled this when they were temporarily aligned in space with Geotail and two of NOAA's GOES satellites in the night-side of Earth's magnetic field. Analysis of data from this unprecedented alignment of eight satellites through the Earth's vast magnetic environment yielded comprehensive details of the energy's journey through a process that forms the aurora, called a substorm. Their results showed that small events unfolding over the course of a millisecond can result in energy flows that last up to half an hour and cover an area 10 times larger than Earth. These flows ultimately power Earth's auroras, heat the plasma inside the Earth's magnetic field, and energize the Van Allen radiation belts.

Scientists used THEMIS data to locate precisely the region between the inner and outer Van Allen radiation belts. This is important to know, because the region between belts has minimal radiation hazards and spacecraft are relatively safe.

### ADVANCED COMPOSITION EXPLORER (ACE)

The Advanced Composition Explorer observes particles of solar, interplanetary, interstellar, and galactic origins, spanning the energy range from solar wind ions to galactic cosmic ray nuclei. ACE measures and enables comparisons of the composition of the solar corona, the solar wind, other interplanetary particle populations, the local interstellar medium, and galactic matter. Changing conditions over the solar cycle are presenting new opportunities, including providing new insights relevant to space weather.

### Recent Achievements

Using data from ACE, we observe significant changes in the average solar wind composition and plasma properties on the time-scale of a solar cycle. We now know that the interplanetary magnetic field decreased by 30% between the last two solar minima, and that charge states of Oxygen are lower in the fast solar wind. In a recently published analysis, we find a systematic change of Carbon, Oxygen, Silicon, and Iron charge states towards lower average values. The most surprising aspect of this analysis concerns the heavy ion content of the solar wind. We show that there was a ~50% decrease of heavy ion abundances relative to Hydrogen as the Sun went from solar maximum to solar minimum.

## OTHER MISSIONS AND DATA ANALYSIS

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Formulation	Development	Operations
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### RAMATY HIGH ENERGY SOLAR SPECTROSCOPIC IMAGER (RHESSI)

The RHESSI satellite focuses on the highest energy X-rays and gamma rays produced by the Sun, helping to observe solar flares of all shapes and sizes.

#### Recent Achievements

Combined observations from RHESSI and SDO have provided the most comprehensive views of magnetic reconnection on the sun. This fundamental process powers solar flares and coronal mass ejections, which sends radiation and particles across the solar system that can effect satellites near Earth and interfere with radio communications. This dataset shows the first comprehensive set of data that is able to constrain and improve models of this fundamental process on the sun.

# AERONAUTICS

Budget Authority (in \$ millions)	Actual	Enacted	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Airspace Operations and Safety Program	0.0	--	<b>131.0</b>	132.7	134.6	135.9	137.3
Advanced Air Vehicles Program	0.0	--	<b>213.6</b>	211.4	205.8	203.3	205.3
Integrated Aviation Systems Program	0.0	--	<b>127.0</b>	125.8	128.0	133.4	134.8
Transformative Aeronautics Concepts Program	0.0	--	<b>79.5</b>	86.8	93.8	95.2	96.2
Aviation Safety	77.6	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Airspace Systems	89.8	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Fundamental Aeronautics	167.7	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Aeronautics Test	74.6	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Integrated Systems Research	99.0	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Aeronautics Strategy and Management	21.0	--	<b>0.0</b>	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>529.5</b>	<b>566.0</b>	<b>551.1</b>	<b>556.6</b>	<b>562.2</b>	<b>567.8</b>	<b>573.5</b>

## Aeronautics .....AERO-2

AIRSPACE OPERATIONS AND SAFETY PROGRAM .....AERO-10

ADVANCED AIR VEHICLES PROGRAM .....AERO-18

INTEGRATED AVIATION SYSTEMS PROGRAM .....AERO-27

TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM.....AERO-34

# AERONAUTICS

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Airspace Operations and Safety Program	0.0	--	<b>131.0</b>	132.7	134.6	135.9	137.3
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Aviation Safety	77.6	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Airspace Systems	89.8	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Fundamental Aeronautics	167.7	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Aeronautics Test	74.6	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Integrated Systems Research	99.0	--	<b>0.0</b>	0.0	0.0	0.0	0.0
Aeronautics Strategy and Management	21.0	--	<b>0.0</b>	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>529.5</b>	<b>566.0</b>	<b>551.1</b>	<b>556.6</b>	<b>562.2</b>	<b>567.8</b>	<b>573.5</b>
Change from FY 2014			<b>-14.9</b>				
Percentage change from FY 2014			<b>-2.6%</b>				



A full-sized tail from a Boeing 757 was modified and equipped with active flow control technology for wind tunnel testing. Active flow control is one of many technologies NASA is maturing that could improve aircraft fuel efficiency.

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The air transportation system of today is an integral part of the U.S. and global economies. It is the primary mechanism for connecting countries across the world through mobility of populations and mobility of goods and services.

Aviation accounts for more than \$1.3 trillion annually of the total U.S. economic activity<sup>1</sup> and is one of the few industries that generate a positive trade balance, \$47.1 billion in 2009 alone<sup>2</sup>. The aviation industry supports more than 10 million direct and indirect jobs, including

<sup>1</sup> "The Economic Impact of Civil Aviation on the U. S. Economy", August 2011, FAA

<sup>2</sup> "Global Aviation Industry Takes off for the World's Largest Aerospace Trade Exhibition in 2012", July 6, 2012, International Trade Administration

# AERONAUTICS

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more than one million high-quality manufacturing jobs<sup>1</sup>.

The overarching impacts of aviation and the air transportation system can be felt right down to the individual; just about every material product produced and purchased today has been touched by aviation in some way. Air transportation of freight valued at more than \$1.6 trillion occurs every year<sup>1</sup>. The number of passengers U.S. airlines carried in 2011 is more than 725 million passengers for both domestic and international flights<sup>1</sup>. Air travelers per year spend more than \$635 billion for business and personal travel<sup>1</sup>. In short, the U.S. aviation industry is critical to both economic and cultural well-being.

Aeronautics research plays a vital supporting role to aviation by enabling game changing technology innovation and development that allows the U.S. aviation industry to continue to grow and maintain global competitiveness. A 2007 study of civil aeronautics research, *An Economic Perspective on Civil Aeronautics Research*, indicated that aeronautics research and development makes substantial contributions to the Nation's economic growth. The study also identified several factors that point to the desirability of government-sponsored research in aeronautics. One of the ways government research is beneficial is because it can reduce the risks that industry would have to take in order to integrate or utilize new technologies. In addition, Government-sponsored research can benefit an entire industry, and even multiple industries, through wide application of research results.

Past research conducted by NASA's Aeronautics Research Mission Directorate (ARMD) has directly benefited today's air transportation system and aviation industry. The tools and technologies that resulted from this research increased the capacity and improved the efficiency, safety, and environmental compatibility of the air transportation system. NASA continues to explore research and develop tools and technologies that can be integrated into more advanced aircraft and airspace systems, including enabling game changing concepts for the future. Research programs in NASA conduct cutting-edge research at both the fundamental and integrated systems levels to address national and global challenges.

NASA aeronautics guides its research efforts using a strategic vision that embraces the multiple roles of aviation and expands the understanding of those roles, while working to address tomorrow's challenges.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA recently developed a new and compelling strategic vision for the Aeronautics Research programs. This strategy is the culmination of a multi-year effort that included gathering industry and other Government agencies' inputs, systems analysis of environmental and market trends, and the identification of societal mega-drivers. The trend analysis indicated that NASA could best contribute to the nation's future societal and economic vitality by focusing efforts in six thrust areas. These six areas align to be responsive to a growing demand for mobility, severe challenges to sustainability of energy and the environment, and technology advances in information, communications, and automation technologies. The thrust areas are:

- Assured autonomy for aviation transformation
- Innovation in commercial supersonic aircraft
- Ultra-efficient commercial vehicles
- Transition to low-carbon propulsion
- Real-time system safety assurance

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<sup>1</sup> "The Economic Impact of Civil Aviation on the U. S. Economy", August 2011, FAA

# AERONAUTICS

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- Safe, efficient growth in global operations

To most effectively manage the research needed to address these strategic thrusts, NASA restructured its research programs, focusing on three specific goals.

The first goal is to pursue innovative solutions aligned to the strategic thrusts. To do this, NASA has formed three mission programs. They are the Airspace Operations and Safety Program, the Advanced Air Vehicles Program, and the Integrated Aviation Systems Program. These programs will clearly define the most compelling technical challenges facing the aviation industry, and retire these challenges in a time frame that is supported by the stakeholders and required by NASA's customers.

The second goal is to incentivize multi-disciplinary convergent research. This goal led to the formation of the Transformative Aeronautics Concepts Program. This program will allow for a flexible and organic environment for NASA researchers to develop high-risk, forward-thinking ideas to address aviation's big problems. This environment will allow for rapid demonstration of feasibility and quick turnover of ideas. This research will be conducted in a multi-disciplinary, integrated manner.

The third goal is to enable greater workforce and institutional agility and flexibility. To do this, the Aeronautics Test Program has been integrated into the mission programs. This will embed the flight research into the performing projects to integrate all research phases and to ultimately allow for expanded flight opportunities. It will also enable more agile research practices that combine high-fidelity simulation, ground testing, and flight research.

Further details pertaining to the restructuring are provided in the program sections of this document.

## ACHIEVEMENTS IN FY 2013

NASA contributes to the Nation's aeronautics and aviation enterprise by performing research in the areas of aeronautical sciences, materials and structures and vehicle and propulsion system performance efficiency, Next Generation Air Traffic Management (NextGen) technologies, aviation safety, and the sustainment and improvement of strategic aeronautical testing capabilities. NASA's achievements in FY 2013 form a strong foundation for the forward-looking strategy.

A key NextGen accomplishment was the successful transfer of the Precision Departure Release Capability (PDRC) concept of operations, technologies, and operational tools to the Federal Aviation Administration (FAA). This was the third successful technology transfer to the FAA of NASA-developed NextGen tools over the past two years. PDRC will enable air traffic controllers to schedule departing aircraft to merge into available slots in the overhead air traffic streams via a numerical predictive capability rather than the existing manual system, ameliorating departure delays in the current system due to missed overhead slot opportunities. An estimated 30,000 aircraft per month could get improved clearances into constrained overhead and en-route flow using PDRC tools. Fully 22 percent of all domestic flights will have significantly improved on-time arrivals, and the number of departure delays will be reduced as approximately 80 percent of the lost overhead slot opportunities are filled.

To help reduce the impact of air travel on the environment, NASA completed Phase I of the in-flight tests to characterize the emissions from aircraft engines burning an alternative biofuel. These tests complement the ground-based tests complete in prior years. Preliminary results indicate that the biofuel blends tested may substantially reduce the emission of black carbon, sulfates, organics, and other particulates. This

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Phase I flight-testing has resulted in an internationally recognized data set that is being used by the domestic and international atmospheric science community for input to climate change models and is informing the development of aviation emission standards.

NASA significantly advanced the understanding and demonstrated the potential benefits of future aircraft configurations, including demonstrating environmental and operational cost benefits of the hybrid wing body (HWB) configuration. Researchers completed the community noise assessment of this configuration by testing it in the 14x22-foot low speed wind tunnel at Langley Research Center. Aircraft noise is hindering the growth of aviation as noise intrudes on individuals and businesses living or situated in and around the Nation's airports, and complaints to local authorities are increasing. Acoustic analysis of the HWB configuration indicates that it will meet the goal of 42-decibel noise reduction from existing noise standards. Test results validated the anticipated noise reduction benefits and provide the industry with validation data that supports future aircraft design investment decisions.

NASA is addressing the most vexing safety problems facing commercial aviation, including a situation where aircraft flying at high altitudes near convective weather experience jet engine power interruptions as the engines ingest air with high concentrations of ice crystals. NASA has developed the world's first capability that successfully reproduces this atmospheric condition on the ground by completing the engine icing ground test capability in the Propulsion Systems Laboratory at Glenn Research Center (GRC). Use of this facility will further the understanding of this phenomenon and the effects on jet engine performance. NASA has demonstrated that jet engines subjected to these conditions in the laboratory setting experience power output rollbacks consistent with in-flight experience. This work supports the validation of analytical models that predict the resulting engine compressor stalls, and will provide test data that supports certification of future jet engines.

## WORK IN PROGRESS IN FY 2014

NASA will develop a scheduling tool, called Extend PDRC, to enable efficient aircraft departure and merging into open slots in the congested overhead traffic stream. Extend PDRC leads toward an Integrated Arrival/Departure/Surface concept. This capability will significantly increase efficiency through accurate prediction of aircraft take-off time enabled by improved scheduling of aircraft pushback from the terminal gate through take-off, which will ultimately lead to reductions in fuel burn and traffic delays.

NASA will perform high-fidelity wind tunnel and computational simulations for a truss-braced wing aircraft conceptual design to measure performance improvements that would lead to reduced fuel use. The truss-braced wing concept is a promising technology for lighter-weight, lower-drag capability in transport aircraft.

NASA will use wind tunnels to demonstrate Ultra High Bypass (UHB) propulsion systems that can be integrated with HWB concepts to meet fuel burn and noise goals. HWB configurations hold the promise of significantly reducing the environmental impact for commercial transport aircraft, offering advantages in noise reduction and fuel burn reduction not available to today's more standard aircraft configurations. Additionally, UHB aircraft engines offer the potential for reduced fuel consumption due to higher operating pressures than today's turbine aircraft engines. This research will investigate the benefits and potential impacts of integrating UHB engines on HWB aircraft configurations.



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NASA will demonstrate a wireless sensor, which provides lightning protection, and can detect and diagnose damage in composite structures. This sensor will be added to an aircraft external surface forming a “smart skin” layer to provide lightning strike protection as well as perform damage detection and diagnosis. Post-strike damage assessment comparisons will be conducted between metal mesh (the current accepted solution) and the wireless sensor system to show compliance for an acceptable level of protection.

NASA will demonstrate a technique known as compositional verification to verify the safety of a complex aircraft or ground automation software system. This technique enables a system-level software safety assessment by breaking down or simplifying the system and examining the safety properties of that system's components.

NASA will conduct a simulation of unmanned aircraft sharing the airspace with manned aircraft, and testing a variety of conditions. This test is the first in a continual flight test campaign over three years, progressively increasing complexity of Unmanned Aircraft Systems (UAS) integration testing.

NASA will upgrade the data acquisition and control systems at the GRC's 10x10-foot Supersonic Wind Tunnel, and will improve the data measurement techniques and flow quality in the Langley Research Center's (LaRC) National Transonic Facility. These improvements are critical to sustaining strategically important test capabilities for both NASA and DOD.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

NASA's aeronautics research in FY 2015 will be focused on providing the most benefit possible within the six strategic thrust areas. A significant activity in each of these areas is highlighted here.

To advance the goals of the safe, efficient growth in global operations strategic thrust, NASA will demonstrate the Concept of Operations for an integrated set of aircraft arrival technologies developed to enable efficient performance during congested operations at busy airports. This demonstration is necessary to allow for wide utilization of Performance Based Navigation (PBN) by the FAA and airlines. PBN uses technologies to transition aviation navigation away from ground-based stations to onboard systems, in which many airlines have already invested. Utilization PBN will lead to reductions in delays, fuel consumption, noise, and emissions. This demonstration is in preparation for technology transfer, and it reflects the completion of a series of high-fidelity simulations to develop and validate a variety of technologies and the concept of operations.

To drive innovation in commercial supersonic aircraft, NASA will develop low sonic boom design software capable of analyzing a complete aircraft at all supersonic flight conditions. The tools would be capable of calculating the flow and performance effects of different engine inlet and nozzle configurations, as well as optimizing a configuration by changing multiple components of the aircraft.

Over the six-year lifetime of the Environmentally Responsible Aviation (ERA) Project, various high potential technologies will be matured and demonstrated in relevant environments. These technologies directly support NASA's goal to advance ultra-efficient commercial vehicles. FY 2015 marks the end of Phase 2 and the final year of execution for the Environmentally Responsible Aviation project. NASA plans to successfully complete each of the eight Integrated Technology Demonstrations, and achieve its mission as it closes out the ERA Project by the end of the fiscal year. At the end of FY 2015, NASA will show the impact of development and analysis of vehicle concepts with the appropriate technology suite to

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simultaneously meet subsonic transport goals in significantly reducing fuel burn, community noise, and nitrogen oxides emission during take-off and landing in the 2020-2025 timeframe.

To advance the transition to low-carbon propulsion, NASA is working with other Government agencies and organizations to characterize the environmental benefits of “drop-in” alternative fuels, by measuring the emissions of these fuels from actual aircraft engines both on the ground and in-flight. “Drop-in” alternative fuels are formulated to work in existing conventional engines, and these are blended with conventional jet fuel when used in flight. Emissions from the engines burning blended fuels are measured in flight by an instrumented chase aircraft flying into the test aircraft’s contrails at various distances.

In support of the goal to assure real-time system safety, NASA will demonstrate that aircraft engine diagnostic systems that rely on advanced sensors can detect faults and hazards between maintenance inspections. This will demonstrate emerging engine health management sensors to monitor engine systems integrity and thermodynamic performance. The technology will integrate high temperature, vibration, emission, and structural health sensor and detection technologies with diagnostics to identify emerging faults before damage occurs.

Within the research related to assured autonomy for aviation transformation, NASA will deliver data, analysis, and recommendations based on an integrated flight test series. These tests will utilize simulated airspace/traffic and a live vehicle (manned UAS surrogate) to inform development of preliminary performance standards by the responsible rule-making organization (RTCA Special Commission on Minimum Performance Standards for Unmanned Aircraft Systems). This is the second in a continual flight test campaign over three years, progressively increasing complexity of UAS integration testing. The test campaign will integrate live flying UAV (or manned surrogate) with ground stations and real-time and simulated air traffic data.

The Aeronautics program would utilize \$43.9 million from the Opportunity, Growth, and Security Initiative to support a diverse set of activities that complement the FY 2015 Aeronautics portfolio.

Specific activities include the following:

- \$7.9 million for the Vertical Lift Project to accelerate the development of advanced technologies needed by U.S. industry to reduce noise and improve performance of vertical lift systems, and to allow for the completion of the Tilt Rotor Test Rig and continuation of research on advanced propulsion concepts;
- \$6.0 million to begin research to enable small UAS operations in low-altitude airspace and over populated areas
- \$24.0 million to add or improve capabilities associated with computational fluid dynamics including model fabrication and ground and flight testing; and laboratory and simulator advancements to improve air traffic operations; and
- \$6.0 million for flight testing advancements to add or improve mobile telemetry capability, research into autonomous flight, supersonic test capability, data acquisition and processing, and dual use capability of the support aircraft.

Further details on Aeronautics program activities are provided in the Opportunity, Growth, and Security Initiative section of this document.

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## **Programs**

Beginning in FY 2015, NASA's Aeronautics programs will be restructured from six programs to four. Much of the technical content in FY 2014 will continue in the new program structure with a sharper focus toward achieving timely and compelling impacts to the six strategic thrust areas. New content is defined throughout this document.

### **AIRSPACE OPERATIONS AND SAFETY PROGRAM**

The Airspace Operations and Safety Program develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Airspace System (NAS) safely. The program also provides knowledge, concepts, and methods to the aviation community to manage increasing complexity in the design and operation of vehicles and the air transportation system.

This program continues the research of the Airspace Systems Program and the aircraft state awareness research and system wide safety research previously conducted within the Aviation Safety Program.

### **ADVANCED AIR VEHICLES PROGRAM**

The Advanced Air Vehicles Program conducts fundamental research to improve aircraft performance and minimize environmental impacts from subsonic air vehicles; develops and validates tools, technologies and concepts to overcome key barriers, including noise, efficiency, and safety, for rotorcraft vehicles; and explores theoretical research for potential advanced capabilities and configurations for low boom supersonic aircraft. The program will also conduct research to reduce the timeline for certification of composite structures for aviation, and will ensure the strategic availability, accessibility, and capability of a critical suite of aeronautics ground test facilities to meet Agency and national aeronautics testing needs.

This program continues much of the research that was in the Fundamental Aeronautics Program, with a new focus on research that is directly related to the newly defined strategic thrusts. It now houses the Advanced Composites Program that was previously in the Integrated Systems Research Program. It also includes the ground test portion of the former Aeronautics Test Program.

### **INTEGRATED AVIATION SYSTEMS PROGRAM**

The Integrated Aviation Systems Program conducts research on promising concepts and technologies at an integrated system level. The program explores, assesses, and demonstrates the benefits of these potential technologies in a relevant environment. The program includes research into environmentally responsible aviation and unmanned system integration into the national airspace. The program will also support the flight research needs across the ARMD strategic thrusts, programs and projects, and will complete flight demonstrations, which will be a collaborative effort across the aeronautical industry and will include international partners as appropriate.

This program continues the Environmentally Responsible Aviation and UAS in the NAS projects, and now includes the flight test portion of the former Aeronautics Test Program.

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## TRANSFORMATIVE AERONAUTICS CONCEPTS

The Transformative Aeronautics Concepts Program cultivates multi-disciplinary, revolutionary concepts to enable aviation transformation and harnesses convergence in aeronautics and non-aeronautics technologies to create new opportunities in aviation. The program's goal is to knock down technical barriers and infuse internally and externally originated concepts into all six strategic thrusts identified by ARMD, creating innovation for tomorrow in the aviation system. Using sharply focused activities, the program provides flexibility for innovators to explore technology feasibility and provide the knowledge base for radical transformation. The program solicits and encourages revolutionary concepts, creates the environment for researchers to become immersed in trying out new ideas, performs ground and small-scale flight tests, allows failures and learns from them, and drives rapid turnover into new concepts.

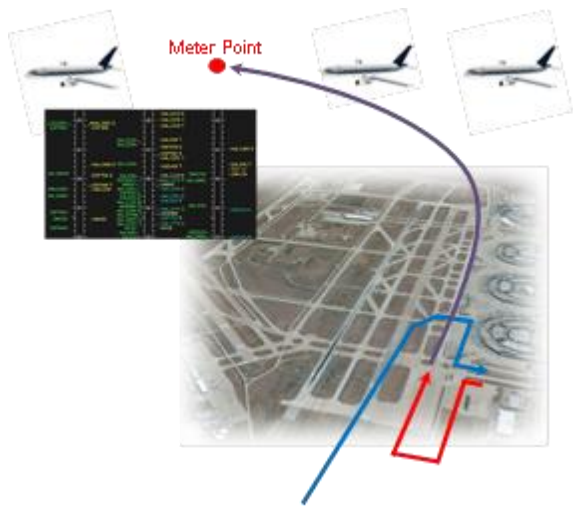
## AIRSPACE OPERATIONS AND SAFETY PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>0.0</b>	<b>--</b>	<b>131.0</b>	<b>132.7</b>	<b>134.6</b>	<b>135.9</b>	<b>137.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Precision Departure Release Capability (PDRC)** automates the negotiation of runway takeoff times for aircraft flying into congested overhead streams, as depicted in the graphic. Today, takeoff times are manually estimated by tower controllers, and are often inaccurate, causing aircraft to miss their assigned slots in the overhead stream, leading to delays and reduced throughput. By connecting scheduling automation tools (such as the data screen above), PDRC improves takeoff time conformance by over 50% from current day operations.

The Airspace Operations and Safety Program (AOSP) creates technologies vital to the implementation of NextGen, the ongoing transformation of the National Airspace System from a ground-based system of air traffic control to a satellite-based system of air traffic management. AOSP seeks to directly benefit the flying public by moving key concepts and technologies from the laboratory into the field to increase capacity and reduce the total cost of air transportation, while striving to make air travel as safe and efficient as possible. The current U.S. air transportation system is widely recognized to be among the safest in the world. Yet, while NextGen will enable efficient passage through the increasingly crowded skies, it will come with increased operating complexity. The vigilance of the aviation community must continue for the United States to meet the public expectations for safety in this complex, dynamic domain. AOSP, with the FAA and its other industry and academic partners, collaboratively conceives and develops NextGen technologies to improve the intrinsic safety of current and future aircraft that will operate in NextGen, and to provide advanced levels of automated support to air navigation service providers and aircraft operators for

reduced travel times and travel-related delays both on the ground and in the sky. These advanced technologies provide shortened routes for time and fuel savings, with associated improvements in noise and emissions, and permit controllers to monitor and manage aircraft for greater safety in all weather conditions. As the predicted volume of air traffic climbs, this transformation aims to reduce gridlock, both in the sky and at the airports.

## **AIRSPACE OPERATIONS AND SAFETY PROGRAM**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

A portion of the safety-related research including systems verification and validation, data mining, prognostics, and flight crew training requirements for assuring safe aircraft control previously conducted in the Aviation Safety Research Program has been transferred into AOSP.

### **ACHIEVEMENTS IN FY 2013**

NASA conducted human-in-the-loop simulations of advanced trajectory-based algorithms that reduce aircraft delays during taxi. Delays on the airport surface have been recognized as one of the major factors limiting the ability of airports to accommodate high levels of surface traffic throughput. These algorithms include a more advanced surface movement planning horizon, of up to one hour, leading to reduced surface congestion. Benefits studies for several complex U.S. airports show a taxi delay reduction of between three to five minutes results in annualized fuel savings of \$2.5 million to \$7.5 million at each airport using these algorithms. Technology transition to FAA may occur as early as 2015.

NASA collaborated with the FAA to explore the use of NASA's PDRC that couples advanced airspace flow management and airport surface traffic tools. PDRC allows precision scheduling of departing aircraft to allow for smooth integration into available slots in the high-altitude overhead streams. Missed departure slots in the overhead stream translate to departure delays and lost system capacity. The technology automates what is today an inefficient manual process for negotiating a take-off time between the control tower and en route control center. As compared to today's process, take-off time conformance is expected to double in improvement, representing an estimated \$20 million in annual system-wide savings. NASA transferred this technology to the FAA in 2013, and it is currently planned to be incorporated in next terminal systems program technology upgrade.

bad weather. Until now, airline dispatchers and FAA traffic managers did not have a way to continuously reevaluate the pre-departure weather avoidance routes for each flight. NASA's Dynamic Weather Routing (DWR) tool enables dynamic, real-time adjustments to flight paths to avoid bad weather with minimum delay while also saving fuel. The tool integrates trajectory-based automation, convective weather modeling that predicts the growth and movement of storms, and algorithms to automatically compute minimum-delay routes around bad weather. The tool demonstrated the potential to provide significant operational savings to airlines. Researchers conducted field trials of DWR with American Airlines in 2013, which demonstrated payoff under real-world air traffic operations. These field tests of DWR demonstrated average savings of close to 10 minutes or, in operating cost, an estimated \$1,700 per flight impacted by severe weather. The technology has been transferred to the users to finalize licensing agreements for implementation.

### **WORK IN PROGRESS IN FY 2014**

NASA will conduct an integrated, high-fidelity simulator demonstration of an aerodynamic model that supports flight crew training requirements for assuring safe aircraft control, validating a capability that does not exist in current-day simulators. As part of a government-industry review of worldwide aviation accidents, the aviation community is looking carefully into enhanced training requirements for stall recognition and recovery to reduce loss-of-control accidents. NASA will validate the model with subscale aircraft flight tests, as well as other available flight test and accident data.

## **AIRSPACE OPERATIONS AND SAFETY PROGRAM**

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NASA will develop and transfer technology for ground-based controller managed spacing of arriving flights combined with flight deck interval management technologies to enable fuel and time savings along with increased capacity for early adopters of Automatic Dependent Surveillance-Broadcast equipage. NASA is jointly working with FAA to partner with airlines, aircraft manufacturers, avionics manufacturers, ground-based automation system integrators, and airports to test these technologies under practical conditions of arriving flights at a dense terminal of a busy commercial airport. Results from integrated technology simulations in 2013 are being used to refine the plan for the Air Traffic Management Technology Demonstration #1 (ATD-1) system evaluation with FAA in 2014 and future field demonstrations expected to enable annual system-wide benefits estimated at several hundred million dollars.

NASA will conduct a simulation of a surface decision support system called the Spot and Runway Departure Advisor that reduces stop-and-go activity on taxiways targeting improved efficiency of airport surface operations. It is expected to reduce departure queues and excessive fuel burn and emissions that result in high operating cost for airlines and adverse impacts on the environment. The simulation will use Charlotte International Airport operations data and will examine how the operations could be improved by better scheduling at various key points on the airport surface.

NASA will apply a technique known as compositional verification to verify the safety of complex aircraft and ground automation software systems. This technique enables a system-level software safety assessment by breaking down (simplifying) the system and examining the safety properties of the system's components. The approach applies automated processes early in the design lifecycle, offering the potential to reduce certification time and costs. These methods and applications can also support verification of concepts and technology of such highly integrated systems to ensure compatibility and validate requirements and performance benefits.

NASA will assess initial results of an innovative NAS modeling architecture that will use real-life, one-way feed of aircraft traffic and weather data and allow shadow-mode testing of advanced, gate-to-gate concepts in an integrated fashion to accelerate application of NextGen technologies. This tool will allow integrated impact assessment of multiple concepts and technologies, evaluation of competing alternatives, and exploration of technologies for improved NAS performance that cannot be evaluated in today's airspace.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA continues to develop and demonstrate ground-based controller managed spacing of arriving flights combined with flight deck interval management technologies. To demonstrate user benefits of these concepts, NASA is jointly working with the FAA and partnering with airlines, aircraft manufacturers, avionics manufacturers, ground-based automation system integrators, and airports to test this integrated set of technologies under practical conditions of arriving flights at a dense terminal of a busy commercial airport. NASA will demonstrate these concepts and technologies in preparation for technology transfer. The sequence of integrated simulations in preparation for field demonstrations of ATD-1 technologies, in collaboration with government and industry stakeholders, is anticipated in the FY 2016-2017 timeframe, as the final phase of the transition process. This complex integrated set of ground-based and flight deck technologies will enable expanded terminal area capacity and reduced flight time and fuel consumption for arriving aircraft.

## **AIRSPACE OPERATIONS AND SAFETY PROGRAM**

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NASA will conduct a demonstration of a surface decision support system called the Spot and Runway Departure Advisor that reduces stop-and-go activity on taxiways. This technology targets improved efficiency of airport surface operations from both air traffic control and airline operations points of view: long departure queues and excessive fuel burn and emissions that result in high operating cost for airlines and adverse impacts on the environment, would be reduced. The demonstration is planned for Charlotte International Airport in concert with USAir/American Airlines airport ramp tower controllers and will examine how the operations could be improved by better scheduling at various key points on the airport surface. Other users of this technology could include FAA tower controllers.

NASA will complete the initial open architecture design, cost estimation, and benefits assessment of an innovative NAS modeling architecture that will use real-life one-way feed of aircraft traffic and weather data and allow testing of advanced gate-to-gate concepts in an integrated fashion to accelerate application of NextGen technologies. The architecture for this new capability will enable shadow-mode assessment of realistic technologies for NextGen. It will allow integrated impact assessment of multiple concepts and technologies, study interactions across different concepts, test competing alternatives, and uncover any potential unknowns related to NAS performance. Application of data mining techniques will be used to identify the precursors and conditions leading to airspace choke points. Identification of these causal and contributing factors will enable mitigation of these conditions in future integrated airspace operations concepts and technologies. This complex modeling and simulation capability will enable rapid evaluation of new airspace management concepts that cannot be evaluated in today's NAS.

### **Program Elements**

#### **AIRSPACE TECHNOLOGY DEMONSTRATIONS (ATD)**

The ATD Project is comprised of a collection of critical technology development and demonstration activities geared toward delivery of near-term benefits to the air transportation system stakeholders.

The Interval Management/Terminal Area Precision Scheduling and Spacing (IM-TAPSS) activity, also referred to as ATD-1, will operationally demonstrate an integrated set of NASA arrival management software technologies for planning and executing efficient arrival operations in the terminal environment of a high-density airport. The research involves tight integration of scheduling and merging and spacing capabilities with the additional objective of increasing the fuel-efficiency of arrival operations. These technologies include tools for ground-based controllers to better manage scheduling and spacing of aircraft in congested terminal airspace as well as applications employing automatic dependent surveillance-broadcast (ADS-B) avionics and technology for use by the flight crew to allow more precise spacing, greater arrival efficiencies, and operational cost savings. Project execution will require multiple integrated simulations conducted with active FAA controllers and airline pilots using airspace modeled after subject U.S. airports to validate performance and operational benefits. In completing the plan for an IM-TAPSS field demonstration, NASA will pursue partnerships with industry system integrators and suppliers and with air carriers to determine optimal operational requirements, and scheduling and traffic-flow characteristics to enable the most beneficial technology demonstration.

The Integrated Arrival/Departure/Surface (IADS) activity will develop and adjust precision schedules for gates, spots, runways, arrival, and departure fixes while ensuring efficient individual aircraft trajectory.



## AIRSPACE OPERATIONS AND SAFETY PROGRAM

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This will reduce unnecessary buffer imposed by the human workload associated with the tasks of simultaneously coordinating and scheduling of arrivals, departures, runway, and surface operations. These inefficiencies are pronounced when the traffic density is high and result in lost slots and/or many stop-and-go operations between gates and runway threshold. The scope of the IADS activities will consider automated technologies for various schedulers for arrivals, departures, surface, runway configuration, and management; conflict detection and resolution; flight deck interval management and conformance monitoring; departure path management; and gate, spot, and runway departure advisories. Initial deliverables will include concept of operation, fast-time analysis to demonstrate the benefits, human-in-the-loop simulation studies to demonstrate the feasibility and gain user confidence, detailed cost-benefit analysis, and requirements for procedures and automation.

The Applied Traffic Flow Management (ATFM) activity will explore concepts and develop technologies to execute more efficient flight paths for en route airspace. Delays in flight plans are largely due to convective weather, and this weather changes over time. Over all, about 25 percent of aircraft get delayed (of which 75 percent is due to weather) and about 65 percent of delays are potentially avoidable. The project will employ learning automation for traffic flow management and digital traffic management initiatives to develop more effect strategic and tactical flow management procedures. Targeted capabilities will include:

- Reduced weather-induced delays by integrating probabilistic weather information with aircraft, flow, and airspace management strategies.
- Dispatcher decision support tools to provide dynamic, efficient routing for airborne aircraft and flows to avoid severe weather at the regional level.
- Aircraft-based technology to support flight-optimizing requests by pilots.
- Increased oceanic airspace operational efficiency by tighter integration of air/ground procedures and technologies to enable trajectory-based operations and reduced separation minima employing ADS-B.
- Methodologies, tools, and procedures for en route pair-wise trajectory management concepts.

The goal of the Technologies for Assuring Safe Energy and Attitude State (TASEAS) activity is to identify risks and provide knowledge needed to avoid, detect, mitigate, and recover from hazardous flight conditions. The TASEAS activities will demonstrate new capabilities that enable pilots to better understand and respond safely to complex situations, and to improve operator effectiveness within aviation systems by incorporating design elements that enhance human contributions to aviation safety. NASA will conduct an integrated, high-fidelity simulator demonstration of a state-of-the-art aerodynamic model of commercial aircraft flight characteristics that supports flight crew training requirements for assuring safe aircraft control. As part of a government-industry review of worldwide aviation accidents, the aviation community is looking carefully into enhanced training requirements for stall recognition and recovery to avoid loss-of-control accidents: the most common cause of fatal aviation accidents worldwide. Augmenting a flight simulator with NASA's aerodynamic model will allow pilots to recognize and respond correctly to conditions that can lead to a stall. NASA will partner with other government agencies and the Commercial Aviation Safety Team (a joint initiative comprised of federal, international, and aviation industry and union leaders) on this activity.

This research primarily aligns with the Safe and Efficient Growth in Global Operations strategic thrust area.

## **AIRSPACE OPERATIONS AND SAFETY PROGRAM**

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### **SHADOW MODE ASSESSMENT USING REALISTIC TECHNOLOGIES FOR THE NATIONAL AIRSPACE SYSTEM (SMART-NAS)**

The SMART-NAS Project will develop an air traffic management simulation capability to explore the integration of alternative concepts, technologies, and architectures at the system level of the NAS. To accelerate the transformation of the entire NAS, proposed functions must be integrated and demonstrated to gain confidence in the performance of the entire system. A shadow-mode NAS will be developed that takes actual operational input from the NAS (weather, flight plans, airports' arrival rates, system constraints, etc.), and simulates the entire system (or parts of it) using proposed alternative architectures, concepts, and technologies to demonstrate performance and validate safe, seamless operations. It will examine, in real-time, robustness, reliability, and stability of concepts, algorithms, and technologies as compared with current NAS operations. To achieve these capabilities, SMART-NAS will employ advanced prognostics, data mining, and data analytics for enhanced decision-making and system assessments. The SMART-NAS Project will reduce the time to test concepts, technologies, and their interactions, interoperability, and integration. It will be capable of real/live, virtual, constructive, and hybrid mode operations to simultaneously operate in real and virtual traffic. SMART-NAS will enable assessments to demonstrate feasibility and benefits that could support a variety of NAS modernization decisions.

This research primarily aligns with the Real-Time System-Wide Safety Assurance strategic thrust area.

### **SAFE AUTONOMOUS SYSTEMS OPERATIONS (SASO)**

The SASO project will identify and develop the maximum possible autonomous capabilities to address the needs of future air transportation and airspace operations. In generations beyond NextGen, greater autonomy will be needed to enable high-performing future systems. Operational complexity will increase to enable and sustain significant growth in passengers and cargo. The goal is to seek the highest level of automation that is justifiable, not automation for automation's sake. The project will meet the need to manage the air transportation system so that it provides maximum efficiency and productivity, while ensuring a safe system where the total cost of operations for all users is affordable and sustainable. The justification will be based on performance needs, including but not limited to mobility, total cost of operation, scalability, flexibility, capacity, productivity, throughput, and the ability to manage mixed equipage. To enable such complex, prognostic decision-making, innovation will be required in the development of verification and validation methods for integrated, autonomous cyber-physical systems. All vehicle types and mixes of operations shall be accommodated (hub-and-spoke, point-to-point, on-demand, personal vehicles, commercial space launches, unmanned aerial vehicles, supersonic, hypersonic, etc.), and all air traffic management services and associated capabilities considered (strategic planning, trajectory and flight planning, airspace management, vehicle management, conflict/collision detection and avoidance, sequencing, spacing, scheduling, weather integrated decision-making, provision of user preferences, etc.).

This research primarily aligns with the Assured Autonomy for Aviation Transformation strategic thrust area.

## AIRSPACE OPERATIONS AND SAFETY PROGRAM

### Program Schedule

Date	Significant Event
Q1 FY 2015	ATD-1 – Simulation at the Air Traffic Control Lab using prototype En Route and Terminal systems with NASA software tools, and technology transfer to FAA
Q3 FY 2015	ATD-1 – Simulation at the FAA William J. Hughes Technical Center
Q4 FY 2015	Spot and Runway Departure Advisor operational field evaluation with an airline and airport partner and technology transfer to the FAA
Q4 FY 2016	Initial evaluation of one future scenario in the shadow-mode NextGen simulator
Q4 FY 2016	Develop initial automated traffic flow management strategies and algorithms for AutoMax to reduce delays under multiple weather possibilities
Q1 FY 2017	ATD-1 – Complete prototype avionics for use in airborne test of flight deck interval management capability
Q4 FY 2017	Evaluate and Demonstrate Advanced flight deck technologies to improve attitude and energy state awareness in a relevant environment

### Program Management & Commitments

Program Element	Provider
ATD	Provider: ARC, LaRC , AFRC, GRC Lead Center: ARC Performing Center(s): ARC, LaRC, DFRC, GRC Cost Share Partner(s): FAA, Honeywell, General Electric, Boeing, Raytheon, Rockwell Collins, Goodrich, Cessna Aircraft Co., American Airlines, United Airlines, EasyJet, Southwest Airlines, Commercial Aviation Safety Team (CAST), Department of Defense (DoD), ONERA
SMART-NAS	Provider: ARC, LaRC, AFRC, GRC Lead Center: ARC Performing Center(s): ARC, LaRC, AFRC, GRC Cost Share Partner(s): FAA, General Electric, American Airlines, United Airlines, Rockwell Collins , Boeing, CAST, DoD, easyJet, Honeywell, ONERA, Southwest Airlines
SASO	Provider: ARC, LaRC, AFRC, GRC Lead Center: ARC Performing Center(s): ARC, LaRC, AFRC, GRC Cost Share Partner(s): FAA, Boeing, General Electric, American Airlines, United Airlines, Rockwell Collins , CAST, DoD, Honeywell, ONERA

## AIRSPACE OPERATIONS AND SAFETY PROGRAM

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### **Acquisition Strategy**

AOSP spans research and technology from foundational research to integrated system capabilities. This broad spectrum necessitates the use of a wide array of acquisition tools relevant to the appropriate work awarded externally through full and open competition. Teaming among large companies, small businesses, and universities is highly encouraged for all procurement actions.

### **MAJOR CONTRACTS/AWARDS**

NASA's Aeronautics programs award multiple smaller contracts, which are generally less than \$5 million. They are widely distributed across academia and industry.

### **INDEPENDENT REVIEWS**

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Expert Review	Nov 2013	The 12-month review is a formal independent peer review. Experts from other Government agencies report on their assessment of technical and programmatic risk and/or program weaknesses.	Determined that satisfactory progress was made in meeting technical challenges. All annual performance indicators were met.	Nov 2014

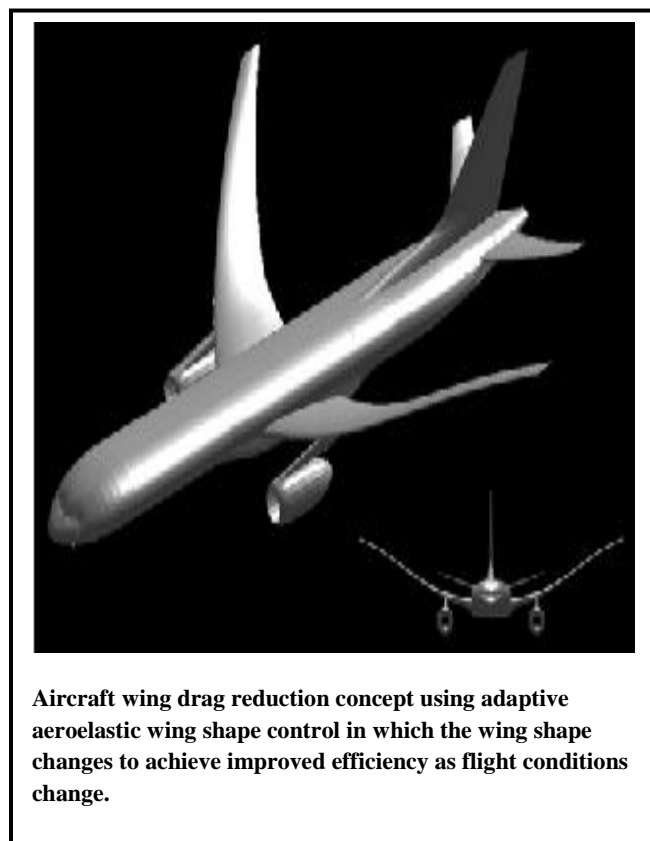
## ADVANCED AIR VEHICLES PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>0.0</b>	<b>--</b>	<b>213.6</b>	<b>211.4</b>	<b>205.8</b>	<b>203.3</b>	<b>205.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Advanced Air Vehicles (AAV) Program develops knowledge, technologies, tools, and innovative concepts to enable safe, new aircraft that will fly faster, cleaner, and quieter, and use fuel far more efficiently. The nation needs these aircraft as the country continues to experience growth in both domestic and international air transportation while needing to protect and preserve the environment. NASA research is inherent in every major modern U.S. aircraft, and the type of research performed by the AAV Program will prime the technology pipeline, enabling continued U.S. leadership, competitiveness, and jobs in the future. Technologies and design capabilities developed for these advanced vehicles will integrate multiple, simultaneous vehicle performance considerations including fuel burn, noise, emissions and intrinsic safety. Across the program, NASA will continue to engage partners from industry, academia, and other government agencies to maintain a sufficiently broad perspective on technology solutions to these challenges, to pursue mutually beneficial collaborations, and to leverage opportunities for effective technology transition.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

The Advanced Composites Project has been transferred from the Integrated Aviation Systems Program into this program, and the ground test portion of the Aeronautics Test Program portfolio is now the Aeronautics Evaluation and Test Capabilities project.

## **ADVANCED AIR VEHICLES PROGRAM**

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### **ACHIEVEMENTS IN FY 2013**

NASA expanded its work on characterization of emissions from alternative fuels with in-flight tests to measure gaseous and particulate emissions from aircraft engines burning alternative fuel. Researchers previously conducted tests on the ground but the FY 2013 Phase I in-flight tests provided the first opportunity to collect key data in flight at high, cruise-relevant altitudes and will help establish hydro-treated renewable jet fuel as a potentially carbon-neutral aviation fuel.

NASA continued to explore new propulsion capabilities including a better understanding of the viability of widely variable speed transmissions using a unique test facility at Glenn Research Center. The ability to significantly change rotor speed can lead to rotorcraft that are both faster and more efficient. Even though several countries are trying to accomplish this, it is a technology that has not yet been developed for manned rotorcraft. In addition, NASA also tested new drag reduction technologies that show potential for considerable fuel savings and increased payload capability simultaneously.

NASA delivered higher fidelity tools for prediction of sonic boom and drag that are suitable for low sonic boom supersonic aircraft design. These tools are needed to determine the shape of aircraft that will produce low boom signatures. To verify the accuracy of these tools, NASA completed wind tunnel experiments to compare experimental data to predictions. The predictions of the sonic boom compared well to the wind tunnel data, increasing the confidence in the prediction capabilities. In addition to improving the capability to design low-boom aircraft, NASA continued to perform experiments to improve understanding of how this low-boom signature will be heard on the ground. This is an important step for collecting data that could inform whether or not over-land supersonic flight is permitted in the future.

NASA developed and improved computational tools that are critical for new vehicle design. These tools include computational fluid dynamics and aircraft drag prediction methods using the latest high-performance computers and advanced modeling of airflow, combustion, and noise generation physics. These advances will lead to improved aircraft, engine, and combustor modeling, which will ultimately allow industry to have more confidence in the ability to accurately predict the performance of new and unusual designs. This capability helps ensure that U.S. industry maintains a competitive edge by exploring more advanced ideas than others and reducing the time it takes to develop new designs.

NASA conducted its first ground-based test of an engine operating in high ice water content icing conditions. During the test, NASA used a real engine known to be susceptible to degraded performance under these conditions. Being able to replicate these flight conditions represents a significant enhancement to the Propulsion Systems Laboratory at Glenn Research Center that has been under development for the past five years. The test duplicated an actual high altitude-icing event that occurred in a similar engine. Over time, the high ice water content icing conditions simulated in Propulsion Systems Laboratory will be validated by more extensive atmospheric data that do not currently exist. NASA expects that engine manufacturers will eventually be able to conduct tests in the laboratory that will support new FAA certification requirements for engines operating under these icing conditions.

NASA also aggressively addressed issues with data accuracy, data validation, and facility productivity at the National Transonic Facility at the Langley Research Center. Through focused efforts, data acquisition and facility measurement and control systems were scrutinized and improved so that high quality and repeatable research and testing data can be provided quickly and without interruption. These advancements will ensure that high Reynolds Number testing capabilities are available and productive to NASA and national programs.

## **ADVANCED AIR VEHICLES PROGRAM**

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### **WORK IN PROGRESS IN FY 2014**

To help demonstrate the benefits of new aircraft configurations and to understand the key challenges associated with these new concepts, NASA is conducting several investigations. To improve the efficiency of wings, NASA will conduct high-fidelity experimental and computational studies of a truss-braced wing configuration, which has very long, slender, and efficient wings supported by an additional brace. Research on these kinds of configurations may lead to significant reductions of fuel burn that may be available by moving beyond the tube-and-wing aircraft shape paradigm. NASA is also completing Phase 2 of the in-flight alternative fuel emissions tests. These flights build on preliminary flights conducted in FY 2013 and will include a wider set of data gathered from more instruments installed on the chase plane.

NASA will complete the assessment of new rotor control technologies by investigating two different concepts. Because it is rotating and creating a complex combination of multiple wakes, the rotor environment is one of the most difficult to understand compared to other air vehicles. New rotor control technologies have the potential to enable a significant leap ahead in modern rotor designs. To advance propulsion technologies, NASA is developing a new type of engine turbine capable of operating efficiently over a wide range of speeds. The variable-speed turbine research is targeted to increase speed, enhance fuel efficiency, and reduce noise for both conventional and advanced rotorcraft configurations.

The next critical steps in overcoming the barrier to overland supersonic flight are flight validation of advanced aircraft design tools and technologies combined with community overflight studies that measure a person's perceptions and responses to low-level sonic booms. The combination of these efforts would provide data that will inform future policy decisions associated with overland supersonic flight. NASA's high-speed effort focuses on ensuring the readiness of low-boom aircraft design tools and on the validation of study methodologies, survey tools, and test protocols required for community overflight studies as described above.

Aeronautics research will advance the capabilities and use of ceramic matrix composites to push the envelope on this material's ability to withstand high temperatures, while being strong and lightweight, which allows for the design of propulsion systems that are more efficient and effective. Work with Government and industrial partners will demonstrate the feasibility of incorporating these ceramic matrix composites into future aircraft engines and accelerate the introduction of their performance benefits into the fleet.

FY 2014 is the first year of execution for the Advanced Composites Project. During FY 2014, the project is pursuing partnerships with industry, academia, and other government agencies to expedite validation of advanced production, test, and analysis methods. FAA and NASA established a collaborative research effort to ensure the Advanced Composites Project will address FAA needs. The project will also initiate small-scale material and structures tests to acquire data to validate new analysis methods and determine new test protocols that will be shared with our partners in industry, academia, FAA, and other Government agencies.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In the Advanced Air Transport Technology Project, NASA will define the initial advanced engine core concept for achieving an overall pressure ratio of greater than 50 and bypass ratios greater than 20. Overall pressure ratio and bypass ratio are closely associated with fuel efficiency of the engine system.

## **ADVANCED AIR VEHICLES PROGRAM**

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This initial advanced engine core concept will include the effects of very small compressor and turbine blades combined with seals and other components to be proven to be effective at temperatures about 1,500 degrees Fahrenheit. The combination of these advancements, integrated into an initial engine core design, will lay important foundation for future jet engine systems that fully exploit the thermodynamic potential of such systems. NASA will also develop control laws necessary to utilize very long, slender, and flexible wings for increasing the efficiency of future aircraft. These control laws are necessary to manage the aerodynamic flutter associated with wings of this type. Flight test data from the X-56A, a remotely-piloted test aircraft leveraged through cooperation with the United States Air Force, will be a critical element in this effort. FY 2015 will also include the final report on the Alternative fuel effects on Contrails and Cruise Emissions (ACCESS) flight test results. The report will be the culmination of the efforts to characterize the atmospheric effects of available alternative jet fuels when emitted at cruise altitudes.

In the Revolutionary Vertical Lift Technology Project, NASA will complete the build of a key rotorcraft engine component, a power turbine capable of variable operational speeds. This technology, originating within NASA then picked up by industry and other Government agencies, will enable a turboshaft engine to operate efficiently over a wide range of speeds compared to current engine systems that only operate most efficient at one particular speed. The ability to efficiently vary engine speed allows future vertical lift vehicles to fly more efficiently at higher speeds by having better control of the operation of the main rotor since it is driven by the turboshaft engine.

In the High Speed Project, NASA will complete delivery of the high fidelity tools for prediction of sonic boom and drag that are suitable for low sonic boom supersonic aircraft design. These prediction tools will enable the design of a supersonic aircraft with a low boom signature across the full, affected land area (carpet) below the flight path and low levels of prediction uncertainty associated with atmospheric and cruise conditions. These tools are needed to determine the shaping for aircraft that will produce low boom signatures. This is an important step for collecting data that could inform whether or over-land supersonic flight is permitted in the future.

In the Advanced Composites Project, NASA will develop high fidelity predictive tools that could replace physical tests and reduce the number of years in the certification process. The first step in the process is to compare experimental testing with state of the art predictions. In FY 2015, the project will complete the first level of building-block tests. These are a series of tests that increase in complexity and help develop an understanding of how test articles respond through experimentation and analysis. The first level of building-block tests validates the computer simulations of failure initiation and progression conducted using the improved physics-based algorithms. The first level building-block test articles will include a variety of test specimens with basic features necessary to address geometry and loading complexities when subjected to static, dynamic, and fatigue loading. The deliverable will be a report describing the correlation of state of the art analysis predictions and the building-block testing.

In the Aeronautics Evaluation and Test Capabilities Project, NASA will complete the delivery of improvements to the Unitary Plan Wind Tunnel (UPWT) at the NASA Ames Research Center to add new non-intrusive measurement capabilities and techniques. These improvements include improved test section optical access for each leg of the UPWT, new Schlieren-grade section windows, and quicker installation of Pressure Sensitive Paint, Infrared Thermography, Particle Image Velocimetry, Model Deformation, and other advanced optically-based techniques.



## **ADVANCED AIR VEHICLES PROGRAM**

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These capabilities and techniques will be necessary to enable efficient and effective research and development for future air vehicles and to provide better integration with complementary high-end computing capabilities for advance aerodynamic analyses. Additionally, utilizing new engine icing test capabilities at the Glenn Research Center, NASA will develop a computational tool to estimate ice accretion on engine components for engines operating in ice-crystal conditions, based on integrating mixed-phase flow and heat transfer modules. Predicted ice accretion locations within the engine and accretion rates will be compared to results from the tests. Simulation deficiencies will be identified.

### **Program Elements**

#### **ADVANCED AIR TRANSPORT TECHNOLOGY**

NASA's vision for advanced fixed wing transport aircraft is to enable revolutionary advances in energy efficiency and environmental compatibility of these future generations of aircraft. These technological solutions are critical to reduce the impact of aviation on the environment even as this industry and the corresponding global transportation continue to grow. Research will explore and advance knowledge, technologies, and concepts to enable giant steps in energy efficiency and environmental compatibility resulting in less fuel burned and less direct impact on the atmosphere. This program will identify potential new safety considerations associated with these advanced technologies and concepts. This critical research helps the sustained growth of commercial aviation that is so vital to the U.S. economy and our quality of life. The knowledge gained from this research, in the form of experiments, data, system studies and analyses, is critical for conceiving and designing more efficient, quieter, and greener aircraft. Advanced air transport research is focused on the future, with an eye towards the N+3 generation, targeting vehicles that are three generations beyond the current state-of-the-art (generation N) and requiring mature technology solutions in the 2025 to 2030 timeframe.

#### **REVOLUTIONARY VERTICAL LIFT TECHNOLOGY**

NASA's vision for vertical lift vehicles includes enabling their unique capabilities to greatly benefit the Nation's civil flight capabilities. The ability to leverage vertical flight and hover, with vastly improved noise, efficiency, and safety, has potential to lead to new missions and markets affecting human and cargo transportation and delivery, increased safety and security in constrained landscapes, and sustained and effective surveillance for natural and manmade disasters. The NASA rotary wing research develops and validates tools, technologies and concepts to overcome key barriers, including noise, efficiency, and safety, for rotorcraft vehicles. The research advances technologies that increase rotorcraft speed, range and payload, and decrease noise, vibration, fuel burn and emissions. Further, this research will enable improved computer-based prediction methods, technologies, and concepts for future high-speed, efficient rotorcraft of various sizes and configurations that will be viable as commercial vehicles operating in the NAS. This will greatly enhance and expand the missions unique to rotorcraft.

#### **HIGH SPEED**

High speed vehicle research includes tools, technologies, and knowledge that will help eliminate today's technical barriers to practical, commercial supersonic flight. These barriers include: sonic boom;

## **ADVANCED AIR VEHICLES PROGRAM**

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supersonic aircraft fuel efficiency; airport community noise; high altitude emissions; prediction of vehicle control, operation, and performance; and the ability to design future vehicles in an integrated, multidisciplinary manner. Research conducted will establish the necessary approaches and techniques for objectively measuring (assessing) the levels of sonic boom acceptable to communities living in the vicinity of future commercial supersonic flight paths. These approaches, techniques, and resulting data will inform both national and international regulatory organizations that set the standards for commercial entities and vehicles to achieve. The research also lays the groundwork for overcoming other challenges facing commercial supersonic flight including energy efficiency, reduced pollutants emitted into the atmosphere, and acceptable engine noise levels in the airport area.

### **ADVANCED COMPOSITES**

NASA is addressing new test protocols and methods to reduce the development and certification timeline for composite materials and structures. It is inevitable that composite structures will see increased application due to the pressure to develop more efficient, sustainable vehicles. The present approach for the development and certification of composites is primarily based on testing. It is time-consuming, and expensive but does provide results that have been rigorously validated. NASA will focus on the development and use of high fidelity and rigorous computational methods, improved test protocols, and standardized inspection techniques to shorten the timeline to bring innovative composite materials and structures to market. NASA will engage key players from Government (FAA and DoD), industry, and academia to mature and verify the methodology, to ensure effective transition to industry, and to assure safety for certification authorities such as the FAA. To achieve the goal of reducing the current 10 to 20 year timeline for development and certification down to five years, NASA will:

- Develop analytical methods and rapid-design tools to reduce structural design cycle time and testing effort during development and certification;
- Develop quantitative and practical inspection methods, data management methods, models, and tools that will increase inspection throughput phases; and
- Develop process models to predict defects that occur in automated manufacturing, improve quality control for co-bond and co-cured interfaces, joints, and discontinuities, and develop cure process models to prevent defect formation during matrix cure.

### **AERONAUTICS EVALUATION AND TEST CAPABILITIES**

The research and test capabilities (both test and analysis assets) necessary to achieve the future air vehicles and operations described above require efficient and effective investment, use, and management. Efforts in this area preserve and enhance those specific research and test capabilities that are necessary to achieve the missions. Among these assets are subsonic, transonic, supersonic, and hypersonic wind tunnels and propulsion test facilities at Ames Research Center, Glenn Research Center, and Langley Research Center. Other NASA-unique test facilities and capabilities critical to the Nation may also be included. This integrated approach to asset planning, use, and management will consider the complementary high-end computing capabilities necessary for advanced analyses in conjunction with the ground experimentation capabilities. Furthermore, it includes the NASA expertise that helps ensure safe and successful use of the assets and high quality of the research outcomes.

## ADVANCED AIR VEHICLES PROGRAM

### Program Schedule

Date	Significant Event
Sep 2015	Integrated analysis of advanced, candidate compact core engine architectures and component technologies contributing to bypass ratio 20+ gas turbine propulsion systems.
Sep 2015	Complete tools for designing efficient, low-boom-capable supersonic commercial aircraft including consideration of all supersonic flight conditions.
Sep 2015	Complete test section improvements in the ARC Unitary Plan Wind Tunnel including advanced capabilities and test techniques such as improved test section optical access and critical optically-based test techniques (new Schlieren-grade section windows, quicker installation of Pressure Sensitive Paint, Infrared Thermography, Particle Image Velocimetry and Model Deformation).
Sep 2015	Complete the replacement of the data acquisition system at the LaRC Transonic Dynamics Tunnel to enable world-class dynamic data capabilities including higher reliability, bandwidth, channel count, processing rates, analyses, and plotting.
Sep 2015	Develop a computer-based simulation tool that will calculate the ice accretion on internal engine components. Results of code calculations will be compared to test results obtained from actual engines running in the engine icing test facility.
Sep 2016	Integrated analysis of advanced, candidate technologies contributing to a 1.5-2 times increase in optimal wing aspect ratio including consideration of aerodynamic and structural efficiency.
Sep 2016	Complete component testing of a variable speed power turbine with potential to greatly improve turboshaft engine efficiency over a wide operating range.
Sep 2016	Modify and validate an aircraft icing prediction code specifically for swept wing ice accretion simulation. Computational model will include physics unique to swept wing flows and ice growth.

### Program Management & Commitments

Program Element	Provider
Advanced Air Transport Technology	<p>Provider: ARC, GRC, LaRC, AFRC</p> <p>Lead Center: GRC</p> <p>Performing Center(s): ARC, GRC, LaRC, AFRC</p> <p>Cost Share Partner(s): US Air Force, Boeing, Pratt &amp; Whitney, Northrop Grumman, General Electric Aviation, United Technologies Corporation, Rolls Royce/Liberty Works, Honeywell, FAA ONERA, DLR, JAXA, Lockheed Martin, Cessna, US Navy, US small business and universities</p>

## ADVANCED AIR VEHICLES PROGRAM

Program Element	Provider
Revolutionary Vertical Lift Technology	Provider: ARC, GRC, LaRC Lead Center: LaRC Performing Center(s): ARC, GRC, LaRC Cost Share Partner(s): Boeing, United Technologies Research Center, US Army, Vertical Lift Consortium (VLC), Bell Helicopter Textron, Sikorsky Aircraft, Rolls Royce/Liberty Works, GE, Pratt and Whitney, FAA, ONERA, DLR, NLR, US Navy, US small businesses and universities
High Speed	Provider: ARC, GRC, LaRC, AFRC Lead Center: LaRC Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): Boeing, Pratt & Whitney, General Electric Aviation, Rolls Royce/Liberty Works, Gulfstream Aerospace, United Technologies Corporation, US Air Force, FAA, JAXA, Lockheed Martin, Aerion Corporation, US Navy, US small businesses and universities
Advanced Composites	Provider: ARC, GRC, LaRC Lead Center: LaRC Performing Center(s): GRC, LaRC Cost Share Partner(s):
Aeronautics Evaluation and Test Capabilities	Provider: ARC, GRC, LaRC, AFRC Lead Center: TBD Performing Center(s): ARC, , GRC, LaRC, AFRC Cost Share Partner(s): The Boeing Company, CAST, DoD, Environment Canada, FAA, Honeywell, INTA (Instituto Nacional de Técnica Aeroespacial), JPDO, National Research Council Canada, ONERA

### Acquisition Strategy

NASA's Advanced Air Vehicles Program spans research and technology from foundational research to integrated system capabilities. This broad spectrum necessitates the use of a wide array of acquisition tools relevant to the appropriate work awarded externally through full and open competition. Teaming among large companies, small businesses, and universities is highly encouraged for all procurement actions.

### MAJOR CONTRACTS/AWARDS

NASA's Aeronautics programs award multiple smaller contracts that are generally less than \$5 million. They are widely distributed across academia and industry.

## ADVANCED AIR VEHICLES PROGRAM

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Expert Review	Nov 2013	The 12-month review is a formal independent peer review. Experts from other Government agencies report on their assessment of technical and programmatic risk and/or program weaknesses.	Determined that satisfactory progress was made in meeting technical challenges. All annual performance indicators were met or justifiably eliminated.	Nov 2014

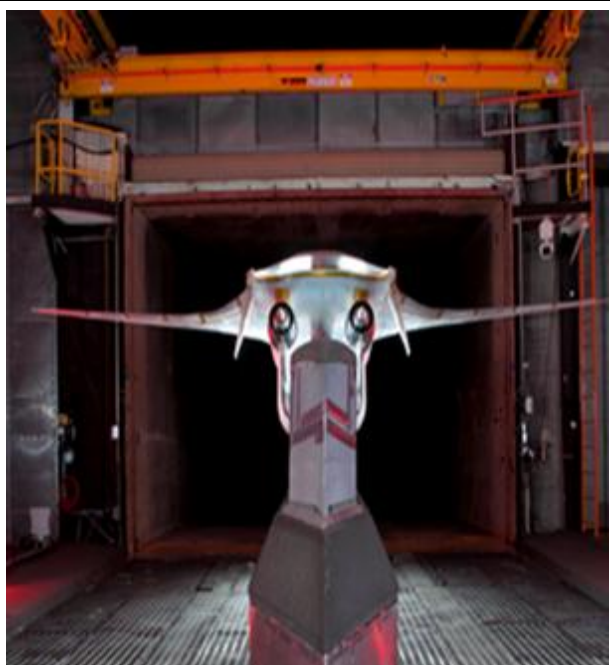
## INTEGRATED AVIATION SYSTEMS PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>0.0</b>	<b>--</b>	<b>127.0</b>	<b>125.8</b>	<b>128.0</b>	<b>133.4</b>	<b>134.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Hybrid Wing Body (HWB) Model with Compact Jet Simulators in Langley's 14x22 Wind Tunnel in support of the HWB Community Noise Experiment. This provided high-quality acoustic and aerodynamic data to assess the NASA/ERA noise reduction goal for an HWB aircraft.**

One of the greatest issues that NASA faces in transitioning advanced technologies into future aeronautics systems is the gap caused by the difference between the maturity level of technologies developed through fundamental research and the maturity required for technologies to be infused into future air vehicles and operational systems. Integrated Aviation Systems Program's (IASP) goal is to demonstrate integrated concepts and technologies to a maturity level sufficient to reduce risk of implementation for stakeholders in the aviation community. The research in this program is coordinated with ongoing, long-term fundamental research within the other three aeronautics research programs, as well as efforts of other government agencies. This helps to ensure the transition of the most promising research between the fundamental research programs and IASP. IASP conducts integrated system-level research on those promising concepts and technologies to explore, assess, and demonstrate the benefits in an operationally relevant environment. IASP matures and integrates technologies for accelerated transition to practical application.

NASA will make significant technology advancements contributing to national aviation challenges through the IASP portfolio. IASP consists of three projects, the Environmentally Responsible Aviation (ERA) Project, the UAS Integration in the National Airspace System (NAS) Project and the Flight Demonstrations and Capabilities Project (FDC).

## **INTEGRATED AVIATION SYSTEMS PROGRAM**

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One of the national challenges that IASP is focused on is the impact of aviation on the environment. In 2008, U.S. major commercial carriers and Department of Defense (DOD) burned 19.6 billion<sup>1</sup> and 4.6 billion<sup>2</sup> gallons, respectively. This fuel consumption released 250 million tons of carbon dioxide into the atmosphere. Additionally, aircraft noise, particularly in the vicinity of airports, continues to be regarded as the most significant hindrance to the NAS capacity growth. The Environmentally Responsible Aviation Project goal is to reduce the impact of aviation on the environment through the development of vehicle concepts and technologies that can simultaneously reduce aircraft fuel burn, noise, and emissions. Using aircraft system-level assessments in addition to ground and flight tests, the project is evaluating promising vehicle configurations and airframe and propulsion system related technologies to assess the combined potential to simultaneously meet challenging fuel burn, emission, and noise reduction goals.

Another national challenge that IASP is addressing is the routine access of UAS into the NAS for civil use. Historically, UAS have supported military and security operations overseas, with training occurring primarily in the United States. In addition, UAS are utilized in U.S. border and port surveillance by the Department of Homeland Security, scientific research, and environmental monitoring by NASA and NOAA, public safety by law enforcement agencies, research by state universities, and various other uses by Government agencies. Interest is growing in civil uses, including commercial photography, aerial mapping, crop monitoring, advertising, communications, and broadcasting. To address the increasing civil market and the desire by civilian operators to fly UAS, the FAA is developing new policies, procedures, and approval processes. The need for developing and implementing new standards, procedures, and guidance to govern civil UAS operations in the NAS in a timely manner has grown more important than ever. NASA's UAS Integration in the NAS Project will contribute capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine civil UAS access to the NAS. Advancing the state of the art is being accomplished through system-level integration of key concepts, technologies, and/or procedures, and demonstrations of integrated capabilities in an operationally relevant environment. Close integration and continued validation with key stakeholders (FAA, DOD, other Government agencies and industry) is a guiding tenet of the project.

NASA's Flight Demonstrations and Capabilities Project will focus on innovation and flexibility, which is consistent with the ARMD strategic plan, program/project activities, other NASA mission directorate activities, and national strategic needs.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The Advanced Composites Project has been transferred into the Advanced Air Vehicles Program. The flight test portion of the former Aeronautics Test Program was incorporated as the new Flight Demonstrations and Capabilities Project within this program.

### **ACHIEVEMENTS IN FY 2013**

FY 2013 was the start of Phase 2 for the Environmentally Responsible Aviation Project. During FY 2013 NASA completed community noise assessments for advanced tube and wing, and hybrid wing body

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<sup>1</sup> Research and Innovative Technology Administration, Bureau of Transportation Statistics, U.S. Department of Transportation website: <http://www.rita.dot.gov/bts>

<sup>2</sup> "Department of Defense Fuel Spending, Supply, Acquisition, and Policy", September 22, 2009

## **INTEGRATED AVIATION SYSTEMS PROGRAM**

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aircraft configurations and engines. NASA demonstrated synergistic acoustic integration between advanced engines and airframe concepts that will enable the goal of 42 decibel cumulative noise reduction below Stage 4 in the 2020 timeframe. In addition, NASA completed ground-based testing of a second generation Geared Turbofan propulsion technology (an Ultra High Bypass engine concept) in partnership with Pratt & Whitney. This assessment quantifies increases in propulsive system efficiency and noise reduction available from this propulsion system technology.

NASA continued to make progress on UAS integration through initial evaluations and risk reduction activities of the project's operationally relevant environment. The relevant environment provided the infrastructure to enable the human-in-the-loop simulations and flight tests required to demonstrate integrated separation assurance, human systems integration, and communication efforts. In addition, NASA conducted simulations that assessed the performance of aircraft separation assurance methods and developed communication models for all classes of UAS. These validated communication models are required to provide confidence in simulation results. Finally, NASA provided recommendations to the FAA for risk-related data collection to support development of UAS regulations.

### **WORK IN PROGRESS IN FY 2014**

NASA plans to complete flight tests on its G-III aircraft of a wing design equipped with adaptive compliant trailing-edge technology. Integration of compliant structures in next generation aircraft will reduce weight and drag contributing to a reduction of fuel burn. The flight test will demonstrate and establish airworthiness for a compliant structure used as large primary control surface in a relevant flight environment and accelerate the infusion of this technology. In addition, NASA will continue to advance Ultra High Bypass technology through low speed ground tests of the geared turbofan performed in FY 2014. NASA will also complete low-speed performance and operability testing of an UHB engine integrated with a semi-span HWB model. This test, planned for FY 2014, will provide a low-speed assessment of the interference effects between the propulsion system and airframe that could impact engine operation, aerodynamic characteristics, and drag (fuel burn).

NASA will evaluate concepts for separation assurance, sense and avoid, and ground control stations with communication system performance estimates through an integrated human-in-the-loop simulation in FY 2014 to provide data for further technology development. In addition, the project will continue to mature and evaluate the Live Virtual Constructive Distributed Environment that will be used to provide demonstrations of UAS integrated in the National Airspace System. The demonstrations will utilize unique flight and simulation assets from geographically dispersed facilities by integrating NASA Centers, FAA facilities and other institutions through the Live Virtual Constructive Distributed Environment.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

FY 2015 marks the end of Phase 2 and the final year of execution for the Environmentally Responsible Aviation Project. NASA plans to successfully complete each of the eight integrated technology demonstrations, and achieve its mission as it closes out the ERA Project by the end of the fiscal year. At the end of FY 2015, NASA will show the impact of development and analysis of vehicle concepts with the appropriate technology suite to simultaneously meet subsonic transport goals associated with fuel burn, community noise, and Landing and Take-off Nitrogen Oxides in the 2020-2025 timeframe.



## **INTEGRATED AVIATION SYSTEMS PROGRAM**

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NASA will deliver data, analysis, and recommendations based on an integrated flight test series with simulated airspace/traffic and a live vehicle to inform development of preliminary performance standards by the RTCA Special Committee on Minimum Performance Standards for UAS.

Also in FY 2015, NASA's goal is to embed flight research throughout all research phases based on the aeronautics research community strategic needs. In addition, NASA will implement Automatic Dependent Surveillance-Broadcast (ADS-B) capability on all the flight test support aircraft to enable the testing of operational design solutions that enable safe, efficient growth in global operations.

### **Program Elements**

#### **ENVIRONMENTALLY RESPONSIBLE AVIATION**

NASA is addressing vehicle related environmental concerns through system-level research and experiments of promising vehicle concepts and technologies that simultaneously reduce fuel burn, noise, and emissions. Research and development efforts are focused on understanding how advanced environmental technologies can best work in an integrated vehicle/aviation operations system. Through system-level analysis, promising advanced vehicle and propulsion concepts and technologies can be down-selected based on their potential benefit towards the stated national goals. Among the technologies to be explored are the following:

- Advanced aircraft architectures that enable simultaneous reduction of noise, fuel burn, and environmentally harmful emissions;
- Advanced propulsion systems for low noise and reduced fuel burn;
- Lightweight, low drag wing and fuselage concepts for reduced fuel burn and noise;
- Fuel flexible, low nitrogen oxide combustor designs; and
- Optimized propulsion/airframe integration concepts for reduced fuel burn and noise.

This research is primarily aligned with the Ultra-Efficient Commercial Transport strategic thrust area.

#### **UNMANNED AIRCRAFT SYSTEMS (UAS) INTEGRATION IN THE NATIONAL AIRSPACE SYSTEM (NAS)**

NASA also focuses on technologies to enable routine civil operations for UAS of all sizes and capabilities in the NAS. Current Federal Aviation Regulations are built upon the condition of a pilot being in the aircraft; therefore many of those regulations are not directly applicable to UAS. To date, the primary user of UAS has been the military. As the UAS user base expands, the technologies and procedures to enable seamless operation and integration of UAS in NAS need to be developed, validated, and employed by FAA through rule-making and policy development.

Specifically, NASA is addressing technology development in several areas to reduce the technical barriers related to the safety and operational challenges. The technical barriers include:

## INTEGRATED AVIATION SYSTEMS PROGRAM

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- Robust separation assurance algorithms;
- Command and control, and air traffic control communication systems;
- Consistent standards to assess UAS ground control stations; and
- Airworthiness requirements for the full range of UAS size and performance.

NASA will validate data and technology through a series of high-fidelity human-in-the-loop simulations (i.e., where a human is part of the simulation and influences the outcome) and flight tests conducted in a relevant environment. Integrated test and evaluation will be conducted focusing on three technical challenges: separation assurance, performance standards and certification, and developing a relevant test environment. The project deliverables will help key decision makers in government and industry make informed decisions, leading towards routine UAS access.

This research aligns with the Assured Autonomy for Aviation Transformation strategic thrust area.

### FLIGHT DEMONSTRATIONS AND CAPABILITIES (FDC)

NASA's FDC Project consists of an integrated set of flight test capabilities and demonstrations. The flight test capabilities include the Western Aeronautical Test Range, and the aircraft required to support research flight tests and mission demands. The project capabilities also include the Armstrong Flight Research Center (AFRC) Simulation and Flight Loads Laboratories, which include a suite of ground-based laboratories that support flight research and mission operations. FDC's capabilities support the flight research needs across the ARMD programs and projects. NASA will demonstrate the feasibility and maturity of new technologies through flight tests, utilizing collaborative partnerships from across the aeronautical industry, and including international partners as appropriate.

These activities support research within all six aeronautics strategic thrust areas.

### Program Schedule

Date	Significant Event
Q1 FY 2015	Completion of Build 1 Test
Q2 FY 2015	Complete Multi-Sector Rig Test 2
Q3 FY 2015	Completion of Build 2 Test
Q3 FY 2015	Completion of all testing of Multi-Bay Box (Removing Box from Pit)
Q3 FY 2015	System level assessment of propulsion induced effects on vehicle performance
Q4 FY 2015	Conduct flight evaluations of Separation Assurance, Human Systems Integration, and Command and Control concepts employing multiple live aircraft

## INTEGRATED AVIATION SYSTEMS PROGRAM

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### **Program Management & Commitments**

Program Element	Provider
Environmentally Responsible Aviation	Provider: ARC, AFRC, GRC, LaRC Lead Center: LaRC Performing Center(s): ARC, AFRC, GRC, LaRC Cost Share Partner(s): Boeing, General Electric, Pratt & Whitney, Air Force Research Laboratory, FAA, Gulfstream, Goodrich, Rolls Royce Liberty Works
Unmanned Aircraft Systems Integration in the National Airspace System	Provider: ARC, AFRC, GRC, LaRC Lead Center: AFRC Performing Center(s): ARC, AFRC, GRC, LaRC Cost Share Partner(s): Rockwell Collins, FAA
Flight Demonstrations and Capabilities	Provider: AFRC, LaRC Lead Center: AFRC Performing Center(s): AFRC, LaRC Cost Share Partner(s): DoD

### **Acquisition Strategy**

NASA's Integrated Aviation Systems Program develops and further matures promising technologies to the integrated system level. This necessitates the use of a wide array of acquisition tools relevant to the appropriate work awarded externally through full and open competition. Teaming among large companies, small businesses, and universities is highly encouraged for all procurement actions.

### **MAJOR CONTRACTS/AWARDS**

NASA's Aeronautics programs award multiple smaller contracts, which are generally less than \$5 million. They are widely distributed across academia and industry.

## INTEGRATED AVIATION SYSTEMS PROGRAM

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Annual Performance	Independent Review Panel	December 2013	The 12-month review is a formal independent peer review. Experts from other government agencies report on their assessment of technical and programmatic risk and/or program weaknesses.	Determined that satisfactory progress was made in meeting technical challenges. All annual performance indicators were met.	December 2014
Relevance	Expert Panel	December 2012	Periodic reviews are carried out by the U.S. users of IASP flight test facilities. The last major community outreach meeting was held in December 2012 with NASA, DoD, and U.S. aerospace industry users at the ARC.	Received industry feedback on how to improve operations, identify future capabilities, and develop relationships.	May 2014

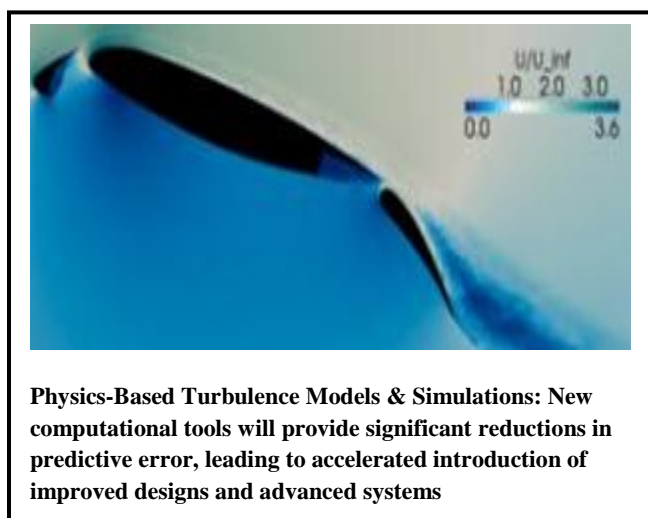
## TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>0.0</b>	<b>--</b>	<b>79.5</b>	<b>86.8</b>	<b>93.8</b>	<b>95.2</b>	<b>96.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The Transformative Aeronautics Concepts (TAC) Program cultivates multi-disciplinary, revolutionary concepts to enable aviation transformation. ARMD's strategic analysis identified challenges in the global demand for mobility, significant energy and sustainability changes, and on-going affordability issues, for which technology can be a key part of the solutions. The TAC Program harnesses convergence in aeronautics and non-aeronautics technologies to solve these problems for the future and to create new opportunities in aviation. The ultimate goal of the program is to knock down technical barriers and infuse internally and externally originated concepts into all six strategic research thrusts identified

by ARMD, creating innovation for tomorrow in the aviation system.

Using sharply focused activities, the program provides flexibility for innovators to explore technology feasibility and provide the knowledge base for radical transformation. The program solicits and encourages revolutionary concepts, creates the environment for researchers to become immersed in trying out new ideas, performs ground and small-scale flight tests, allows failures and learns from them, and drives rapid turnover into new concepts. Further, the TAC Program places attention on computational and experimental tools that are critical for supporting development and enabling aviation transformation by investing in never-done-before developments that can provide paradigm-shifting analysis and experimental capability. All of this research is done while aggressively engaging the traditional aeronautics community as well as broader, non-traditional partners.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

This program did not exist prior to FY 2015. There are no changes from FY 2014.

## **TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM**

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### **ACHIEVEMENTS IN FY 2013**

This program is new in FY 2015.

### **WORK IN PROGRESS IN FY 2014**

This program is new in FY 2015.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

NASA will complete specific activities in the Convergent Aeronautics Solutions (CAS) Project that started in the previous Aviation Safety Program where NASA provides research solutions in a unique role as a member of an aviation community partnership. Specific knowledge to support the understanding and mitigation of current and future aviation hazards is provided in such initial areas as remote ice-sensing technologies, diagnosis and mitigation of lightning hazards, and the detection and diagnosis of life-limiting faults in off-nominal turbine engine operation. During FY 2015, NASA will assemble data in support of algorithms used in ground-based sensors systems that support the needs of the aviation community to provide terminal area icing weather information. NASA will also complete a conceptual design for an advanced sensing system, which provides not only the required lightning protection, but also can provide damage diagnosis in composite structures. Finally, in cooperation with its community partners, NASA will demonstrate diagnostics systems to detect faults between major inspections in an engine test.

NASA's Airspace Systems Program hosted an all-stakeholders' workshop in FY 2014 to define the functional requirements of a low-altitude, civilian application of UAS, and the corresponding air traffic management system called UAS Traffic Management (UTM). To assess feasibility of UTM, NASA will begin FY 2015 activities in the CAS Project focused on developing an initial prototype, and conducting simulations to validate design requirements. The goal of UTM is to enable safe and efficient low-altitude airspace operations for new aviation opportunities for goods delivery, infrastructure surveillance, agricultural support, search and rescue, and medical services delivery by providing critical airspace management services.

NASA will continue development of next-generation, high-performance, computational methods and tools that have the potential to dramatically reduce the cost and error in simulation of complex turbulent flows. In FY 2015 the Revolutionary Tools and Methods (RTM) Project will document turbulence prediction results obtained using advanced models for standard test cases involving flow separation and other challenging flows not well-predicted by current methods.

NASA will continue funding new research ideas through both the external Leading Edge Aeronautics Research (LEARN) fund as well as follow-on phases of promising research for NASA employees and selected external LEARN awards. NASA will evaluate the most promising ideas for incorporation into the existing programs.

## **TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM**

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### **Program Elements**

#### **CONVERGENT AERONAUTICS SOLUTIONS**

The Convergent Aeronautics Solutions (CAS) Project uses short-duration activities to establish early-stage concept and technology feasibility for high-potential solutions. Internal teams propose ideas for overcoming key barriers associated with large-scale aeronautics problems associated with ARMD's six strategic thrusts. The focus is on merging traditional aeronautics disciplines with advancements driven by the non-aeronautics world to advance innovative solutions to these barriers to open and enable new capabilities in commercial aviation. The teams will conduct initial feasibility studies, perform experiments, try out new ideas, identify failures, and try again. At the end of the cycle, a review determines whether the developed solutions have met their goals, established initial feasibility, and identified potential for future aviation impact. During these reviews, the most promising capabilities will be considered for continued development further by other ARMD programs or by direct transfer to the aviation community. In the dynamic environment of new ideas, ARMD also gains significant value from the knowledge gained in activities that do not proceed.

One initial activity that will be piloted in CAS is related to low-altitude civilian applications of UAS, which have been imagined for goods delivery, infrastructure surveillance, agricultural support, search and rescue, and medical services delivery. In order to explore the concept's feasibility, CAS will study a system concept called UAS Traffic Management (UTM). The goal of UTM is to enable safe and efficient low-altitude airspace operations by providing critical services such as airspace design, separation management, weather avoidance, routing, and contingency management. UTM will support UAS ranging from those with minimal avionics capability, to those that are autonomous, and allow safe operations in presence of current vehicles (e.g., gliders, general aviation, helicopters).

#### **REVOLUTIONARY TOOLS AND METHODS**

The Revolutionary Tools and Methods (RTM) Project advances state-of-the-art computational and experimental tools that are vital to aviation applications in the six strategic thrusts. The project develops new computer-based tools, models, and associated scientific knowledge that will provide first-of-a-kind capabilities to analyze, understand, and predict performance for a wide variety of aviation concepts. These revolutionary tools will be applied to accelerate NASA's research and the community's design and introduction of advanced concepts. Examples include the development and validation of new computational tools that are used to predict the complex turbulent airflow around vehicles and within propulsion systems, ultimately leading to greater abilities to predict future vehicle performance in flight. Another important area of research, applicable across a number of air vehicle types, is the understanding of new types of strong and lightweight materials that are vital to aviation. The RTM Project also focuses on revolutionary experimental methods to support and enable concept development and benefits assessment across multiple ARMD programs and disciplines.

#### **LEADING EDGE AERONAUTICS RESEARCH FOR NASA (LEARN)**

The LEARN Project explores the creation of novel concepts and processes with the potential to create new capabilities in aeronautics research through awards to university and industry teams. The LEARN Project incorporates a competitive review process of the external teams' proposals to develop integrated

## TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

solutions for complex technical problems captured in the ARMD strategic thrusts, followed by short duration activities for feasibility assessment. Follow-on phases of the most promising ideas are also funded. With this process, NASA funds also help catalyze external investments toward solving problems aligned with NASA interests. Like the CAS Project, the LEARN Project's goal is to identify and mature the new concepts and then infuse promising concepts into the ARMD research portfolio for further development or enable new avenues of aeronautics in the community. Developing new ideas – whether they originate within or external to NASA – are a critical part of NASA Aeronautics' approach to enabling transformation in aviation.

### Program Schedule

Date	Significant Event
Q2 FY 2014	Aeronautics Seedling Fund, Round 4 Awards
Q2 FY 2014	Leading Edge Aeronautics Research for NASA, Round 2 Awards
Q2 FY 2014	Leading Edge Aeronautics Research for NASA, Round 1 Further Study Awards
Q3 FY 2014	Aeronautics Seedling Fund, Round 3 Further Study Awards
Q4 FY 2014	Leading Edge Aeronautics Research for NASA, Round 3 Awards
Q1 FY 2015	Initial call for CAS proposals from internal teams on large-scale aeronautics problems important to ARMD.
Q2 FY 2015	Aeronautics Seedling Fund, Round 4 Further Study Awards
Q2 FY 2015	Leading Edge Aeronautics Research for NASA, Round 2 Further Study Awards
Q3 FY 2015	Leading Edge Aeronautics Research for NASA, Round 4 Awards

### Program Management & Commitments

Program Element	Provider
Convergent Aeronautics Solutions	Provider: ARC, GRC, LaRC, AFRC Lead Center: TBD Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): TBD
Revolutionary Tools and Methods	Provider: ARC, GRC, LaRC, AFRC Lead Center: TBD Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): TBD



## TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

### Acquisition Strategy

The research conducted through Transformative Aeronautics Concepts activities will use a wide array of acquisition tools relevant to the research objectives including external solicitations through full and open competitions.

### MAJOR CONTRACTS/AWARDS

The Transformative Aeronautics Concepts Program awards smaller contracts, which are generally less than \$1 million.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	ARMD Mission Program and External Expert	Feb 2014	Review of completed LEARN and internal seedling Further Study Activities to determine whether they have met their goals and identified potential for future impact.	Expected result to be identification of successful activities and their potential for continued development by other ARMD programs or external entities.	Sep 2015
Performance	ARMD Mission Program Directors	No previous review	Review of initial, completed CAS Project activities to determine whether they have met their goals, established initial feasibility, and identified potential for future aviation impact.	Expected result is the identification of the promising capabilities for further development by other ARMD programs or for direct transfer to the aviation community.	Nov 2016
Performance	Expert Review	No previous review	The 12-month review is a formal independent peer review. Experts from other Government agencies report on their assessment of technical and programmatic risk and/or project weaknesses.	Expected result to be recommendations for relevance, quality, and programmatic performance improvement.	Nov 2015

## SPACE TECHNOLOGY

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Partnership Development and Strategic Integration	28.8	--	<b>33.8</b>	33.7	33.7	33.9	33.9
SBIR and STTR	165.4	--	<b>190.7</b>	200.9	212.1	212.1	212.1
Crosscutting Space Tech Development	247.3	--	<b>256.6</b>	190.1	185.9	198.5	203.5
Exploration Technology Development	173.0	--	<b>224.5</b>	287.9	288.0	282.4	284.7
<b>Total Budget</b>	<b>614.5</b>	<b>576.0</b>	<b>705.5</b>	<b>712.6</b>	<b>719.7</b>	<b>726.9</b>	<b>734.2</b>

### Space Technology ..... TECH-2

PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION ..... TECH-8  
 SBIR AND STTR ..... TECH-14  
 CROSSCUTTING SPACE TECH DEVELOPMENT ..... TECH-21  
 EXPLORATION TECHNOLOGY DEVELOPMENT ..... TECH-37

# SPACE TECHNOLOGY

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Partnership Development and Strategic Integration	28.8	--	<b>33.8</b>	33.7	33.7	33.9	33.9
SBIR and STTR	165.4	--	<b>190.7</b>	200.9	212.1	212.1	212.1
Crosscutting Space Tech Development	247.3	--	<b>256.6</b>	190.1	185.9	198.5	203.5
Exploration Technology Development	173.0	--	<b>224.5</b>	287.9	288.0	282.4	284.7
<b>Total Budget</b>	<b>614.5</b>	<b>576.0</b>	<b>705.5</b>	<b>712.6</b>	<b>719.7</b>	<b>726.9</b>	<b>734.2</b>
Change from FY 2014			<b>129.5</b>				
Percentage change from FY 2014			<b>22.5%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Alliant Techsystems (ATK)'s MegaFlex™ solar array is one of two concepts NASA is supporting the development of next generation solar arrays and the Asteroid Retrieval Mission. New array technology will support a system capable of generating more than twice the power for the same mass and using only 1/3 the packing volume relative to current systems. NASA is developing these advanced arrays primarily to support high powered Solar Electric Propulsion (SEP), which has potentially important implications for long duration human spaceflight, as well as communications satellites because of their significant power demands.

Space Technology conducts rapid development and infusion of transformative space technologies that enable NASA's missions and increase the Nation's capabilities in space. The programs within Space Technology develop and demonstrate near-term and far-reaching technological solutions as well as enhancements that increase capability and reduce technological risk, making U.S. space activities more affordable and reliable. By engaging the brightest minds on the Agency's toughest technological challenges, NASA spurs innovation throughout the aerospace enterprise.

Space Technology uses different approaches to advance critical space technologies needed for future missions through the technology pipeline, and strengthens the Nation's current and future aerospace workforce. By using a variety of funding mechanisms, including contracts, grants, fellowships, prize authority, and funded Space Act Agreements, NASA opens the potential pool of technology suppliers to NASA Centers, other Government agencies, industry, academia, small businesses, and individual entrepreneurs.

# SPACE TECHNOLOGY

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Under the direction of the Space Technology Mission Directorate, NASA addresses technology areas found in the Agency's Technology Roadmaps as prioritized by the National Academies. This includes technologies that support the U.S. space industry, other government agencies, NASA's future science missions, as well as human spaceflight endeavors beyond low Earth orbit. The Space Technology portfolio supports a combination of early stage conceptual studies, discovering entirely new technologies (technology readiness levels (TRLs) 1-3); rapid competitive development and ground-based testing (TRLs 3-5) to determine feasibility; and flight demonstrations in relevant environments to complete the final step to mission utilization (TRLs 5-7). Space Technology funds the development of pioneering technologies that will increase the Nation's capability to perform space science, improve operations in space, and enable deep space human exploration. In order to ready NASA for future science and human exploration missions, significant progress is necessary in technology areas including: high-power solar electric propulsion, life support and resource utilization, entry, descent, and landing, space robotic systems, optical communications, navigation, lightweight structures, and space observatories, each essential for future science and human exploration missions. Developing these solutions will help stimulate the growth of the Nation's innovation economy by enabling further technological development in areas such as nanotechnology, robotics, advanced manufacturing and synthetic biology.

The Space Technology account also supports NASA's Office of the Chief Technologist (OCT), which coordinates the Agency's overall technology portfolio to identify development needs, ensures that programs work together when appropriate, and minimizes duplication of effort. By coordinating Agency efforts, the office facilitates integration of available and new technology into operational systems across NASA's missions and engages domestic and international stakeholders, scientists and the public in support of the agency's Asteroid Grand Challenge. The Chief Technologist also engages the broader aerospace community, including other Government agencies, to identify opportunities to collaborate on breakthrough capabilities. The office leads and enhances technology transfer and commercial partnership opportunities through a wide range of users to ensure the Nation realizes the full value of these development efforts.

American technological leadership is vital to our national security, economic prosperity, and global standing. The United States' continued economic leadership is, in part, due to the technological investments made in earlier years, through the work of the engineers, scientists, and elected officials who had the wisdom and foresight to make the investments our country required to emerge as a global technological leader. That commitment accelerated the economy with the creation of new industries, products, and services that yielded lasting benefits. A technology-driven NASA will continue to fuel our Nation's economic engine for decades to come.

For more on Space Technology, go to: <http://www.nasa.gov/spacetech>.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA reformulated the Cryogenic Propellant Storage and Transfer project from a dedicated flight demonstration to a series of ground demonstrations. In addition, the Laser Communications Relay Demonstration will be restructured and the Sunjammer Solar Sail project will be delayed, which will impact near-term milestone dates and potentially impact final launch dates. Other adjustments in Space Technology's budget profile are driven by upcoming project milestones of on-going, high-priority development efforts and support of required increases in the Small Business Innovation Research and Small Business Technology Transfer Programs.

# SPACE TECHNOLOGY

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## ACHIEVEMENTS IN FY 2013

- Fostering the development of the commercial reusable suborbital transportation industry, Flight Opportunities flew 35 technologies on four different commercial platforms.
- NASA selected more than 380 research and technology proposals from over 260 American small businesses for contract awards worth a combined approximate value of \$154 million.
- Through fellowships, research and development partnerships with small businesses, and flight opportunities, Space Technology funded over 400 activities with U.S. academic institutions.
- Low Density Supersonic Decelerator, designed to enable precise landing of higher-mass payloads to the surface of planets, conducted three critical full-scale tests of advanced ring-sail parachutes and supersonic inflatable aerodynamic decelerators to validate performance prior to the first system-level, supersonic flight demonstration set for 2014.
- Laser Communications Relay Demonstration developed flight hardware and conducted ground validation activities of advanced laser communication systems, working toward dramatic increases in data rates for commercial communications satellites.
- The PhoneSat mission launched as a rideshare on the inaugural flight of the Orbital Sciences Corporation's Antares vehicle in April 2013. Built within a rapid development cycle, these three cubesats were equipped with a smartphones and other affordable, off-the-shelf components, to successfully demonstrate command and control capability of operational satellites.
- Game Changing Development completed several high-priority technologies that were initiated in FY 2012 including the fabrication, testing, and delivery of advanced components needed for next generation Extra Vehicular Activity suits (high energy density batteries and a humidity and carbon dioxide removal system), and a neutron spectrometer and mass chromatograph for use by Advanced Exploration Systems. In addition, NASA and industry partners successfully manufactured and hot-fire tested a rocket injector assembly built using additive manufacturing.
- Small business and Game Changing Development partners developed a transformative self-supporting multi-layer insulation material. Developed by SBIR partner Quest Thermal Group, the material retains durability while reducing heat leak. The project demonstrated a 50 percent reduction in heat leak while reducing the mass by approximately 40 percent as compared to traditional multi-layer insulation.

## WORK IN PROGRESS IN FY 2014

- Kicking off seven planned launches over the next two years, Space Technology completed hardware development of the Edison Demonstration of Smallsat Networks (ESDN) spacecraft, which will perform an orbital demonstration of a cluster of eight cubesats to perform cross-linked network communications and distributed science measurements.
- The Low Density Supersonic Decelerator project will conduct its first supersonic system level flight demonstration of a ring-sail parachute and a supersonic inflatable aerodynamic decelerator.
- Game Changing Development will complete the Composite Cryogenic Propellant Tank project by scaling up the successful 2.4-meter prototype (completed in FY 2013) to fabricate and ground test a full-scale 5.5-meter diameter tank, significantly reducing the structural mass of future launch vehicles and, as a result, dramatically increasing their payload mass to orbit.
- Technology Demonstration Missions will conduct thermal vacuum and performance tests for two competing approaches for large scale, deployable solar array systems from ATK and Deployable Space Systems. Along with the arrays, Space Technology will develop and test Hall thrusters and

## SPACE TECHNOLOGY

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their associated advanced power processing units for a planned high-power Solar Electric Propulsion demonstration targeted for 2018.

- As a demonstration of a successful technology progression, small business partner Made in Space (FY 2013 SBIR Phase II) delivered a three-dimensional printer for a 2014 flight demonstration on the International Space Station (ISS) with support from Game Changing Development. Initiated through the SBIR program, Made in Space qualified their hardware for spaceflight parabolic flight demonstrations funded by Flight Opportunities. Once aboard the ISS, the unit will represent the first demonstration of three-dimensional printing technology in space.
- Game Changing Development is delivering to Exploration key improvements above state of the art capabilities. This includes optical gyroscopes; variable oxygen regulator and carbon dioxide removal system for portable life support systems; a 3-kilowatt non-flow through fuel cell; a 100-watt electrolyzer; and advanced batteries with double the life expectancy and more than double the specific energy of state of the art batteries.
- The Low Density Supersonic Decelerator project will conduct its first supersonic flight demonstration of a ring-sail parachute and a supersonic inflatable aerodynamic decelerator.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

- Following payload testing in FY 2014, Space Technology will conduct a Green Propellant demonstration mission to validate a new propellant formula, compatible thrusters, and integrated propulsion system, making available to industry a safe and better performing alternative to highly toxic hydrazine for use on future space missions. This mission will also include first time flight for Game Changing Development's Self Supporting High Performance Multi-Layer Insulation (SSMLI) material.
- Deep Space Atomic Clock will also conduct an in-space demonstration of a new space clock applicable for future planetary science and exploration missions, as well as next generation GPS satellites, dramatically improving navigational accuracy, and increasing bandwidth availability for transmitting science data.
- The Low Density Supersonic Decelerator project will conduct its final two supersonic flight demonstrations of a ring-sail parachute and a supersonic inflatable aerodynamic decelerator. Together these technologies will allow for at least three times greater landed mass at Mars over Curiosity, and offer a pathway to landed masses as high as 15-metric tons for human missions.
- Sunjammer Solar Sail will hold its Flight Readiness Review and finalize preparations for launch to conduct a one year demonstration of the world's largest solar sail, seven times larger than ever flown in space, enabling propellant free propulsion for next-generation space weather systems.
- Game Changing Development will initiate the development of oxygen recovery technology to reduce consumables for deep space human exploration missions, and competitively develop an advanced battery to increase the energy storage capability of future science and exploration systems.
- Game Changing will test and deliver several thruster designs for micro-electrospray propulsion thruster designs that will transform CubeSat propulsion and offer a highly reliable alternative to reaction wheels for fine pointing capability on large satellites.
- Small Spacecraft Technology will conduct a mission to boost the amount of data a small satellite can transfer by demonstrating the use of a deployed solar array as a radio antenna reflector on a cubesat, and a second mission demonstrating in-space laser communications using two cubesats.

# SPACE TECHNOLOGY

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The Space Technology Mission Directorate would utilize \$100 million from the Opportunity, Growth, and Security Initiative to support a diverse set of activities that complement the FY 2015 Space Technology portfolio.

Specific activities include the following:

- \$21.0 million for Closed Loop Life Support System: ISS Utilization
- \$18.0 million for Composite Structural Technologies
- \$10.0 million for Robotics Challenge
- \$7.0 million for Advanced Manufacturing
- \$10.0 million for Small Spacecraft Technology Demonstrations
- \$6.0 million In-Space Assembled and Manufactured Structures
- \$6.0 million for NASA Innovative Advanced Technologies
- \$18.0 million for HIAD-Commercial Cargo Vehicles
- \$4.0 million for Lander and Ascent Vehicle Composites

Further details on Space Technology activities are provided in the Opportunity, Growth, and Security Initiative section of this document.

## **Programs**

### **PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION**

This program supports the Office of the Chief Technologist, which provides the strategy, leadership, and coordination that guide NASA's technology and innovation activities. OCT documents and analyzes NASA's technology investments and tracks progress, aligning them with the Agency's plan. OCT leads technology transfer and technology commercialization activities, extending the benefits of NASA's technology investments so they have a direct and measurable impact on daily life. The office employs principles that encourage partnerships, technology use, and commercialization; ensuring NASA technologies energize the commercial space sector, and provide the greatest benefit to the Nation.

### **SMALL BUSINESS INNOVATION RESEARCH (SBIR) AND SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)**

SBIR and STTR continue to support early-stage research and mid-TRL development performed by small businesses through competitively awarded contracts. These programs produce innovations for both Government and commercial applications. SBIR and STTR provide the high-technology small business sector with opportunities to develop space technology for NASA, and commercialize those technologies to provide goods and services that address other national needs based on the products of NASA innovation.

# SPACE TECHNOLOGY

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## CROSSCUTTING SPACE TECHNOLOGY DEVELOPMENT

Crosscutting Space Technology Development activities enable NASA to develop transformative, broadly applicable technologies and capabilities necessary for NASA's future science and exploration missions and support the space needs of other U.S. Government agencies and the commercial space enterprise. To achieve these goals, NASA's Crosscutting Space Technology Development activities span early-stage conceptual studies through flight demonstrations, employing a variety of funding mechanisms, including grants, broad agency announcements, announcement of opportunities, and prize opportunities. Investment areas within this account includes: Space Technology Research Grants, NASA Innovative Advanced Concepts, the Center Innovation Fund, Centennial Challenges, Game Changing Development, Technology Demonstration Missions, Small Spacecraft Technology, and Flight Opportunities.

## EXPLORATION TECHNOLOGY DEVELOPMENT

Exploration Technology Development advances technologies required for humans to explore beyond low Earth orbit. The program leverages the existing technical strength of the NASA Centers and addresses known needs in support of future human exploration activities through Game Changing Development, and Technology Demonstration Missions. Example projects include Composite Cryogenic Propellant Tanks, Solar Electric Propulsion, Green Propellant Infusion Mission, Cryogenic Propellant Storage and Transfer, and Human-Robotic Systems. ETD technologies are higher risk investments that support architecture and systems development efforts within the Exploration account by maturing breakthrough technology prior to systems integration.



## PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>28.8</b>	<b>--</b>	<b>33.8</b>	<b>33.7</b>	<b>33.7</b>	<b>33.9</b>	<b>33.9</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Following an SBIR contract to develop wind power technology suitable for Mars, more than 200 NASA-derived Northern Power 100 wind turbines are in operation across the world. The turbines shown in this picture are from an installation in the Italian countryside.**

The Office of the Chief Technologist (OCT) serves as the NASA Administrator's principal advisor on matters concerning Agency-wide technology policies and programs. OCT's Partnership Development and Strategic Integration efforts provide the strategy and leadership that guide NASA's technology and open innovation activities. Through OCT, NASA fosters technology transfer, including commercialization of technologies emerging from NASA's research and development activities.

OCT coordinates NASA internal and external technology strategic planning and technology transfer. This office documents, tracks, and analyzes NASA's technology investments and technological innovations, ensuring they are consistent with the NASA technology needs and

strategy. Additionally, OCT documents, demonstrates, and communicates the societal impact of NASA technology investments on behalf of the Agency. OCT also fosters the use of open innovation approaches within the agency such as crowdsourcing, incentive prizes, challenges, and citizen science that enable NASA to engage a broad community of entrepreneurs, non-traditional disciplines, and space enthusiasts in addressing and solving tough problems in technology development and scientific discovery.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

In June 2013, the Administration announced the Asteroid Grand Challenge, "to find all asteroid threats to human populations and know what to do about them," an effort utilizing open innovation approaches and public-private partnerships, to accelerate the work NASA and the global community are already doing to find potentially hazardous asteroids.

## **PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION**

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### **ACHIEVEMENTS IN FY 2013**

NASA's Technology Transfer program captured and processed 1,593 invention disclosures, filed 136 patents, executed 32 patent licenses, and signed 1,184 software usage agreements. OCT also implemented a number of activities to improve technology transfer, including release of a new Cooperative Research and Development Agreement (CRADA) policy aimed at increasing the number of cooperative research partnerships. In addition, NASA re-launched its technology transfer website (<http://technology.nasa.gov/>). Improvements to the website include improved search and licensing functions, templates for licensing and software usage agreements, and release of the annual Spinoff report, which highlights dozens of successfully commercialized technologies in diverse fields. Since the site launched last November, NASA has seen an increase in new partnership and licensing leads coming in through the portal.

NASA continued to analyze the value of and pilot new approaches to using innovative partnerships, incentive prizes, and challenges to facilitate and accelerate innovation both within and outside the Agency. NASA@Work, the Agency's internal challenge platform, enjoyed its most active year yet with 11,700 people registered on the platform (a 30 percent increase from the previous year) and 19 challenges conducted, with an average of 35 solutions submitted in response to each challenge. Throughout 2013, OCT coordinated the use of incentive prizes and crowdsourcing activities throughout NASA, including initiating the policy development process for NASA's first prizes, challenges, and crowdsourcing NASA Policy Directive.

NASA also continued to expand the use and capability of TechPort (a tool the Agency uses to track and analyze its technology portfolio) to include broader access, enabling NASA to efficiently disseminate key information about its current technology investments for public benefit.

### **WORK IN PROGRESS IN FY 2014**

NASA will continue to execute technology patent licenses and is implementing revised technology transfer policies, and conducting updated technology transfer training for Agency personnel. Additionally, NASA continues to explore innovative methods both for reaching new industry audiences and for making technologies available. Examples of work in this area include crowd sourcing of new ideas for new applications of technologies originally designed for NASA missions; development of a public catalog of all available NASA software; and categorization of NASA's technology portfolio by industry sectors and actively marketing to these industries. In addition, NASA added a new "quick launch" licensing process that makes select NASA patents available for non-negotiated set-priced licensing with fast turnarounds and a simplified licensing agreement.

OCT has initiated an update of the NASA Technology Roadmaps, expanding their scope to include information technologies and aeronautics. OCT will also begin the biennial update of the Strategic Technology Investment Plan and make information about the Agency's technology portfolio available to the public via TechPort.

Additionally, OCT will work closely with other Government agencies to crosswalk NASA investments to their technology efforts, enabling new opportunities for technology use and sharing of efforts.

## **PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION**

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### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

OCT will complete the update of the NASA Technology Roadmaps, prepare them for an independent review, and finalize the update of the Strategic Technology Investment Plan. The NASA Technology Executive Council will use the investment plan to optimize the technology portfolio, aligning Agency investments to address priorities and provide capabilities supporting near-term missions and long-term national needs.

NASA Centers will engage with university business schools for technology marketing assessments to discover new ways that industry can apply for our technologies, and receive draft business plans on how NASA technologies can be adopted by industry. While NASA benefits from the business and marketing insights into its technology portfolio, business schools benefit from the "real world" experience of working with licensable technologies and working with NASA technology transfer personnel to understand the breadth of federal technologies and resources available to industry. Additionally, NASA will develop new guidelines to increase access for students to use NASA technologies, such as allowing simple non-negotiated licenses with no upfront fees, should students choose to pursue commercial applications.

OCT will analyze emerging space trends and assess economic indicators related to the Nation's emerging space activities to identify opportunities for leveraging public-private partnerships to advance NASA's Mission and contribute to national economic growth. As a part of this effort, OCT will continue to support research grants in economic analysis related to emerging space activities, and will release a Broad Area Announcement to strengthen the economic analysis options available to the Agency for optimizing technology investments.

## **Program Elements**

### **PARTNERSHIP DEVELOPMENT**

Partnership Development provides leadership for Agency technology transfer and commercialization activities, and increases the exchange of ideas and technologies with external organizations. Through Partnership Development, NASA is responding to the legislative requirements and Administration priorities in promoting technology transfer. Technology Transfer offices at each NASA Center pursue applications for the NASA-developed technologies and use partnerships, licenses, and agreements to transfer the technologies from the laboratory to the marketplace. NASA's technologies provide advanced capabilities, new tools, equipment, and solutions for industry. This spurs economic growth, creates new markets, and helps U.S. industry be competitive and maintain global technological leadership.

Partnership Development has four primary functions:

- **Enabling Technology Transfer:** Provides Agency-level management and oversight of NASA-developed and owned intellectual property, and manages transfer of these technologies to external entities. Activities include active collection and assessment of all NASA inventions, strategic management and marketing of intellectual property, negotiation and management of licenses, development of technology transfer-focused partnerships, and the tracking and reporting of

## **PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION**

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metrics related to these activities, such as numbers of new inventions, patents, licenses, cooperative research and development agreements, and software use agreements.

- **Facilitating Partnerships:** Provides Agency-level coordination, negotiation, and development of partnership agreements that expand and strengthen NASA's transfer, commercialization, and use of externally developed technologies.
- **Utilizing Prizes and Challenges:** Provides Agency-level leadership and coordination of NASA's organizations that conduct prizes and challenges to spur innovation and increase the number and type of individuals participating in innovation activities. NASA uses prizes and competitions to provide technology breakthroughs that lower mission costs, and strengthen expertise to develop solutions for tomorrow.
- **Emerging Space:** Provides analytical support to Agency decision makers concerning the rapid growth of national and international entrepreneurial space communities, their technology needs, and opportunities for NASA to develop or transfer technologies that will facilitate their growth. Activities include monitoring commercial activities, evaluating historical trends, investigating current technology needs, coordinating collaboration discussions, and fostering activities that benefit new markets and the fullest use of space for commercial purposes.

### **STRATEGIC INTEGRATION**

Strategic Integration develops policy, requirements, and strategy for NASA's technology development activities in support of the Chief Technologist by coordinating with NASA mission directorates, other Government agencies, and external organizations. These efforts help to identify priorities, needs, technology development opportunities, and activities that assist NASA in achieving its goals and enable NASA to benefit from cross-agency technological advancements.

Strategic Integration performs an Agency-level technology coordination role to assist NASA in meeting mission requirements while filling technology gaps, anticipating future needs, and avoiding duplication of effort, through mechanisms such as the Technology Roadmaps. To facilitate technology coordination, Strategic Integration manages the execution of the NASA Technology Executive Council, a decision body; and the Center Technology Council, a recommendation council. Both councils are designed to ensure full-Agency participation in technology planning and decision-making activities. The NASA Technology Executive Council works to align the Agency's technology investments with the current priorities, minimize duplication, and ensure that needed capabilities are developed. The Center Technology Council provides advice to the Office of the Chief Technologist and the NASA Technology Executive Council on major issues that relate to technologies of importance to NASA, with a focus on Agency-wide NASA technology policies and programs.

Additionally, to facilitate strategic planning of Agency technology development, NASA developed the Technology Portfolio System (TechPort). This web-based tool captures, tracks, and supports analysis of NASA's technology investment portfolio in an efficient and coordinated manner. NASA uses the system to document and track technology investments, comparing the portfolio against the strategic plan and utilizing the NASA Technology Executive Council to make appropriate adjustments. Strategic Integration identifies opportunities to use NASA-developed technology in future NASA missions and supports documentation and communication of the societal impact of NASA technology investments.

## PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION

### Program Schedule

Date	Significant Event
FY 2014	Initiate NASA Strategic Technology Investment Plan and Technology Roadmaps updates
FY 2014	TechPort operational and made available to the public
FY 2015	Strategic Technology Investment Plan Update
FY 2015	NASA Technology Roadmaps finalized

### Program Management & Commitments

Program Element	Provider
Partnership Development	<p>Provider: N/A</p> <p>Lead Center: NASA Headquarters (HQ)</p> <p>Performing Centers: Each NASA Center has a Technology Transfer Officer and support staff.</p> <p>NASA Ames Research Center (ARC) runs Emerging Space Office</p> <p>Cost Share Partners: N/A</p>
Strategic Integration	<p>Provider: N/A</p> <p>Lead Center: NASA HQ</p> <p>Performing Center: Chief Technologists at each Center. TechPort operation representatives at each Center.</p> <p>Cost Share Partners: N/A</p>

## **PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION**

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### **Acquisition Strategy**

#### **INDEPENDENT REVIEWS**

<b>Review Type</b>	<b>Performer</b>	<b>Last Review</b>	<b>Purpose</b>	<b>Outcome</b>	<b>Next Review</b>
Other	National Academies	Feb 2012	Final report reviewing NASA's draft Technology Roadmaps.	Report identified key technologies that furthered development of space capabilities for the nation's aerospace industry. NASA finalized the roadmaps and implemented the Strategic Space Technology Implementation Plan development in response to these recommendations.	2015

## SBIR AND STTR

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>165.4</b>	<b>--</b>	<b>190.7</b>	<b>200.9</b>	<b>212.1</b>	<b>212.1</b>	<b>212.1</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Marshall Porterfield, NASA Life and Physical Sciences Division Director talks about the human body in microgravity. The Vegetable Production System ("Veggie"), a container used for growing plants on the ISS, is pictured in the foreground. Veggie, developed by Orbitec, Inc of Madison, WI, is capable of producing salad-type crops to provide the crew with a palatable, nutritious, and safe source of fresh food.**

NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs fulfill a statutory requirement to support early-stage research and development. The programs provide the small business sector with an opportunity to compete for funding to develop technology for NASA and to commercialize that technology to spur economic growth. Research and technologies funded by competitively awarded SBIR and STTR contracts have made important contributions to numerous NASA missions and projects. The Agency is actively working to increase the number of NASA-funded SBIR and STTR technologies used in NASA's missions and projects.

SBIR and STTR investments establish a critical early stage foundation for technologies that will soon be demonstrated in space alongside other complementary programs of Space Technology. Examples of these activities include advanced

solar array technology to support solar electric propulsion systems; innovative insulation technologies to support advanced cryogenic propellant operations; the first additive manufacturing demonstrations in low Earth orbit; and telerobotics demonstrations on the ISS. SBIR and STTR are investing in new sensor technology, novel robotics concepts, affordable methods of access to low Earth orbit, and increasingly flexible and adaptable spacesuit designs, all that may one day be utilized by NASA's science and exploration missions. Elsewhere, SBIR and STTR technology will be able to support emergency operations in the face of natural disasters by helping develop Earth science applications tools that will enable real-time collaboration between first responders and storm forecasters.

NASA issues annual program solicitations for the SBIR and STTR programs that set forth a substantial number of topic areas that companies are able to propose to. Both the list and description of topics are sufficiently comprehensive to provide a wide range of opportunities for small business concerns to participate in NASA's research and development programs. SBIR and STTR funding awards are divided

## **SBIR AND STTR**

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into three phases. Phase I awards give small businesses the opportunity to establish the scientific, technical and commercial merit, and feasibility of the proposed innovation in fulfillment of NASA needs. Phase II awards focus on the development, demonstration, and delivery of the proposed innovation. The most promising Phase I projects are awarded Phase II contracts through a competitive selection based on scientific and technical merit, expected value to NASA, and commercial potential. Phase II Enhancement (II-E) is an incentive for cost sharing to extend the research and development efforts of the current Phase II contract. Phase III is the commercialization of innovative technologies, products and services resulting from a Phase II contract. Commercialization includes further development of technologies for transition into NASA programs, other Government agencies, or the private sector. Phase III contracts receive funding from sources other than the SBIR and STTR programs and may be awarded without further competition.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The SBIR and STTR programs reauthorization annually increases the required rate of investment for each program relative to extramural Agency Research and Development (R&D) beginning in FY 2012 and continuing through FY 2017. In accordance with the law, NASA will increase the SBIR investment by 0.1 percent to 2.9 percent of Agency Research and Development.

### **ACHIEVEMENTS IN FY 2013**

SBIR and STTR awarded 292 Phase I SBIR and STTR contracts and 95 Phase II SBIR and STTR contracts in FY 2013. In addition, NASA funded small businesses saw success in getting hardware approved for the ISS and seeing new commercial opportunities including:

- Orbital Technologies Corp (Orbitec) of Madison, WI developed, through SBIR funding, a low cost, collapsible plant chamber with LED lighting, called VEGGIE. The Phase II project developed prototype chambers that could operate on the ISS and support testing of in-situ food production. In FY 2013, NASA's Human Exploration Operations Mission Directorate (HEOMD) initiated a Phase III contract with Orbitec to develop a flight-qualified unit for demonstration at the ISS in 2014.
- Through a Phase III project, Made In Space, Inc. of Wilmington, DE will deliver the first three-dimensional printer to the ISS in 2014. Made in Space received Phase I and Phase II awards from SBIR and qualified their technology for use on the ISS through parabolic flights funded by Space Technology's Flight Opportunities program.
- The Techshot Bone Densitometer will allow NASA to conduct bone density research on orbit, outside of the realm of past experimentation on Earth. The benefits from the ongoing and planned research and development for the specialized X-ray system could change the way we measure animal and human bone density on the ISS as well as on Earth, leading to further advancement of medical diagnosis and treatment of osteoporosis. In early FY 2013, Techshot of Greenville, IN received a Phase III contract to develop the bone densitometer into Flight hardware, with anticipated delivery in December 2013 and flight to the ISS in April 2014.
- STTR Company LongWave Photonics, LLC of Boston, MA analyzes the interference from reflected light seen when a quantum cascade laser (QCL) illuminates a sample. LongWave Photonics, LLC developed algorithms to analyze the distances between reflections to examine foam materials and other thermal coatings being considered for use on future space vehicles. This process also shows potential in examining coatings on controlled-release pharmaceutical tablets.



## **SBIR AND STTR**

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- The SBIR and STTR programs participated in 60 technical exchanges and face-to-face summits with 208 SBIR/STTR firms participating. These summits support companies as they look to transition beyond Phase II funding.
- In accordance with direction in the recent SBIR and STTR reauthorization, the programs engaged in outreach activities with institutions supporting socially and economically disadvantaged persons to explore how these communities may further participate in both programs.
- NASA is seeing growth in its Phase II-E participation with small businesses leveraging over \$3 million in matching funds from NASA to enable additional maturation of their technologies enabling more rapid utilization by potential stakeholders.

### **WORK IN PROGRESS IN FY 2014**

- Space Technology released the annual SBIR and STTR solicitation in November and expects to make new Phase I selections in the third quarter of FY 2014. Phase II selections, as a follow-on from Phase I awards made in FY 2013, occur in the second quarter of FY 2014.
- NASA's SBIR and STTR programs have made key improvements to their website including a new search tool that will allow firms to pull SBIR subtopics by technology areas. SBIR firms are now able to search for subtopics that closely match their proposed technological innovation, and firms will now have easy access to information that will guide them through the submission and award process.
- SBIR and STTR technologies continues to support numerous Space Technology projects including: Human Exploration Telerobotics (TracLabs), ElectroDynamic Debris Eliminator (Star, Inc.), Science Neutron Star Interior Composition Explorer's (NICER's) XNAV experiment (Microcosm, Inc.), non-flow-through and regenerative fuel cells (Infinity Fuel Cell and Hydrogen, Inc), and Solar Electric Propulsion (Deployable Space Systems).

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The SBIR and STTR programs will continue addressing NASA's core competencies through a solicitation aligned with Space Technology roadmaps and the National Aeronautics Research and Development Plan. The budget requested will support new SBIR and STTR Phase I and Phase II awards associated with the solicitation released in fall of 2014.

## **Program Elements**

### **SBIR**

The SBIR program was established by statute in 1982 and reauthorized in 2011 to increase research and development opportunities for small business concerns. The program stimulates U.S. technological innovation, employs small businesses to meet Federal research and development needs, increases ability for small businesses to commercialize innovations they derive from Federal research and development, and encourages and facilitates participation by socially disadvantaged businesses.

## SBIR AND STTR

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In FY 2015, the SBIR program is supported at a level of 2.9 percent of NASA's extramural research and development budget. In FY 2014, the maximum value for an SBIR Phase I contract will be \$125,000 for a period of performance of six months. For Phase II, the maximum total value of an SBIR award will be either \$750,000 or \$1,500,000 over a 24-month period of performance, depending on the specific topic proposal area. The total number of awards made, and funds obligated to them, are based on the quality of proposals received.

### STTR

The STTR program, established by statute in 1992, and reauthorized in 2011 to award contracts to small business concerns for cooperative research and development with a non-profit research institution, like a university. NASA's STTR program facilitates transfer of technology developed by a research institution through the entrepreneurship of a small business, resulting in technology to meet NASA's core competency needs in support of its mission programs. Modeled after the SBIR program, STTR is funded based on 0.40 percent of the NASA extramural research and development budget. In FY 2015, the maximum value for an STTR Phase I contract is \$125,000 for a period of performance of twelve months. For Phase II, the maximum total value of an STTR award is \$750,000 over a 24-month period of performance. The number and size of awards are based on the quality of proposals received.

### Program Schedule

SBIR and STTR Program Year 2014 solicitation and award schedule is below.

Date	Significant Event
Nov 2013	FY 2014 SBIR and STTR Phase I Solicitation Opens
Jan 2014	FY 2014 SBIR and STTR Phase I Solicitation Closes
Mar 2014	FY 2014 Mission Directorates Evaluations of Phase I proposals
Mar 2014	FY 2015 Topics Requested from Mission Directorates and Centers
Apr 2014	FY 2014 Phase I Awards Selected (Dependent on Appropriations)
Apr 2014	FY 2014 SBIR Phase II Awards Selected (from 2012 Awards)
May 2014	FY 2014 STTR Phase II Awards Selected (from 2012 Awards)
Aug 2014	FY 2015 Final Topics and Subtopics Reviewed and Concurred on by Mission Directorates and Centers
Nov 2014	FY 2015 Solicitation Open
Jan 2015	FY 2015 Solicitation Closes

## SBIR AND STTR

### Program Management & Commitments

Program Element	Provider
SBIR and STTR	Provider: Various Small Businesses and their research partners Lead Center: NASA HQ; Level 2: ARC Performing Center(s): All Centers play a project management and implementing role. Cost Share Partner(s): SBIR Phase II-E matches cost share funding with SBIR and STTR up to \$250,000 of non-SBIR and non-STTR investment(s) from a NASA project, NASA contractor, or third party commercial investor to extend an existing Phase II project to perform additional research.

### Acquisition Strategy

SBIR and STTR program management, in conjunction with NASA Center Chief Technologists and a mission directorate steering council, work collaboratively during the SBIR and STTR acquisition process (from topic development and proposal review and ranking) in support of final selection. Mission directorate and NASA Center personnel interact with SBIR and STTR award winners to maximize alignment and implementation of the SBIR and STTR products into NASA's future missions and systems. Space Technology writes SBIR and STTR topics and subtopics to address NASA's core competencies and aligns with the Agency's Technology roadmaps.

### MAJOR CONTRACTS/AWARDS

In addition to the 294 Phase I SBIR and STTR contracts and 81 Phase II SBIR and STTR contracts mentioned previously, the NASA SBIR and STTR programs awarded 25 Phase II-E contracts in FY 2012. The Phase II-E matches cost share funding with SBIR and STTR funds up to \$150,000 of non-SBIR and non-STTR investment(s) from a NASA project, NASA contractor, or third-party commercial investor to extend an existing Phase II project to perform additional research. Phase II-E contracts in FY 2013 were worth a total of \$3.1 million from the SBIR and STTR programs, along with \$6.1 million in non-SBIR matching contributions (see list below). In addition, the SBIR and STTR program tracked 51 Phase III awards in FY 2013, bringing a total of \$16.5 million in non-SBIR funding to NASA SBIR/STTR contractors to further develop or commercialize their technologies. These companies are listed below:

Vendor	Location (of work performance)
Busek Company Inc.	Natick, MA
Cbana Laboratories	Champaign, IL
CFD Research Corporation	Huntsville, AL
Colorado Power Electronics, Inc.	Fort Collins, CO
Cornerstone Research Group, Inc.	Dayton, OH
Creare, Inc.	Hanover, NH

## SBIR AND STTR

Vendor	Location (of work performance)
Energid Technologies	Cambridge, MA
Honeybee Robotics Ltd. (3 projects)	New York, NY
Intelligent Automation, Inc.	Rockville, MD
Microcosm, Inc.	Hawthorne, CA
MicroLink Devices, Inc.	Niles, IL
MTECH Laboratories, LLC	Ballston Spa, NY
Orbital Technologies Corporation	Madison, WI
Paragon Space Development Corporation	Tucson, AZ
Redondo Optics, Inc.	Redondo Beach, CA
SJT Micropower	Fountain Hills, AZ
Systems Technology, Inc. (two projects)	Hawthorne, CA
Tietronix Software, Inc.	Houston, TX
Vanilla Aircraft, LLC	Falls Church, VA
VIP Sensors	San Juan Capistrano, CA

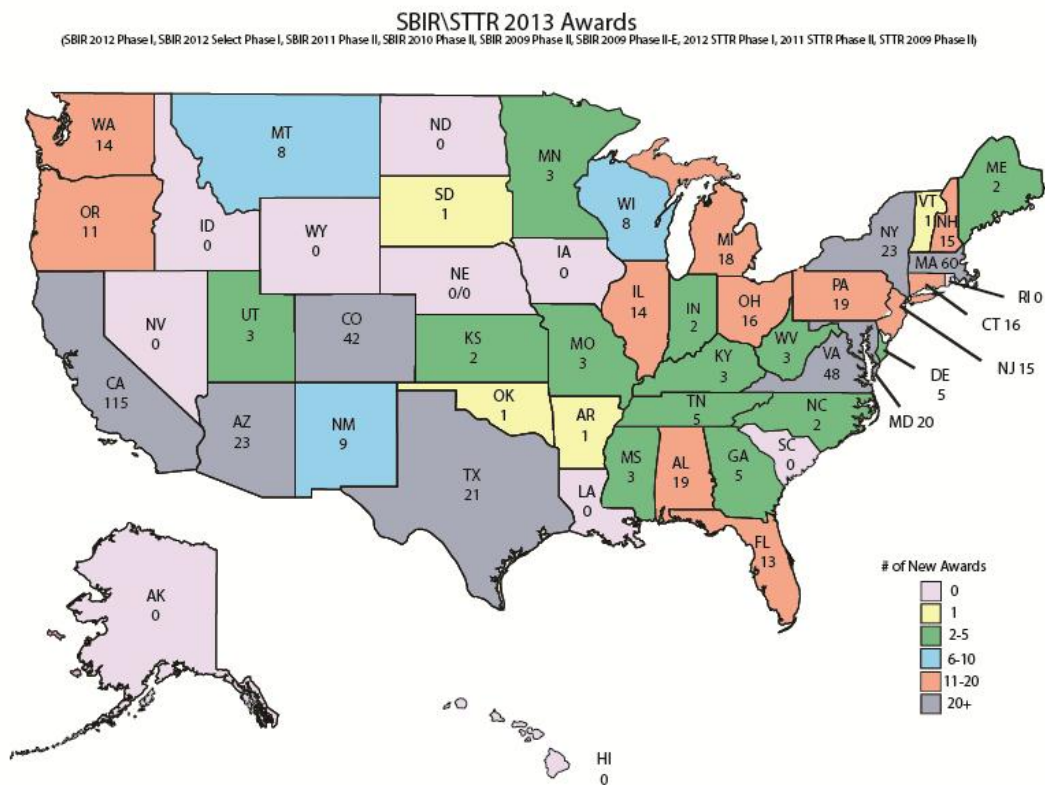
## INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	National Academies	Ongoing	Assessment of the SBIR program.	TBD	FY 2014
Performance	GAO	Nov 2012	The GAO has been tasked to assess all SBIR and STTR programs for their performance in combating Waste, Fraud, and Abuse.	GAO found no concerns to address.	Ongoing

## SBIR AND STTR

### HISTORICAL PERFORMANCE

Selections made during FY 2013, represented by geographic location.



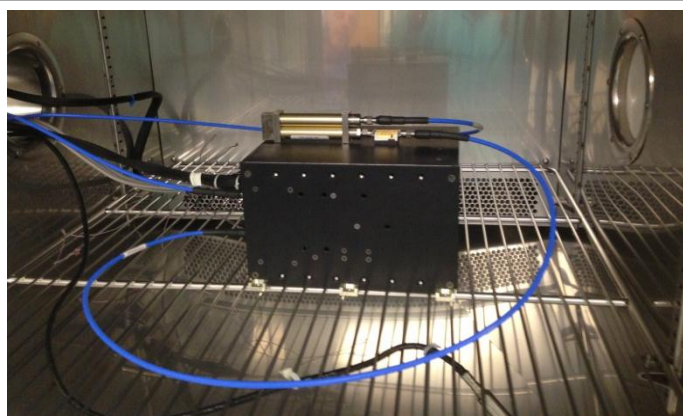
## CROSSCUTTING SPACE TECH DEVELOPMENT

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>247.3</b>	<b>--</b>	<b>256.6</b>	<b>190.1</b>	<b>185.9</b>	<b>198.5</b>	<b>203.5</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**The Engineering Model for Deep Space Atomic Clock just before thermal testing for calibration. The Deep Space Atomic Clock is a miniaturized, mercury-ion, atomic clock that is 100 times more accurate than today's state of the art space clocks used for spacecraft navigation systems. Developed by the Jet Propulsion Laboratory, the clock will demonstrate ultra-precision timing in space and its benefits for one-way radio-based navigation.**

NASA invests in crosscutting technologies with the objective of enabling or significantly advancing relevant capabilities for multiple aerospace customers. Through these efforts, NASA ensures the emergence of new ideas and the incorporation of advanced capabilities into its missions, while also contributing to the needs of other Government agencies and the larger aerospace industry.

Maturing technologies from idea and concept inception all the way through validation in a relevant environment is a significant challenge that comes with inherent technical and programmatic challenges. The program effectively and efficiently manages technology development, as it works through expected challenges in the maturation

process. By supporting projects at all technology readiness levels, Crosscutting Space Technology Development (CSTD) creates a technology cascade, starting with innovation and early stage technology investigations, and eventually resulting in mature, ready-to-implement technologies that increase the nation's in-space capabilities. In the process of creating these new technologies, NASA supports research opportunities and inspires the next generation of inventors, scientists, and engineers.

Technologies advanced within CSTD target needs of multiple areas both within and outside of NASA simultaneously, including addressing needs for deep space human exploration while also enabling more capable space science missions, such as opening future outer planetary missions to a broad class of mission type. Space Technology will invest in a number of targeted technologies to enable low-cost, frequent access to the outer solar system. Space Technology investments in power, radiation protection, entry, descent, and landing, avionics, and sample return made over the next three years will enable missions – including Discovery-class missions -- to provide access to compelling planetary science targets that include Enceladus, Europa, Titan, Jupiter, and Saturn. These investments are broadly

## **CROSSCUTTING SPACE TECH DEVELOPMENT**

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applicable to Agency science and robotic precursor missions to the Moon, asteroids, and Mars. This program also supports NASA's role in the National Nanotechnology Initiative, the Advanced Manufacturing Partnership, and the Materials Genome Initiative. These efforts enable NASA to develop and advance technological capabilities in support of Agency mission directorates, enable collaborations with other Government agencies, and support private industry through an expansion of the Nation's technology-base.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

Reduced prior year funding for Laser Communications Relay Demonstration (LCRD) results in the reevaluation and restructuring of the project to encourage greater involvement of industry, including industry investments and partnerships to help fully realize the potential of this new technology. The Sunjammer Solar Sail Demonstration is in the process of being re-phased and will be rescheduled upon identification of a new flight opportunity. The Center Innovation Fund will significantly reformulate to focus on a smaller number of individual Center activities. NASA also introduces a Foundational Engineering Science initiative within Space Technology Research Grants as described further below.

## **Program Elements**

### **EARLY STAGE INNOVATION**

Space Technology Research Grants annually conducts a series of competitive solicitations targeting high-priority technology areas challenging a spectrum of academic researchers, from graduate students to senior faculty members to make science, space travel, and exploration more effective, affordable, and sustainable. Investigators funded through Space Technology Research Grants work with researchers from NASA Centers to address key challenges identified in the Technology Roadmaps that might be more amenable to solutions emerging from academia. Examples include Hall thruster channel erosion prediction to benefit advanced solar electric propulsion; shape change materials suitable for integration into the next generation of spacesuits; far-infrared, background limited detectors to observe the Cosmic Microwave Background; and intelligent robots for in-space assembly of structural systems. In addition, NASA will place an emphasis on foundational engineering science, targeting collaboration with the fundamental research community, with the objective of advancing key space engineering and science disciplines important to the Nation. This effort will be conducted in collaboration with the Offices of the Chief Scientist, the Chief Technologist, and the Chief Engineer.

NASA Innovative Advanced Concepts (NIAC) solicits early studies of visionary concepts in support of NASA's future missions and broader aerospace enterprise needs. NIAC executes annual solicitations seeking exciting, unexplored, technically credible new concepts that could one day "change the possible" in space and aeronautics. NIAC efforts improve the Nation's leadership in key research areas, enable far-term capabilities, and spawn disruptive innovations that make aeronautics, science, and space exploration more effective, affordable, and sustainable.

The Center Innovation Fund stimulates aerospace creativity and grassroots innovation at the NASA Centers. Selected activities will fall within the scope of NASA's space technology roadmaps, or enhance capabilities that contribute to NASA strategic goals and/or significant national needs. Partnerships with

## CROSSCUTTING SPACE TECH DEVELOPMENT

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academia, private industry, individual innovators, as well as other NASA Centers and Government labs are encouraged.

Centennial Challenges uses partnerships to host prize competitions aimed at finding solutions to technical challenges that support NASA's missions in aeronautics and space. NASA provides the prize money, and collaborates with private non-profit entities to manage the competitions at no cost to NASA. The Sample Return Robot challenge, hosted by Worcester Polytechnic Institute, demonstrates that robots can locate and retrieve geologic samples from a wide and varied terrain without human control or use of terrestrial navigation aids. Centennial Challenges is partnering with the Aeronautics Research Mission Directorate to conduct the Unmanned Aircraft Systems (UAS), Airspace Operations Challenge (AOC). The AOC seeks to demonstrate how to overcome the key technological barriers that will allow unmanned aircraft to autonomously sense and avoid other vehicles within a congested airspace. Future challenges will address NASA's efforts in robotics for human exploration and planetary science missions, and asteroid detection, characterization, and mitigation in support of the Asteroid Grand Challenge.

### Achievements in FY 2013

- Space Technology Research Grants engaged 73 universities across 35 states and one U.S. territory in the conduct of high risk/high payoff, low TRL space technology research. These efforts included the awarding of 65 new Space Technology Research Fellowships and continuation of 122 fellowships from previous selections. Space Technology continued grants for 10 early career faculty researchers (three-year grants awarded in 2012) for research in high priority technology areas, and ten university-led grants (two-year grants awarded in 2012) for study of innovative, early-stage space technologies designed to improve space radiation monitoring and protection, spacecraft and system thermal management, and optical space science observation systems. In addition, Space Technology awarded 10 new grants to universities to address technology challenges that may improve astrophysics scientific instruments, oxygen recovery for space life support systems, cryogenic propellant storage for long-duration space exploration, and identification, characterization and protection from near-Earth asteroids.
- NIAC completed 18 Phase I studies from FY 2012. Through its FY 2013 solicitation, NIAC selected 12 new Phase I, and 6 new Phase II studies, continuing the most promising previous Phase I efforts. NIAC projects have generated over 150 national and international media articles, and its FY 2013 solicitation drew more than 500 proposals. Selections for Phase II included topics such as on-orbit fabrication of large spacecraft components (Spiderfab), development of a gravitational wave detector, sample return systems, and multi-purpose robots capable of landing in any orientation. Spiderfab was later selected as an SBIR Phase I project.
- Centennial Challenges awarded a \$5,000 prize to Team Survey from California, whose robot successfully completed Level I of the Sample Return Robot challenge by demonstrating a robot that could autonomously retrieve the sample and return it to the base.
- The Center Innovation Fund supported 250 activities at NASA Centers. Several technologies were further developed or utilized by other NASA missions, including development of a towed glider airlaunch concept (AFRC), and a solid-state ultracapacitor that could replace batteries (MSFC).

### Work in Progress in FY 2014

- Space Technology Research Grants will engage research teams selected in previous solicitations through its network of research collaborators. In addition, the program has issued competitive



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solicitations targeting high-priority technology areas such as: asteroid detection, characterization and mitigation in support of the Asteroid Grand Challenge; lasers to improve data collection for Earth science missions and communications for planetary missions; digital materials; and soft robotics for planetary science. Solicitations will be awarded later in the fiscal year.

- NASA has released a solicitation for the FY 2014 Phase I NIAC awards, which will select promising Phase I concepts, including technologies supporting the Asteroid Grand Challenge. The Phase II solicitation and awards will occur later in the fiscal year.
- Centennial Challenges used a seed fund and NASA@Work crowdsourcing to cultivate challenge ideas, to encourage prize competitions across the agency, and to pilot varying types of prize competitions. The Agency continues to seek new Allied Organizations and challenge concepts from both internal and external entities. The program will conduct the third Sample Return Robot Challenge and the initial Unmanned Aircraft Systems (UAS) Airspace Operations Challenge. In support of the Asteroid Grand Challenge, the program will initiate a challenge targeting deep space communications and propulsion technologies that would fly as secondary payloads onboard the Space Launch System (SLS)/Orion EM-1 flight. New challenges under development include a Mars Ascent Vehicle challenge, a Europa Ice Melt Through challenge, and a partnership with DARPA on the Disaster Relief Robotics challenge.

### Key Achievements Planned for FY 2015

- Space Technology Research Grants will continue to support a robust portfolio of grants focused on developing low TRL, high-risk/high-payoff technologies. Technology development efforts from grants selected in previous years will communicate their results through publications and presentations. Competitive solicitations will be released targeting high-priority technology areas, keeping the pipeline filled with new ideas and approaches for making science, space travel, and exploration more effective, affordable, and sustainable.
- NASA will initiate new Phase I NIAC awards and further develop the most promising concepts for Phase II NIAC studies, and Center Innovation Fund efforts will continue with the completion of previous year awards and the selection of new awards.
- NASA will continue ongoing Centennial Challenges until awarded. Space Technology also intends to execute first year competitions for the Mars Ascent Vehicle and Europa Ice Melt through challenges. Centennial Challenges will diversify the types of challenges and prizes that it offers to include multi-track challenges and those that involve partnerships with the other Mission Directorates and other Government agencies.
- Applicants for awards of Space Technology Research Grants, NIAC, and Center Innovation Fund funding will be encouraged to address high-priority topics such as asteroid detection and mitigation, and reducing the mass needed to explore space through In Situ Resource Utilization, development and use of lightweight materials, and in-space fabrication and assembly.

### GAME-CHANGING DEVELOPMENT (CROSSCUTTING)

Within Game Changing Development, NASA focuses on maturing transformational technologies across the critical gap between early stage innovation and flight demonstration. NASA will measure the success of the Game Changing Development investments as a whole, rather than expecting each project to produce breakthrough or revolutionary results. NASA expects that, over time, the dramatic advances in transformative space technology, such as crosscutting efforts funded here, will enable entirely new NASA missions, and lead to solutions for a wide variety of technological challenges. Game Changing

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Development emphasizes direct partnerships and co-funding from NASA, industry, and/or other government agencies, to advance specific technologies requested by those customers. For example, key technology developments will address challenges identified for outer planetary science missions by the Science Mission Directorate. Game Changing Development makes fixed duration investments aligned with the needs of the NASA Mission Directorates, industry and other government agencies, and can be categorized within the following two investment areas:

### **Affordable Destination Systems and Instruments**

Supports technology development of high data rate communications, scientific instruments and sensors, advanced navigation systems, improved flight computing, and synthetic biology systems. Included within portfolio, and supported in partnership with both SCA and Planetary Science, are technologies that enable deep space optical communication to provide 100 to 1,000 times increases in data rates available on NASA's deep space missions. Deep Space Optical Communications technologies are considered essential for future human missions to Mars and have a wide range of applicable planetary science missions including those to Mars and the Jovian system. Game Changing is also developing a high performance flight computing system in collaboration with the Air Force Research Laboratory. This development effort will lead to vastly improved in-space computing performance, energy management, and increased radiation fault tolerance. In collaboration with the Science Neutron Star Interior Composition Explorer (NICER) mission, Game Changing is developing Station Explorer X-ray Timing and Navigation Technology (SEXTANT) as a payload on the International Space Station in FY 2017. SEXTANT will evaluate real-time X-Ray data from known regular pulsars to demonstrate deep space navigation – effectively using pulsars for deep space navigation similarly to the way we use GPS on the Earth today.

### **Achievements in FY 2013**

- Completed checkout of uplink receiver and optical payload design for Deep Space Optical Communications, which will improve photon counting by ten times and improve data return volumes by eliminating analog detector readout noise.
- Game Changing Development made awards to BAE, Honeywell, and Boeing to support development of next generation High Performance Spaceflight Computing systems. These systems will improve space based computing performance by 100 times, improve energy management, and improve the ability for the processors to correct and continue operating with errors and component upsets caused by the harsh environments of space.

### **Work in Progress in FY 2014**

- Will complete development of a prototype deep space optical transceiver, integrated optical space receiver and ground detector array for Deep Space Optical Communications.
- Began development of highly accurate gyroscopes using fast light optical technology. A benchtop system with closed loop electronics will complete and undergo testing to inform the final design of follow on demonstration units. These new gyroscopes offer the opportunity to revolutionize high precision inertial measurements for deep space missions. From the status quo, this technology increases sensitivity and reduces positioning errors leading to significant advancements in guidance, navigation, and control.

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- Initiated a shared development effort with NASA's Astrophysics Division to advance coronagraph technology for the Wide-Field Infrared Survey Telescope (WFIRST)-Astrophysics Focused Telescope Assets (AFTA) mission that will enable imaging of nearby exoplanets to assess exoplanet atmospheres.

### **Key Achievements Planned for FY 2015**

- High Performance Spaceflight Computing partners will deliver conceptual architecture designs of radiation hardened, fault tolerant advanced multicore flight processors. Game Changing will evaluate these designs against NASA benchmarks, which will inform further designs for Phase II of this effort.
- Complete development and testing of compact field demonstration units of passive and active fast light optical gyroscopes that will detect rotation rates orders of magnitude smaller than best current technologies.
- SEXTANT will complete flight software development.

### **Lightweight Materials and Advanced Manufacturing**

Supports innovation in low-cost manufacturing processes such as additive and digital manufacturing. NASA looks for opportunities to improve the manufacturing technologies, processes, and products prevalent in the aerospace industry. Investments will also focus on advancing composite and metallic joining manufacturing processes, identifying ideal material mixtures, developing in situ resource construction techniques, and developing advanced manufacturing techniques in partnership with industry. This element also supports nanotechnology research and applications for aeronautics and space, focused primarily on reducing vehicle mass and improving reliability through the development of carbon nanotube based, ultra-high strength composite structures, and nanotechnology derived sensors. These efforts support NASA's role as part of the President's Advanced Manufacturing Partnership, including the Agency's role in the National Network for Manufacturing Innovation, and contribute to NASA's participation and interface with the National Nanotechnology Initiative and the Materials Genome Initiative.

### **Achievements in FY 2013**

- In partnership with Aerojet Rocketdyne, successfully hot-fire tested a liquid oxygen/gaseous hydrogen rocket injector assembly built using additive manufacturing technology. This effort will lead to an advanced, low-cost version of the RL-10 upper stage engine, the dominant U.S. upper stage engine in use today.
- Validated several approaches for increasing the tensile strength of carbon nanotube sheets and yarns by as much as a factor of three and developed new composite processing options. These efforts, in collaboration with industry, have led to significant gains in tensile strength and modulus since project start. This knowledge gained is feeding into the construction a carbon nanotube reinforced pressure vessel, which tests for resiliency on a suborbital sounding rocket flight planned for FY 2015

### **Work in Progress in FY 2014**

- Deliver a three-dimensional printer to the ISS, demonstrating feasibility of on-demand metal additive manufacturing, in collaboration with the Human Exploration and Operations Mission Directorate.

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- Characterize the material property trade space of Bulk Metallic Glass for use in gearboxes and demonstrate novel manufacturing strategies with the aim of developing a new U.S. industry for gear fabrication.
- Initiate development of affordable fabrication techniques for future high performance rocket engines components using two different additive manufacturing techniques. The technology offers the potential to dramatically improve the time consuming and labor intensive approaches used in the fabrication of current rocket engines.

### Key Achievements Planned for FY 2015

- Demonstrate the use of structural nanocomposites in the payload fairing of a suborbital launch vehicle. We predict that the launch will demonstrate reduced structural weight over conventional materials and a reduced vibration environment in the payload bay.
- Use additive manufacturing to manufacture low cost upper stage rocket engine components. After assembly the resulting rocket engines will undergo hot fire testing to demonstrate the performance and reliability of additively manufactured components.

As projects complete their life cycle, Game Changing will select additional technologies through competitive solicitations open to industry, academia, and the NASA Centers, and identify successful efforts with Space Technology Research Grants, Center Innovation Fund, NIAC, and SBIR/STTR. Game Changing will target technology developments activities that have high potential for partnerships and co-funding with the Science and Exploration Mission Directorates.

## TECHNOLOGY DEMONSTRATION MISSIONS (CROSSCUTTING)

To bridge the gap between early development and mission utilization, Technology Demonstration Missions (TDM) matures system-level space technologies that can benefit multiple aerospace industry stakeholders, testing prototypes and demonstration units through demonstrating them in a relevant environment. Focused areas for these demonstration missions address needs that not only support future NASA missions, but also respond to the demands of other government agencies and the commercial space sector. To remain affordable, flight demonstrations of technologies that have passed feasibility ground testing are supported primarily through hosted payloads, rideshares and secondary payloads. Further, the portfolio of demonstration projects is managed under strict cost and schedule guidelines, particularly after they transition from formulation to implementation. The program will conduct formulation studies on concepts such as advanced life support demonstration on-board the ISS, including wastewater and oxygen recovery. These technologies hold the possibility of practically eliminating the need for consumables on future human exploration missions. The program will also investigate the use of composite structures for the Space Launch System upper stage as well as landers, reducing their dry-mass and commensurately increasing their payload mass. Work will begin on advanced power systems for outer planetary science missions where solar arrays often prove inefficient. The current portfolio of crosscutting TDM is described below:

### Low Density Supersonic Decelerators

Space Technology is developing and demonstrating new entry, descent, and landing (EDL) technologies capable of increasing the landed mass and landing precision over current baseline systems. NASA has been using Viking era parachutes for decades and EDL systems have reached the upper limit of their utility (one metric ton) relative to the demand for increasing entry mass. Space Technology is developing

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and testing a variety of decelerator systems to support future Mars missions. The project is designing, developing, and testing a ring-sail parachute as well as a pair of supersonic inflatable aerodynamic decelerator systems. The parachute and inflatable decelerators will push through a series of tests utilizing wind tunnels, balloon drops, rocket sleds, and rocket-powered, high-altitude supersonic flight demonstrations at 180,000 feet. This effort is funded, in part, through a partnership with NASA's Planetary Science Division. Once proven, these technologies are expected to be used in future robotic science missions to Mars, increasing the landed mass capability to three or four metric tons, and have potential to scale up to 15-metric tons landed mass to accommodate requirements for human missions to Mars.

### **Achievements in FY 2013**

- Entered the implementation phase following successful design reviews and completed a supersonic sled test campaign to verify the design of the Supersonic Inflatable Aerodynamic Decelerator.
- Last fall, Space Technology conducted two verification test campaigns of a ring-sail parachute, and conducted subscale parachute testing on eleven designs to evaluate performance and finalize the design for the 30-meter supersonic parachute that will be used in FY 2014 and FY 2015 test campaigns.

### **Work in Progress in FY 2014**

- Conduct final sled tests for both the ring-sail parachute and the larger of the two supersonic inflatable aerodynamic decelerator test articles, and conduct the first high-speed, high-altitude flight demonstration to simulate Mars atmospheric entry and descent conditions.

### **Key Achievements Planned for FY 2015**

- Conducts final two supersonic, high-altitude, system-level flight demonstrations to simulate Mars Atmospheric entry and descent conditions. This will complete Space Technology's validation efforts for the world's largest planetary parachute and the first supersonic inflatable decelerators.
- Upon successful completion, results will be presented to the Mars 2020 project for consideration of incorporation into the landing sequence.

### **Laser Communications Relay Demonstration**

Demonstrates optical communications relay services between geosynchronous orbit (GEO) and Earth. The outcome of this demonstration will be optical communications technology that provides data rates up to 100-times higher than today's radio frequency based communication systems. This could have major implications for NASA, other agencies, and the U.S. satellite-building and communications industries.

### **Achievements in FY 2013**

- Conducted a Systems Requirements Review, conducted peer reviews on the requirements and preliminary designs, and continued development activities for the optical space terminal, controller electronics, and space switching unit.

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### **Work in Progress in FY 2014**

- Conducted a Preliminary Design Review and will procure modems, beacon lasers, and controllers required for design testing set to be conducted in late FY 2014.
- Spurred by reduced appropriations, NASA will evaluate LCRD and restructure it to encourage the greater involvement of industry, including industry investments and program partnerships in order to help fully realize the potential of this new technology

### **Key Achievements Planned for FY 2015**

- TBD, depending on outcome of the review.

### **Deep Space Atomic Clock**

Working with the Jet Propulsion Laboratory, Space Technology is working to validate a miniaturized, mercury-ion, atomic clock that is 100 times more accurate than today's state of the art space clocks used for spacecraft navigation systems. Deep Space Atomic Clock will demonstrate ultra-precision timing in space and its benefits for one-way radio-based navigation. It will free precious deep space communications bandwidth to perform greater scientific data return instead of receiving and transmitting navigation updates. The enhanced navigation and opening of communications bandwidth permitted by the new clock will dramatically improve the science return capabilities of future Discover and New Frontiers missions, particularly for outer planetary missions. Precision timing and navigation provided by the new clock also have the potential to improve the Nation's next generation GPS system. The demonstration is planned for launch via rideshare on a SpaceX Falcon Heavy (STP-2) along with the Surrey Orbital Test Bed in late 2015, and is funded in a partnership with SCan.

### **Achievements in FY 2013**

- Completed design of the ultra-stable oscillator, global positioning system receiver, and clock, and successfully completed its system Preliminary Design Review in mid-2013 moving from the design phase toward project implementation.

### **Work in Progress in FY 2014**

- Complete critical design review and fabricate the global positioning system receiver and clock ultra-stable oscillator, and conduct final payload integration and testing.

### **Key Achievements Planned for FY 2015**

- Complete final payload integration and testing and conduct a Flight Readiness Review in early FY 2015 for a launch currently scheduled for late FY 2015.

### **Sunjammer Solar Sail Demonstration**

Space Technology partner L'Garde, Inc. will develop, deploy and operate a solar sail with an area seven times larger than any sail flown in space. The mission has potential applicability to a wide range of future space missions including serving as an advanced space weather warning system, providing more timely and accurate notice of solar flare activity. This technology also will allow for propellantless deep space exploration missions, and includes a partnership with the National Oceanic and Atmospheric Administration (NOAA). Mission objectives include demonstration of segmented deployment of a solar sail and conducting attitude control, passive stability and trim using tip-vanes. Sunjammer will also

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attempt to fly to and maintain position at sub-L1 and/or pole sitter position. The National Research Council's Committee on a Decadal Strategy for Solar and Space Physics recently identified the tremendous potential of solar sails in supporting future heliophysics missions.

### **Achievements in FY 2013**

- Completed a series of deployment tests of a flight-like 89-foot prototype boom that will provide structural support for the solar sail once unfurled. NASA worked with L'Garde to mature both the mission and system design, approving the project for full implementation in early FY 2013.

### **Work in Progress in FY 2014**

- Conducted a Critical Design Review and is entering its final design and fabrication of booms and sail quadrants. The project plans to identify a new ride-share partner, begin coordination of interfaces, and launch environments.

### **Key Achievements Planned for FY 2015**

- Complete the initial assembly, integration, and conduct final launch environment tests and checkouts. Final launch preparations and Flight Readiness Review are, currently scheduled for the second quarter of FY 2015.

## **SMALL SPACECRAFT TECHNOLOGY**

Small Spacecraft Technology develops and demonstrates technologies to enable new small spacecraft capabilities, applicable for NASA's missions in science, exploration, other government agencies, the commercial aerospace enterprise, and the academic space sector. Small spacecraft can provide a low-cost platform for rapid in-space testing of new technologies and innovations, and offer a transformative paradigm for more agile and rapid space system development. Small spacecraft also have the potential to offer lower cost methods of accomplishing science and exploration objectives currently performed by larger spacecraft, as well as the potential to perform unique missions not possible with conventional spacecraft, such as simultaneous space weather observations from dozens of small satellites distributed around the globe. NASA will share the results of the program's technology developments and demonstrations with the national space community to provide opportunities for infusion into ongoing or planned missions.

- Edison Demonstration of Smallsat Networks will fly a group of eight small satellites to demonstrate their utility as low-cost platforms for coordinated space science observations and perform cross-link network communications between the individual satellites to relay science data. Each satellite carries an instrument for measuring the space radiation environment and the information from all satellites will be transmitted across the satellite network and downlinked to the ground through any one of the individual satellites.
- Integrated Solar Array and Reflectarray Antenna, a three-unit CubeSat that will demonstrate a radio frequency communication system that dramatically boosts the amount of data that the satellite can transmit by using the back of its solar array as a reflector for the antenna.
- Optical Communications and Sensor Demonstration will demonstrate a laser communication system for sending large amounts of information from a CubeSat satellite to Earth and

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demonstrate low-cost radar and optical sensors for helping a pair of 1.5-unit CubeSats maneuver near each other.

- CubeSat Proximity Operations Demonstration will use two three-unit CubeSats to demonstrate rendezvous and mechanical docking of small spacecraft in orbit.
- Small Spacecraft Technology manages 13 Smallsat Technology Partnerships with universities. Partners will collaborate with NASA Centers for two years, working to improve small spacecraft capabilities in the areas of communication, guidance, navigation and control, propulsion, energy storage, instrumentation and manufacturing.
- In addition, the program manages five focused development projects in the area of small spacecraft propulsion. These one-year grants support industry teams as they develop thrusters, motors, and propulsion systems effective for use on small spacecraft. The program is also supporting development of technology for a small Earth return capsule demonstrated on a suborbital flight.

### **Achievements in FY 2013**

- The PhoneSat mission sent three cubesats into space as a rideshare on the inaugural launch of the Orbital Science Corporation's Antares vehicle in April 2013. The PhoneSat spacecraft are estimated to be the lowest-cost spacecraft ever launched by NASA and employ off-the-shelf mobile phone components as the on-board flight computer and avionics control system. This flight demonstration opens the potential for use of such satellites as extremely low-cost platforms for science, exploration, and commercial ventures in space.

### **Work in Progress in FY 2014**

- NASA will launch two, second generation PhoneSats in the first half of the fiscal year. These satellites improve on the earlier PhoneSats by adding solar panels for long-life power, two-way communication, and reaction wheels for attitude control.
- The Edison Demonstration of Smallsat Networks (EDSN) spacecraft cluster of eight small satellites expects to launch in late FY 2014. NASA is collaborating with the Operationally Responsive Space Office for the launch on the Super Strypi launch vehicle. NASA is also providing a unit for dispensing multiple satellites for this launch.

### **Key Achievements Planned for FY 2015**

- Small Spacecraft Technology will have two of its new flight projects ready for launch in FY 2015: the Integrated Solar Array and Reflectarray Antenna and the Optical Communications and Sensor Demonstration missions will be preparing for launch in mid-2015.
- With Massachusetts Institute of Technology (MIT), Small Spacecraft Technology will design and begin fabrication of a flight model "Small Sat in a Day" with the goal of applying advanced manufacturing techniques to construct a complete small satellite system as quickly and inexpensively as possible.
- Small Spacecraft Technology is continuously assessing the state of the art in small spacecraft technology and plans to support a robust portfolio of focused technology developments and flight demonstrations based on progress to date and future needs for NASA missions and the larger space community.



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### FLIGHT OPPORTUNITIES

Flight Opportunities matures technologies by providing affordable access to space environments using commercially available suborbital flights, which also facilitates the development of the commercial reusable suborbital transportation industry. Flight Opportunities also procures commercial parabolic flights to test technologies in environments that simulate microgravity and the reduced gravity environments. In FY 2013, Flight Opportunities had seven companies on contract to provide integration and flight services aboard commercial reusable suborbital vehicles. In addition, the Zero G Corporation is on contract through NASA's Reduced Gravity Office for parabolic flights. These vehicles carry payloads in reduced gravity and near the boundary of space. The program supports flights for externally funded payloads selected through Announcements of Flight Opportunities and NASA funded technology payloads previously selected through FY 2012 and FY 2013 NASA Research Announcements. In addition, the team is collaborating with Science and other NASA programs to make space available for technologies appropriate for the available platforms within Flight Opportunities.

### Achievements in FY 2013

- Flight Opportunities funded flight campaigns for technology payloads using four flight providers, supporting 35 unique technology demonstrations on a variety of flight platforms.
- Five parabolic flight campaigns conducted on board Zero G's parabolic aircraft, supporting 24 payload flights (22 unique technologies).
- Among the suborbital providers, UP Aerospace's SpaceLoft system supported six technology demonstrations, Near Space Corporation's Balloon and High Altitude Shuttle Systems supported five technology demonstrations, and Masten Space System's Xombie supported two payloads.
- Space Technology has over 120 space technology payloads in its pipeline for microgravity testing including these FY 2013 selections: 34 new payloads through its Announcement of Opportunities, 10 funded payloads for development through a NASA Research Announcement, and 6 payloads selected from NASA Mission Directorates or other government agencies.
- Demonstrating the usefulness of suborbital platforms to NASA's technology maturation needs, Science selected four payloads to fly on Flight Opportunities vehicle platforms, and the FAA has used Flight Opportunities platforms to mature positioning technology (Automated Dependent Surveillance-Broadcast) needed to track aircraft and suborbital vehicles.

### Work in Progress in FY 2014

- Flight Opportunities expects one to two additional providers to be utilized for the first time in FY 2014 and will schedule multiple flight campaigns based on payload demand using all eligible flight providers.
- Technologies previously flown on Flight Opportunities flight platforms have been qualified to demonstrate on the International Space Station including a 3D printer developed by Made in Space (launching in 2014) and the Reduced Gravity Flight Demonstration of the Resonant Inductive Near-field Generation System (RINGS) from the University of Maryland and Aurora Flight Sciences (delivered August 2013).
- With a demand of approximately 150 payload flights expected, Space Technology will procure approximately 15 suborbital flights and 4 parabolic flight weeks in support of Agency technology development efforts.
- Flight Opportunities will release a request for proposals seeking new flight providers to provide commercial flight services for NASA funded science and technology demonstrations across a

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variety of relevant environments. Multiple contract awards will continue to support the flight needs of the selected technology payloads)..

### Key Achievements Planned for FY 2015

- Flight providers will continue operating under commercial flight service contracts following selection through the FY 2014 competitive solicitation for Suborbital Reusable Launch Vehicle services.
- Flight providers will continue to fly Research and Development technology payloads on platforms that provide reduced gravity or other relevant environments required to test technologies in order to advance their technology readiness. Payloads currently in the pipeline will be flown on the vehicle most appropriate for their technology maturation needs.
- The program expects to conduct approximately 30 flights and continue to select technologies through Announcements of Flight Opportunities.

### Program Schedule

Specific timelines for deliverables and achievement major milestones vary from project to project, and depend on successful demonstration of experimental capabilities.

### Program Management & Commitments

Program Element	Provider
Space Technology Research Grants	Provider: U.S. Universities Lead Center: NASA HQ program executive, Level 2 GRC Performing Center(s): Various Cost Share Partner(s): N/A
NASA Innovative Advanced Concepts	Provider: Various Lead Center: NASA HQ program executive Performing Center(s): Various Cost Share Partner(s): Cost sharing is encouraged
Center Innovation Fund	Provider: NASA Centers Lead Center: NASA HQ program executive Performing Center(s): All Cost Share Partner(s): Cost sharing is encouraged
Centennial Challenges	Provider: Various Lead Center: NASA HQ program executive, Level 2 MSFC Performing Center(s): MSFC Cost Share Partner(s): External partners fund competition events; NASA supplies prize money

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Program Element	Provider
Game Changing Development	Provider: Various Lead Center: NASA HQ program executive, Level 2 Performing Center(s): Langley Research Center (LaRC) Cost Share Partner(s): Various
Technology Demonstration Missions	Provider: Various Lead Center: NASA HQ program executive Performing Center(s): MSFC Cost Share Partner(s): Other NASA programs, NOAA
Small Spacecraft Technology	Provider: Various Lead Center: NASA HQ program executive Performing Center(s): ARC, GSFC, MSFC, Glenn Research Center (GRC), LaRC, Johnson Space Center (JSC), Jet Propulsion Laboratory (JPL) Cost Share Partner(s): Air Force Research Laboratory (AFRL), Various universities
Flight Opportunities	Provider: Various Lead Center: NASA HQ program executive Performing Center(s): AFRC Cost Share Partner(s): Various

### **Acquisition Strategy**

Crosscutting Space Technology Development uses a blended acquisition approach, conducting both open competitive and strategically guided processes. Solicitations are open to the broad aerospace community to ensure engagement with the best sources of new and innovative technology. As such, CSTD efforts are performed by the Nation's highly skilled workforce in industry, academia, across all NASA Centers, and in collaboration with other Government agencies. Awards are based on technical merit, cost, and impact to the Nation's future space activities. NASA uses acquisition mechanisms such as broad agency announcements, NASA research announcements, Space Act agreements, requests for proposals and prize competitions, with awards guided by priorities cited in the space technology roadmaps and by NASA mission directorates. Future solicitations particularly within Game Changing Development, Flight Opportunities, and Small Spacecraft Technologies will endeavor to use funded Space Act agreements where these approaches are likely to yield acquisitions that are more efficient.

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### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
<i>Technology Demonstration Missions</i>		
Laser Communications Relay Demonstration	David Israel, Principal Investigator, GSFC	Greenbelt, MD
Deep Space Atomic Clock	Todd Ely, Principal Investigator California Institute of Technology, JPL	Pasadena, CA
Solar Sail	Nathan Barnes, Principal Investigator L'Garde, Inc.	Tustin, CA
Low Density Supersonic Decelerator	Mark Adler, Project Manager, California Institute of Technology, JPL	California Institute of Technology, JPL
<i>Small Spacecraft Technology</i>		
Integrated Solar Array and Reflectarray Antenna (ISARA)	Richard Hodges, JPL Pumpkin Inc., Naval Research Laboratory	Pasadena, CA San Francisco, CA Washington, DC
Optical Communications and Sensor Demonstration (OCSD)	Siegfried Janson, Aerospace Corporation	El Segundo, CA
Cubesat Proximity Operations Demonstration (CPOD)	Charles MacGillivray, Tyvak Nano-Satellite Systems LLC Applied Defense Solutions Inc 406 Aerospace LLC California Polytechnic State University	Orange, CA  Columbia, MD Bozeman, MT San Luis Obispo, CA
Edison Demonstration of Smallsat Networks	Deborah Westley, ARC MSFC Montana State University Santa Clara University	Moffett Field, CA Huntsville, AL Bozeman, MT Santa Clara, CA

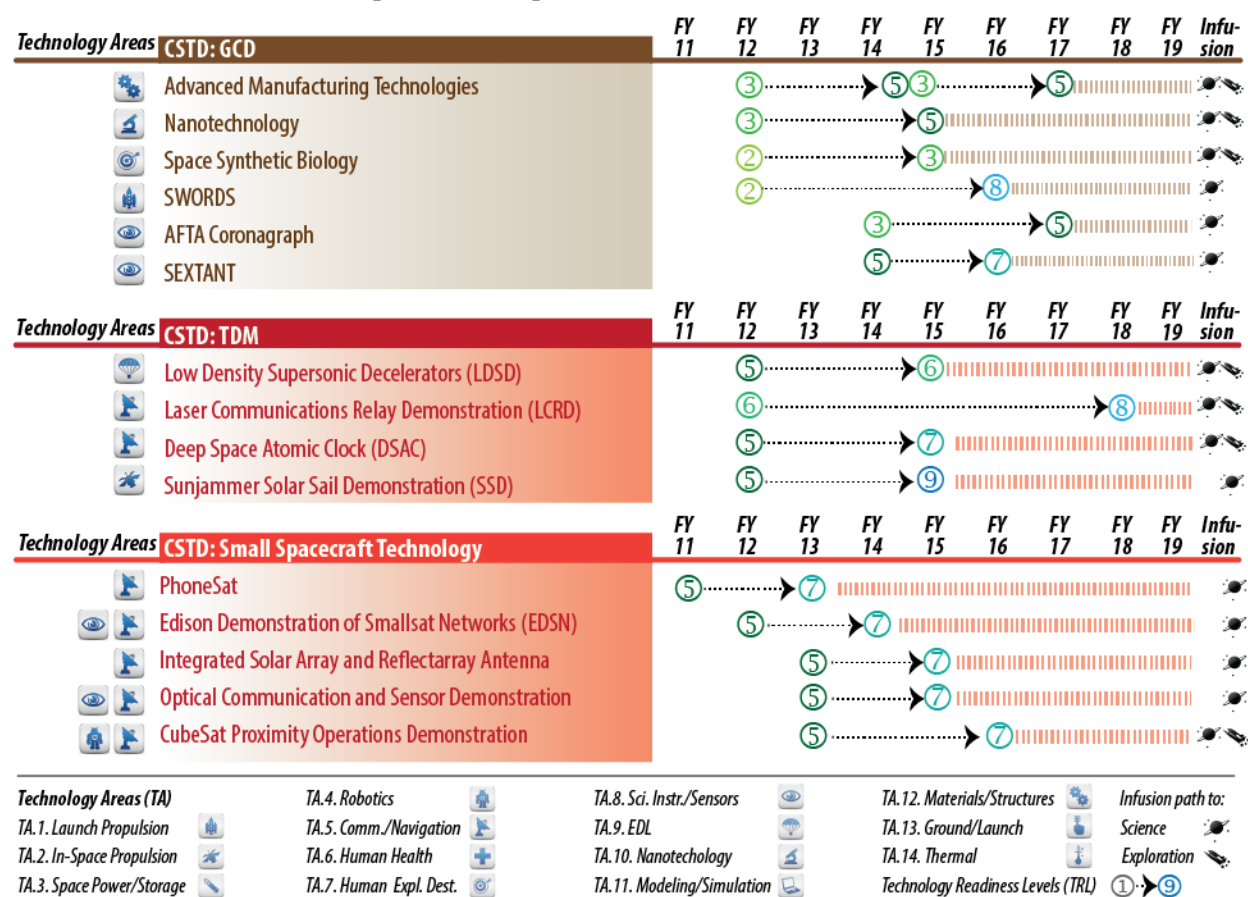
### INDEPENDENT REVIEWS

None.

# CROSSCUTTING SPACE TECH DEVELOPMENT

## HISTORICAL PERFORMANCE

This technology investment overview identifies a subset of active Space Technology development efforts, illustrating core technology areas that aligned with the Space Technology roadmaps and anticipated technology maturation through the life cycle of the project leading to its potential use within NASA's existing and future science and exploration missions. By design, each of these technologies has significant utility for a variety of government and commercial users as well. All the projects listed below are on track to mature and deliver technology advancements in the timeframe specified. Specific timelines for deliverables and achievement major milestones vary from project to project, and are dependent on successful demonstration of experimental capabilities.



## EXPLORATION TECHNOLOGY DEVELOPMENT

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>173.0</b>	<b>--</b>	<b>224.5</b>	<b>287.9</b>	<b>288.0</b>	<b>282.4</b>	<b>284.7</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



For the DARPA robotics challenge, Space Technology developed a next-generation humanoid robot and control paradigm capable of performing dynamic, dexterous and perception-intensive tasks in a variety of scenarios. The Johnson Space Center team applied successful practices used to develop multiple generations of Robonaut and incorporated technologies from collaborators with academic, commercial, and other government partners.

The capabilities NASA pursues within Exploration Technology Development (ETD) provide both the near-term enabling and the long-range transformative technologies required to conduct future human exploration missions beyond low Earth orbit. Space Technology develops and demonstrates these technologies to permit affordable and reliable human exploration missions for destinations that include the Moon, Lagrangian points, near Earth asteroids, and Mars. Through ETD, Space Technology conducts subsystem and system-level technology development and testing in laboratories and ground facilities, as well as technology demonstrations in relevant space flight environments.

Exploration Technology Development focuses on the highest priority human spaceflight technology gaps as identified by the National Academies in their review of the NASA Space Technology Roadmaps, and is guided by the technology prioritization studies performed by Exploration's human spaceflight architecture studies. Technology development is closely coordinated with the system capability demonstrations pursued within NASA Exploration and particularly within the Advanced Exploration Systems (AES) Program.

Among the priorities identified, Game Changing supports the following space technology themes: Lightweight Materials and Structures, Future Propulsion and Energy Systems, Affordable Destination Systems and Instruments, Advanced Entry Decent and Landing, and Revolutionary Robotics and

Autonomous Systems. Game Changing Development pursues proof of concept development and testing and either provides technologies for direct utilization within exploration missions, or transfers them into

## **EXPLORATION TECHNOLOGY DEVELOPMENT**

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Technology Demonstration Missions and/or to Exploration's Advanced Exploration Systems for relevant demonstration and final development.

NASA also funds the following Technology Demonstration Missions within ETD: Solar Electric Propulsion, Cryogenic Propellant Storage and Transfer, and the Green Propellant Infusion Mission. After successful maturation and demonstration of these technologies, Space Technology will implement them directly into future human exploration systems, spacecraft, and infrastructure and enable their use by other agencies and U.S. industry..

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

Cryogenic Propellant Storage and Transfer will reformulate from a flight demonstration mission into a series of large-scale ground demonstrations supportive of future exploration propulsion needs and upgraded versions of SLS. In addition, Game Changing efforts in Adaptive Deployable Entry and Placement Technology (ADEPT), Nuclear Systems, and Autonomous Systems will experience schedule delays based on available funding.

## **Program Elements**

### **GAME-CHANGING DEVELOPMENT (EXPLORATION)**

Within ETD, FY 2013 program activities and FY 2014 plans have been organized into several human exploration-specific Game Changing Development themes:

#### **Affordable Destination Systems and Instruments (ADSI)**

Game Changing supports technology development in the areas of in-situ resource utilization, environmental control and life support systems, and space radiation mitigation. Improved in-situ resource utilization will enable sustainable human exploration through use of local resources found at future exploration destinations. Together, Exploration and Space Technology are jointly sponsoring investigations for the Mars 2020 mission to address the highest priority human exploration knowledge gaps and technology development objectives. Of particular interest for the Mars 2020 mission is exploration technology investigations that have the potential to reduce the mass, volume, and power associated with an oxygen-production plant on the surface of Mars. Likely, a Mars 2020 investigation will be an In-Situ Resource Utilization (ISRU) module that will test the separation of carbon dioxide from the Mars atmosphere and its conversion to oxygen. This demonstration will serve as a precursor to future human exploration missions, which will require an autonomous oxygen production plant for rocket propellants and life support. Space Technology also focuses on developing next-generation life support technologies including significant improvements to water processing and recovery, thermal control, and spacesuit components. Game Changing Development will seek a competitive phased procurement to begin the development of a true closed-loop (greater than 80 percent) highly reliable air revitalization system targeting an eventual demonstration on the ISS. Game Changing is also developing and demonstrating on the ISS new phase change material heat exchangers that will test both the melting of paraffin and water to reject heat. The heat exchanger is also a necessary system for Orion if it is to operate for long periods in distant lunar retrograde orbit. ADSI also supports development of radiation protection

## **EXPLORATION TECHNOLOGY DEVELOPMENT**

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techniques by assessing the feasibility of protection methods, and developing transformative technologies to improve radiation forecasting, monitoring, and protection for future deep space exploration vehicles and habitats.

### **Achievements in FY 2013**

- Conducted final fabrication, testing and delivery of neutron spectrometers and continued volatile analysis instruments in preparation for the delivery of these ISRU components to Advanced Exploration Systems. These instruments will prove useful for future precursor missions to other planetary bodies in the search of water and other in-situ resources.
- Next Generation Life Support continued development of an alternative water processor, initiating wastewater treatment tests on the biological waste processor and functional testing on the forward osmosis secondary treatment system. Once integrated, the water processor has the potential to recover and reuse 85 percent more spacecraft wastewater than the current state of the art.
- The advanced radiation team developed probabilistic models moving toward development of a radiation warning system prototype, which is necessary to allow humans operating in space to seek shelter in a protective environment in the event of an extreme solar radiation event.

### **Work in Progress in FY 2014**

- Delivers to Exploration: Variable Oxygen Regulator that significantly increases the number of pressure settings on the Extra Vehicular Activity (EVA) suit pressure regulator, enhancing and improving EVA operations and pre-breathe protocols; Rapid Cycle Amine that provides an integrated carbon dioxide removal and humidity control system and that can regenerate in real time during an EVA; and an Alternative Water Processor capable of recycling wastewater from sources expected in future exploration missions including both hygiene and laundry water.
- Initiated a Phase III SBIR contract with Mezzo Technologies to continue development of a space-rated, phase change material heat exchanger. In advance of an ISS demonstration, Game Changing will work with Mezzo to conduct design reviews, develop two engineering design units, and conduct ground tests to verify the capabilities of this water-based heat exchanger.
- Completed a three-year development effort with final fabrication and testing of the lunar advanced volatile analysis subsystem in preparation for delivery to Advanced Exploration Systems to demonstrate ISRU.
- With Exploration, will select an ISRU payload provider in the summer of 2014 and co-fund the development of the ISRU demonstration hardware for use on the Mars 2020 mission.
- Release a solicitation to develop air revitalization system technologies that will nearly double (increase to at least 80 percent) the oxygen recovery capability for spacecraft life support systems. Awards will be made in early FY 2015.

### **Key Achievements Planned for FY 2015**

- Continue to collaborate with Exploration to design and develop an ISRU demonstration for use as an instrument on the Mars 2020 mission. This payload will demonstrate the production of consumable and propellant-grade oxygen from the Mars atmosphere. The



## EXPLORATION TECHNOLOGY DEVELOPMENT

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demonstration will identify risks associated with relying on ISRU architecture and allow NASA to mitigate those risks for future exploration missions.

- Fabricate two high-performance EVA glove prototypes that will address fatigue/injury, mobility, fit, and durability issues seen with the status quo spacesuit gloves.
- With Mezzo Technologies, Space Technology will select a design for a phase change material heat exchanger, fabricate a demonstration unit, and deliver it to JSC for evaluation prior to final demonstration on ISS. If the unit is approved and successful, NASA will be able to implement the technology into Orion giving it the ability to work at full power levels and a maximum crew during all portions of lunar orbits.

### Advanced Entry Descent and Landing (AEDL)

Designs, analyzes, and tests technologies, components, and architectures needed for planetary entry missions. This effort is critical because spacecraft experience extreme heating as they rely on a planet's atmosphere to slow the spacecraft for landing. Much of the work in AEDL involves developing efficient ways to reduce spacecraft re-entry speed while providing protection from extreme heating. A current guiding focus of our AEDL investment portfolio is to develop the materials and technologies needed to allow more capable robotic and eventual human missions to Mars surface. Specific innovations and concepts under development and validation include a new generation of ablative thermal protection materials and mechanically deployable aeroshells. Missions use aeroshells to protect a spacecraft from extreme heating while using a planet's atmosphere to create drag to slow the spacecraft prior to a successful landing. These novel Thermal Protection System (TPS) materials will dramatically simplify manufacturing processes and costs while allowing adaptability to a variety of spacecraft demands. One such remarkable breakthrough is the first utilization of a three-dimensional layer-to-layer woven Thermal Protection System, which has applications for extreme entry environments. Using a woven design allows the material to be compliant and far less prone to cracking, unlike Shuttle tiles or other heat shield materials in use today. Also by adjusting the weaving, the density of the material is customizable for specific applications. The materials will likely see initial utilization on the Orion crew vehicle; but also are supported by the Science Mission Directorate for their potential application on future planetary science missions. Game Changing Development, in partnership with AES and SMD, will develop the second generation Mars Entry, Descent, and Landing Instrumentation (MEDLI) sensor suite for the Mars 2020 mission heat shield. This effort builds on the success of Curiosity's MEDLI instrumentation, and further improves our understanding of entry system performance. The AEDL activity also funds advanced analytics and modeling for hypersonic flight including aerothermodynamics and material thermal response analyses. This improved modeling capability will in the future yield lower mass entry systems due to a better understanding of the needed thermal protection system thickness margins.

### Achievements in FY 2013

- Arcjet tests of the Woven TPS successfully demonstrated applicability of the materials to the compression pads of the Orion crew vehicle, as well as future science missions.
- Utilizing knowledge gained from the successful FY 2012 suborbital demonstration, Game Changing began conceptual design work for a future in-space demonstration of a hypersonic inflatable aerodynamic decelerator. The Langley team also fabricated a second-generation inflatable structure and conducted electrical systems checkout for the inflation segment.

## EXPLORATION TECHNOLOGY DEVELOPMENT

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### Work in Progress in FY 2014

- Initiated architecture design for a heatshield using Woven Thermal Protection Systems (TPS). Game Changing will also complete a flexible test article for Conformal TPS that uses a different strategy to offer a compliant (less susceptible to cracking) TPS solution. Thermal response models to validate performance for both are under development.
- Game Changing has also completed design and build of a ground test article for a mechanically deployable aeroshell that unfurls and deploys in a similar fashion to an umbrella.

### Key Achievements Planned for FY 2015

- Develop a prototype heat shield for extreme entry environments using Woven TPS that will achieve up to 40 percent reduction in TPS mass compared to the current state of the art. The ARC led team will work with partners at JSC, LaRC, and Bally Ribbon Mills to fabricate and characterize materials, develop a baseline seam design, upgrade weaving infrastructure in the process of developing an engineering test unit.
- The MEDLI+ effort is a Mars 2020 follow on to the MEDLI entry system instrumentation flown on Mars Science Laboratory. The new instrumentation package will further explore aspects of the actual entry conditions and response of the thermal protection system, informing the design of future, spacecraft entry systems.

### Future Propulsion and Energy Systems

In the area of propulsion, Game Changing is supporting the development of lightweight micro-electric propulsion technologies. These miniaturized electrospray propulsion systems can perform station keeping, orientation and pointing for small spacecraft. Following successful demonstration, these micro propulsion systems will offer alternate fine pointing and directional control capability for larger spacecraft, possibly providing an alternative or redundancy to the reaction wheels currently used, and addressing a common failure mode seen on many spacecraft. In addition, Game Changing is making critical advancement in power generation, storage, and transmission technologies. This includes testing power conversion and thermal management technologies for future in-space nuclear power applications, targeting the development of a small yet scalable (1- to 10-kilowatt) fission power system. This approach offers tremendous potential for more capable outer planetary science missions where solar power becomes impractical and limited Plutonium availability impairs radioisotope generators. In addition, the system also serves as a modular surface power solution for future human missions to Mars. Game Changing also supports advanced in-space power including high efficiency solar cells, improving both reliability and most importantly, affordability. Considered essential for future power hungry exploration missions, Game Changing aims to bring the cost of space arrays more in line with affordable solar technology used on Earth. Game Changing also investigates and matures advanced lithium-ion batteries through the study of new anodes, cathodes, and electrolyte chemistries, with resulting batteries capable of more than double the specific energy of the best current commercially available batteries.

### Achievements in FY 2013

- Advanced In-Space Power developed a 1-kilowatt non-flow through fuel cell that will operate up to 10,000 hours maintenance free and completed work on advanced batteries with double the life expectancy, and more than double the energy density of the current state of the art.

## EXPLORATION TECHNOLOGY DEVELOPMENT

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- Conducted ground testing of high power Hall thrusters, comparing the results with computational models to verify their ability to endure long-duration use with minimal thruster erosion. High power Hall thrusters provide a highly affordable pathway to achieve all electric propulsion for commercial and government satellites, while simultaneously addressing an enabling propulsion capability for the Asteroid Redirect Mission as well as human missions to Mars.
- The ATK MegaFlex and DSS Mega-ROSA solar array concepts completed a Manufacturing Readiness Review (MRR).
- Selected three proposals for the development of lightweight micro-thruster propulsion technologies (NASA's JPL, Pasadena, CA, Busek Company, Inc., Natick, MA, MIT, Cambridge, MA.).
- Nuclear Systems conducted testing on subsystems required to develop the power conversion unit that converts thermal energy from a reactor to electrical power.

### Work in Progress in FY 2014

- Deliver to AES: a 3-kilowatt, non-flow through fuel cell, which reduces system mass and eliminates the primary cause of failure by replacing pumps with a passive wicking system.
- Delivers a 100-Watt electrolyzer, developed to gain experience in working with materials likely required in a space-qualified regenerative fuel cell system. This proof of concept system could result in the development of an operationally capable regenerative system in the future.
- Completes and evaluates the performance of the competing microfluidic electrospray propellant (MEP) systems ahead of transition of one of more of the propulsion systems to Small Spacecraft Technology for an in space demonstration.
- Planned integrated testing of the Nuclear Systems technology demonstration unit (TDU), demonstrating all the components for an in-space power system besides the reactor.

### Key Achievements Planned for FY 2015

- Develop high temperature power processing units and advance solar cell fabrication including development of micro-lens concentrators, mechanical cell stacking, and bonding. Solar cell technology will support solar electric propulsion development by dramatically cutting cell fabrication costs.
- Initiate a new Sterling cycle based small fission effort in support with the Exploration and Science Mission Directorates.

### Lightweight Materials and Advanced Manufacturing

Supports innovation in low-cost manufacturing processes and develops advanced space structures and material systems, as well as modeling and testing to support these capabilities. A major component of this effort is Composite Cryogenic Propellant Tanks, which use advanced composite materials to develop very large, lightweight propellant tanks using out-of-autoclave manufacturing techniques. Current autoclave processes for composites require use of a complex, high pressure, high temperature vessel that is expensive to procure and operate, particularly when accommodating larger articles such as the propellant tanks. Upon successful validation, the composite tanks will see potential application to future launch vehicles including an advanced composite upper stage for the SLS, with the potential of increasing its

## **EXPLORATION TECHNOLOGY DEVELOPMENT**

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payload capability by 30 percent. In addition, NASA will have contributed to improving upon composite aerospace manufacturing processes, potentially drastically reducing the cost and time required to manufacture very large composite aerospace structures. Game Changing is also supporting structural systems including inflatables for habitats and other space based applications, as well as deployables, rigidizables and tension frames. The objective of this effort is to characterize two, high strength, woven webbing materials for utilization in the restraint layer of inflatable space structures, evaluate end of life material properties and develop methodologies for damage tolerant designs.

### **Achievements in FY 2013**

- Fabricated, delivered and successfully pressure tested a 2.4-meter diameter composite propellant tank. The tank successfully passed pressurized liquid hydrogen load tests, and provided engineering data and a proof-of-concept to support the final 5.5-meter tank design.
- Game Changing completed development and ground testing of a self-supporting, multi-layer insulation material critical for long-term cryogenic fluid storage. This technology, initiated through the SBIR program by Quest Thermal Group, achieved 10 to 25 percent lower heat leak compared to the state of the art and will transition to in-space testing as part of the Green Propellant Infusion Mission. Follow-on plans also call for incorporation of the technology onto the Cryogenic Propellant Storage and Transfer, Technology Demonstration Mission.

### **Work in Progress in FY 2014**

- After the completion of fabrication, Boeing (Seattle, WA) will deliver a 5.5-meter diameter Composite Cryogenic Propellant Tank to MSFC. The tank will then undergo pressurized liquid hydrogen testing to ensure it can hold extremely cold cryogenic propellants under launch conditions and loads.
- Game Changing will also build upon the inflatable structures of Transhab and subsequent Bigelow concepts, and refine characterization and evaluation methods for use of inflatable structures in the context of Exploration architecture requirements. The final product, delivered in spring 2014, will include test data and design guidelines for damage tolerant materials applicable to inflatable space structures subject to the harsh environments of space.

### **Key Achievements Planned for FY 2015**

- Game Changing will invest in new efforts focused on the development of lightweight materials and structures to reduce the cost of future spacecraft.

### **Revolutionary Robotics and Autonomous Systems**

This area supports advancement of human-robotic systems that amplify astronaut productivity and reduce the risk that the mission will fail. Specific technology efforts include robotically supported spacesuit gloves and improved jetpacks for extravehicular activities; hardware upgrades for Robonaut 2, a humanoid robot undergoing testing on the ISS. In addition, Space Technology is building on its experience with Robonaut 2 and participation with DARPA on the robotic disaster relief challenge by developing and fielding an all-electric fully mobile and dexterous humanoid robot (R5). The team also began development and support for a robotic testbed used to test the viability of asteroid capture systems.

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Robonaut 2 demonstrations on the ISS may continue with a goal of putting R2 into routine service on the ISS to offload maintenance tasks from crew. NASA's robotics efforts led to an exoskeleton system, a wearable robot with initial utility as an in-space exercise device. This robot will also serve as a joint and muscle health monitor for astronauts, and could develop into a mobility assistant for people with disabilities. Human Robotics Systems technology also supports the Agency's role in the National Robotics Initiative that develops robotics technologies for space exploration that can also support manufacturers, businesses and other entities.

### **Achievements in FY 2013**

- Completed functional testing of the next generation "jet pack" prototype for use on future extravehicular activities.
- JSC engineers completed testing on the exoskeleton, to validate usability for astronaut fitness and joint monitoring. Held discussions with the Veterans Administration to determine if the exoskeleton can benefit veterans with disabilities.
- Adding far greater system mobility, the JSC team completed robotic legs for Robonaut 2.
- Conducted fully automated re-planning of crew activities in response to simulated habitat failure, which would reduce dependence on Mission Control to manage an emergency.

### **Work in Progress in FY 2014**

- Deliver robotic legs to the ISS to provide greater mobility for Robonaut 2.
- Developed a next-generation humanoid robot based off Robonaut to compete in the DARPA Robotics challenge trials. This robot (R5) is able to perform dynamic, dexterous, and perception-intensive tasks in a variety of scenarios. As part of the challenge, the team is collaborating with the Open Source Robotics Foundation to develop an open source robot operating system.

### **Key Achievements Planned for FY 2015**

- Complete proposals selected under the National Robotic Initiative and perform new ground and space-based telerobotics demonstrations.
- Initiate new efforts under the following areas: habitat automation, enhancements for Robonaut, and supporting technologies for the robotic segment of the Asteroid Redirect Mission.
- Game Changing will continue and enhance its participation and partnership with DARPA on the disaster relief robotics challenge fielding R5 in the final competition.

## **TECHNOLOGY DEMONSTRATION MISSION (EXPLORATION)**

NASA will continue development of exploration-specific Technology Demonstration Missions that directly enable future human exploration as well as provide fully developed capabilities for U.S. Government agencies, and the overall space industry. Technology Demonstration Missions takes technologies that have cleared the proof-of-concept, and initial ground testing stage, and demonstrates their capabilities within integrated systems in a relevant flight environment. This step is considered the final step prior to the implementation or incorporation of the technologies into future missions. The current portfolio of exploration-specific Technology Demonstration Missions is described below:

## **EXPLORATION TECHNOLOGY DEVELOPMENT**

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### **Solar Electric Propulsion**

Space Technology will continue development of high-powered Solar Electric Propulsion. The system will employ solar arrays with advanced deployable structures, magnetically shielded Hall thrusters, and high voltage power processing technologies matured and tested under Game Changing Development. NASA will leverage internal and external expertise and industry partners to develop a cost effective high-powered Solar Electric Propulsion demonstration system. This SEP system will utilize 30 to 50 kilowatt deployable solar arrays with half the mass and one third the packaging volume relative to the best current arrays; 10 to 15 kilowatt Hall thrusters with magnetic shielding to permit several years of continuous operations without degradation; and high-voltage advanced power processing units. This full-scale SEP flight demonstration will provide propulsion for the asteroid redirect mission. Once proven, high-powered solar electric propulsion can be used to enable orbit transfer for satellites, accommodate increasing power demands for government and commercial satellites, and power NASA's future robotic science and human exploration missions outside the Earth-moon system.

#### **Achievements in FY 2013**

- Game Changing Development transitioned several Solar Electric Propulsion project elements over to the Technology Demonstration Missions (Hall Thrusters, Power Processing Units, and Solar Array Structures). TDM supported the Asteroid Redirect Mission (ARM) Mission Formulation Review (MFR) in July 2013. The ATK MegaFlex and DSS Mega-ROSA solar array concepts completed a Manufacturing Readiness Review (MRR) and began fabrication of their ground demonstration systems.

#### **Work in Progress in FY 2014**

- Finishes the design, prototype performance, and diagnostic testing of the high-power Hall thruster and associated high-voltage power processing units followed by development of end-to-end electric propulsion system specifications. On successful subsystem testing, the integrated electric propulsion system will complete and test late in the fiscal year.
- ATK and Deployable Space Systems will conduct thermal-vacuum deployment tests of their advanced solar array designs prior to delivery to NASA. These risk-reduction activities will support development and acquisition activity for the space demonstration of high-powered SEP.

#### **Key Achievements Planned for FY 2015**

- As it enters the formulation phase as part of the Asteroid Redirect Mission, Solar Electric Propulsion will initiate the acquisition process for major subsystems including solar array systems, thrusters and associated power processing units.

### **Cryogenic Propellant Storage and Transfer**

Advancing Cryogenic Propellant Storage and Transfer (CPST) technologies meet the needs of both NASA exploration systems and commercial launch providers by demonstrating the capability of in-space long-term storage and transfer of cryogenic propellants (liquid oxygen and liquid hydrogen), essential for transportation on deep-space exploration missions. The cryogenic propulsion stage must be capable of performing long-term storage as well as propellant transfer in a zero-g environment. The same capabilities are sought after within multiple crosscutting applications, including propellant depots. Budget impacts led to the reformulation of CPST from a sub-scale flight demonstration into a series of full-scale

## EXPLORATION TECHNOLOGY DEVELOPMENT

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ground demonstrations that will align with the development and infusion schedule of the Agencies exploration activities.

### **Achievements in FY 2013**

- Completed manufacture of individual CPST ground test article components including liquid acquisition and line chilldowns, low conductivity struts and a newly patented Radio Frequency Tank Eigenmode Sensor.
- Completed testing of the 90-Kelvin cryocooler and the active cooling system for CPST demonstrating one-third reduction in liquid hydrogen boil off ahead of designing a complete system to store cryogenics efficiently.
- Conducted a series of industry workshops to gather data on design and test results to ensure that the technologies under development will meet the requirements of commercial partners.
- A mission-level system requirement and mission definition review was held to evaluate whether the proposed architecture is responsive to functional and performance requirements.

### **Work in Progress in FY 2014**

- Initiated Reformulation effort to move from a sub-scale flight demonstration to a series of full-scale ground demonstrations that will inform the block upgrade strategy for the SLS upper stage. After completing reformulation and receiving approval for a series of increasingly complex ground demonstrations, the project will begin the development of the first ground system and focusing on integrated multi-layer insulation and radio-frequency mass gauging.

### **Key Achievements Planned for FY 2015**

- Transition to a ground unit demonstration activity based on the plan developed in FY 2014.

### **Green Propellant Infusion Mission**

Space Technology and partners are designing, building, testing, and launching a dedicated spacecraft to demonstrate green propellant propulsion with the goal to provide an alternate to hydrazine fuel. Hydrazine, which has been extensively used since the 1960's for space systems, is a reliable and effective storable mono-propellant, but requires complicated transportation, handling and ground and flight operations because it is highly corrosive and highly toxic. Spacecraft developers actively seek green alternatives to hydrazine propellant (in-space storable mono propellants). Higher performing and safer green propellant alternatives are at a tipping point. Once demonstrated within the context of an in-space application, rapid incorporation will occur into a variety of spacecraft. NASA selected Ball Aerospace to demonstrate the capabilities of AF-M315E. This innovative, low-toxicity mono-propellant is expected to improve overall vehicle performance. This fuel also has the potential to improve processing efficiency and decrease operational costs by reducing health and environmental hazards. Ball Aerospace joins NASA, the Department of Defense, and Aerojet Rocketdyne to develop a spaceflight payload to demonstrate a green propellant subsystem for a small to medium-size spacecraft, resulting in a highly safe and functional green propellant system ready for use by commercial and government customers. NASA

## EXPLORATION TECHNOLOGY DEVELOPMENT

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secured a rideshare opportunity for an FY 2015 technology demonstration via the STP-2 launch of a SpaceX Falcon Heavy.

### **Achievements in FY 2013**

- Completed system requirements and preliminary design reviews. The prime contractor awarded a subcontract to Aerojet Rocketdyne for the propulsion system, and developed and tested two thruster models moving toward the development of flight-weight thrusters.

### **Work in Progress in FY 2014**

- Conducted peer reviews of the propulsion subsystem and propellant system tests prior to critical design review. Aerojet Rocketdyne completed development and conducted continuous operations testing of 1-newton and 22-newton thruster lab models. Partners Ball Aerospace and Aerojet Rocketdyne will integrate and test flight hardware ahead of the FY 2015 flight demonstration.

### **Key Achievements Planned for FY 2015**

- Finalize integration of the propulsion and spacecraft systems and ensure the spacecraft and systems are prepared for the flight demonstration currently scheduled for late FY 2015.

## **Human Exploration Telerobotics**

Demonstrates telerobotic operations concepts for controlling robots over long distances to support human exploration missions and reduce risk for further development and future operation of telerobotic flight systems. Demonstrations primarily utilize the International Space Station to demonstrate multiple telerobots simulating multiple destinations (i.e. low Earth orbit, Lunar waypoint, Near Earth Asteroid, and Mars orbit). The program also assesses full implementation readiness and technology gaps and makes use of commercial, open source and open standards. The Human Exploration Telerobotics team demonstrates continued and progressively challenging operations for Robonaut 2 and Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) on the ISS, as well as the demonstration of remote robotic operations, where robots on Earth are operated from the ISS to simulate similar operations of robots at planetary destinations from crewed vehicles.

### **Achievements in FY 2013**

- Conducted challenging telerobotics demonstrations on three platforms. The team performed command and control (both from ISS and from the ground) of Robonaut 2 to perform functions aboard the ISS including conducting tool readouts and learning to grasp, transfer and utilize wipes to clean railings inside the ISS.
- From Mission Control, guided SPHERES through the Japanese Experimental Module (Kibo) using video survey capabilities, and mapped Wi-Fi signal strength in the U.S. segment of the ISS.
- Conducted surface telerobotics by controlling the K-10 rover at ARC from the ISS.



## EXPLORATION TECHNOLOGY DEVELOPMENT

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### Work in Progress in FY 2014

- In November, the team demonstrated ground control of Robonaut 2 to perform complex manipulation tasks. Upon delivery of Robonaut 2 climbing legs developed by Game Changing, the team will characterize robot performance, mobility and further develop Robonaut 2's capabilities to perform ISS support tasks.
- SPHERES will incorporate use of tablet and smartphone devices (Apple iOS and Android platforms) to conduct smartphone vision based navigation, three-dimensional mapping of the ISS, and testing on a new smartphone controller.
- This effort will conclude as a TDM once all planned milestones are successfully completed. Game Changing Development will conduct future telerobotics activities as described under Revolutionary Robotics and Autonomous Systems beginning in FY 2015

### Program Schedule

Both Game Changing Development and Technology Demonstration Missions are composed of sets of uncoupled project elements. Specific timelines for deliverables and milestones vary from project to project, and are widely dependent on the results of design, development, fabrication, analyses, and testing.

### Program Management & Commitments

NASA is implementing an integrated management approach to ETD and CSTD projects to capitalize on technical and management synergies. The two main projects under the ETD program, exploration-specific Game Changing Development and exploration-specific Technology Demonstration Missions, each have a Level 1 Headquarters program executive and Center managed Level 2 project office (shared with CSTD).

Program Element	Provider
Game Changing Development	Provider: NASA HQ program executive Lead Center: LaRC Performing Center(s): All Cost Share Partner(s): Varies
Technology Demonstration Missions	Provider: NASA HQ program executive Lead Center: MSFC Performing Center(s): All Cost Share Partner(s): Varies

## EXPLORATION TECHNOLOGY DEVELOPMENT

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### **Acquisition Strategy**

Additional competitively selected project elements will augment those openly selected, created as guided activities in FY 2014, or earlier. The focused technology areas for additional competitive project elements are determined by the priorities established within the Exploration program architecture studies as well as the NASA technology roadmapping and the Strategic Technology Investment Plan. To the extent possible and advantageous to the Government, future Game Changing Development procurements will use funded Space Act Agreements in place of Cost Plus Fixed Fee or Fixed Price contracts. Technology Demonstration Missions will use both open competition, and directed activities in critical near term areas. Technology Demonstration Missions proposers are strongly encouraged to partner and cost share with non-NASA entities.

### **MAJOR CONTRACTS/AWARDS**

Element	Vendor	Location (of work performance)
TDM-Solar Electric Propulsion	Margaret Nazario, Project Manager, GRC; JPL	Cleveland, OH Pasadena, CA
TDM-Cryogenic Propellant Storage and Transfer	Susan Motil, Project Manager, GRC; MSFC, GSFC, KSC, ARC	Cleveland, OH; Huntsville, AL, Greenbelt, MD; Hampton, VA, Cape Canaveral, FL, Moffett Field, CA
TDM Green Propellant	Ball Aerospace (Prime); Aerojet Rocketdyne Corporation; U.S. Air Force Research Laboratory; U.S. Air Force Space and Missile Systems Center; GRC; LaRC; KSC	Boulder, CO; Redmond, WA; Edwards, CA; Albuquerque, NM; Cleveland, OH; Cape Canaveral, FL

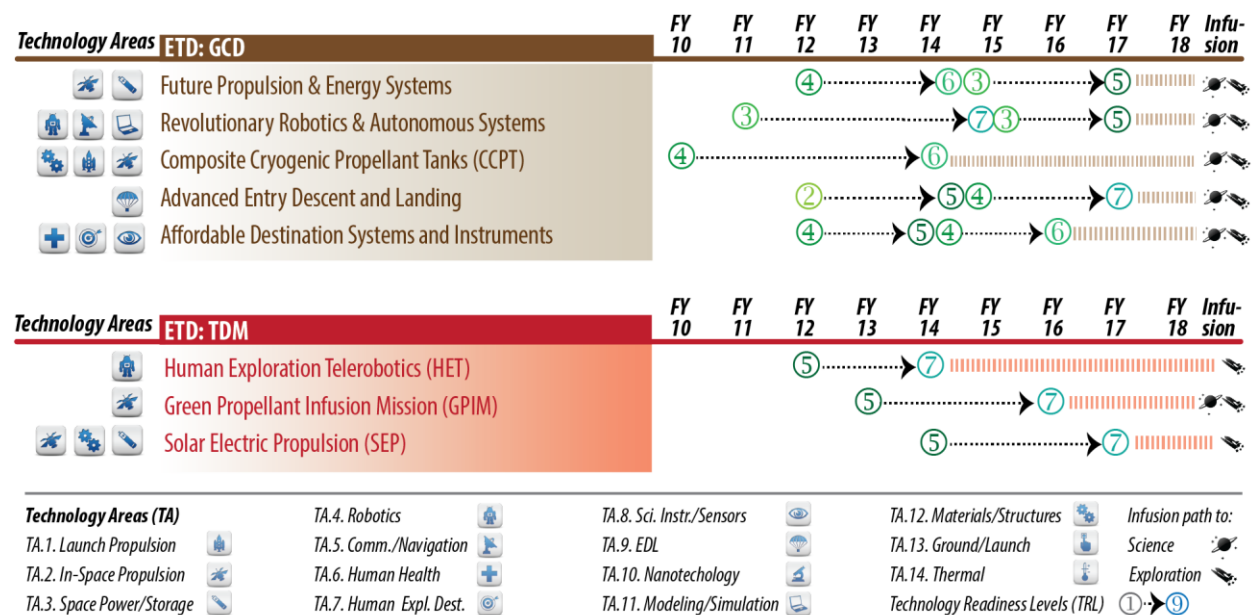
### **INDEPENDENT REVIEWS**

None.

## EXPLORATION TECHNOLOGY DEVELOPMENT

### HISTORICAL PERFORMANCE

The following technology investment overview identifies a subset of active Space Technology development efforts, illustrating their core technology areas (aligned with the Space Technology roadmaps) and anticipated technology maturation path through the life cycle of the project as awarded. By design, each of these technologies has significant utility with a variety of government and commercial users as well. All the projects listed below are on track to mature and deliver technology advancements in the timeframe specified.



# HUMAN EXPLORATION AND OPERATIONS

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Budget Authority (in \$ millions)	Actual		FY 2015	Notional			
	FY 2013	FY 2014		FY 2016	FY 2017	FY 2018	FY 2019
Exploration	3705.5	4113.2	3976.0	4079.9	4061.2	4119.5	3673.4
Space Operations	3724.9	3778.0	3905.4	3951.9	4051.0	4073.8	4601.8
Total Budget	7430.4	7891.2	7881.4	8031.8	8112.2	8193.3	8275.2

HUMAN EXPLORATION AND OPERATIONS.....HEO-2

# HUMAN EXPLORATION AND OPERATIONS

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual		FY 2015	Notional			
	FY 2013	FY 2014		FY 2016	FY 2017	FY 2018	FY 2019
Exploration	3705.5	4113.2	<b>3976.0</b>	4079.9	4061.2	4119.5	3673.4
Space Operations	3724.9	3778.0	<b>3905.4</b>	3951.9	4051.0	4073.8	4601.8
<b>Total Budget</b>	<b>7430.4</b>	<b>7891.2</b>	<b>7881.4</b>	<b>8031.8</b>	<b>8112.2</b>	<b>8193.3</b>	<b>8275.2</b>
Change from FY 2014			<b>-9.8</b>				
Percentage change from FY 2014			<b>-0.1 %</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

NASA is entering a new era in human spaceflight: exploration beyond low Earth orbit. The early steps to human exploration of deep space are well underway, with research into long-duration spaceflight continuing aboard the International Space Station (ISS), as the next generation space transportation system nears initial flight testing. To enable this focused effort, NASA has shifted to a new paradigm for access to low Earth orbit. Recent commercial resupply missions to the ISS have demonstrated the ability of the U.S. space transportation industry to carry cargo, and ultimately crew. But before we can send humans safely into deep space for extended missions, we must complete the vital research already in work, accomplish key technology, and enhance the supporting capabilities that NASA requires for mission success. The Human Exploration and Operations (HEO) budget funds all these with a portfolio of development and operational programs, utilizing a mix of government-led contracts, milestone-based private-sector agreements, and international partnerships to extend the boundaries of human space exploration, and generate new scientific and technical knowledge.

### Capability Driven Exploration: Enabling Multiple Destinations

In this new era, NASA is implementing a multiple destination exploration strategy, using a capability-driven approach. As we continue to advance our ability to conduct a sustainable campaign of exploration leading to Mars, we will exploit the opportunities afforded by other locations, such as cis-lunar space – the volume of space around the Earth-moon system, from which we can mount missions to other destinations. An early demonstration of capabilities needed to operate in deep space is NASA's Asteroid Redirect Mission, which is designed to robotically encounter and redirect an asteroid into a stable orbit around the Moon. There, astronauts aboard the Orion Multi-Purpose Crew Vehicle, launched on the Space Launch System (SLS), will acquire a sample from the asteroid to bring back to Earth. This mission presents an affordable means to fulfill the President's call to send astronauts to a near-Earth asteroid by 2025. The human and robotic missions planned over the next several years will extend our progress along this capability-driven framework, leading to eventual human expeditions to Mars.

### Spaceflight Cornerstone: International Space Station

The ISS offers a unique platform for NASA and its International Partners to learn how to live and work in space. Research, technology demonstrations, tests, and experiments on the ISS continue to advance the

# HUMAN EXPLORATION AND OPERATIONS

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capabilities required for future long-duration missions, including autonomous rendezvous and docking, advanced communications systems, human health and behavior in space, as well as basic research in biological and physical sciences.

In addition, the ISS is a National Laboratory for commercial research, allowing researchers and entrepreneurs representing a wide range of disciplines to develop groundbreaking technologies and products. HEO's Space Operations account funds ISS operations, while both the Space Operations and Exploration accounts fund research and development efforts on ISS.

## **Affordable American Access to Low Earth Orbit: Commercial Spaceflight**

NASA and the U.S. space transportation industry are well on the way to developing an affordable capability to carry crew to ISS by the end of 2017, bolstering American leadership while eliminating reliance on the Russian Soyuz to transport American astronauts. This competitive commercial approach versus a traditional NASA-owned and operated system, allows the Agency to reduce costs, improve affordability and sustainability, and stimulate the private sector space industry. With two companies now providing reliable cargo resupply services to ISS through the Space Operations account, the Exploration budget funds development activities for commercial crew systems. As with cargo, Space Operations will eventually purchase commercial crew transportation services, once proven.

## **Exploration Beyond Low Earth Orbit: Space Launch System/Orion Multi-Purpose Crew Vehicle**

Exploring deep space requires the capability to transport crew and large masses of cargo beyond low Earth orbit. NASA is developing a crew capsule, a heavy-lift launch vehicle, and supporting ground facilities and systems for deep space exploration. SLS leverages previous NASA systems. Orion will carry up to four humans to orbit, provide emergency abort capability, sustain the crew while in space, and provide safe reentry from deep space. Upgraded ground operations capabilities will process flight hardware, assemble and launch the vehicles, and recover crew after the mission.

As part of extensive development efforts, the crew capsule's initial flight test will occur in 2014, when an uncrewed Orion vehicle launches from Cape Canaveral atop a Delta IV launch vehicle, for a check of aerodynamic and thermal performance, structure, and systems during a four-hour, two-orbit flight, 3,600 miles above the Earth. The complete SLS/Orion system will launch uncrewed in FY 2018 for the first Exploration Mission, with SLS carrying an uncrewed Orion vehicle into space for a 25 day journey beyond the Moon and back to Earth. The first crewed mission is scheduled to launch in FY 2021-2022. HEO's Exploration account funds major development and technology efforts.

## **Enabling Deep Space Exploration: Research and Support**

NASA requires enhanced research and technological capabilities to travel beyond low Earth orbit and these activities are well underway. Researchers are studying the effects of long duration space exploration on humans in an effort to safeguard crews and assure mission success. New technologies are finding their way into systems and capabilities geared toward supporting eventual missions to Mars. The demands of deep space require assuring robust communications and data download, while maintaining reliable and affordable access to low Earth orbit. These efforts all continue to be critical priorities within the Space Operations and Exploration accounts.

# EXPLORATION

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		FY 2019
Exploration Systems Development	2883.8	3115.2	<b>2784.4</b>	2863.3	2905.9	2982.1	3106.6
Commercial Spaceflight	525.0	696.0	<b>848.3</b>	872.3	791.7	730.9	172.0
Exploration Research and Development	296.7	302.0	<b>343.4</b>	344.3	351.8	394.7	394.7
<b>Total Budget</b>	<b>3705.5</b>	<b>4113.2</b>	<b>3976.0</b>	<b>4079.9</b>	<b>4049.4</b>	<b>4107.7</b>	<b>3673.4</b>

## Exploration .....EXP-2

### Exploration Systems Development

ORION MULTI-PURPOSE CREW VEHICLE .....	EXP-6
Crew Vehicle Development .....	EXP-8
SPACE LAUNCH SYSTEM .....	EXP-17
Launch Vehicle Development.....	EXP-19
EXPLORATION GROUND SYSTEMS.....	EXP-29
Exploration Ground Systems Development .....	EXP-31

### Commercial Spaceflight

COMMERCIAL CREW .....	EXP-39
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### Exploration Research and Development

HUMAN RESEARCH PROGRAM.....	EXP-46
ADVANCED EXPLORATION SYSTEMS.....	EXP-53

# EXPLORATION

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Exploration Systems Development	2883.8	3115.2	<b>2784.4</b>	2863.3	2905.9	2982.1	3106.6
Commercial Spaceflight	525.0	696.0	<b>848.3</b>	872.3	791.7	730.9	172.0
Exploration Research and Development	296.7	302.0	<b>343.4</b>	344.3	351.8	394.7	394.7
<b>Total Budget</b>	<b>3705.5</b>	<b>4113.2</b>	<b>3976.0</b>	<b>4079.9</b>	<b>4049.4</b>	<b>4107.7</b>	<b>3673.4</b>
Change from FY 2014			<b>-137.2</b>				
Percentage change from FY 2014			<b>-3.3%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Three panels protecting NASA's Orion from the heat, wind, and acoustic loads it will experience during the early part of the climb into space fall away during a successful separation test. The panels jettison as Orion climbs out of the atmosphere to reduce weight and allow Orion to reach orbit.**

As NASA shapes the future of human space exploration, the Agency has developed a unique, multi-destination strategy using a capability-driven approach. Human Exploration and Operations (HEO) programs continue to develop a robust core set of evolving capabilities within the Exploration budget, intended to ensure flexibility, affordability, and sustainability in the Nation's human spaceflight program. This approach provides the Agency adequate flexibility to carry out increasingly complex missions to a range of destinations over time.

HEO's Exploration Systems Development programs are creating the first components of this architecture for human exploration beyond low Earth orbit, leading to the human exploration of Mars. The first, foundational elements include the Orion Multi-Purpose Crew Vehicle, the Space Launch System (SLS), and Exploration Ground Systems (EGS). At the same time, the Commercial Crew Program aims

to reduce reliance on foreign providers for crew access to low Earth orbit. NASA is engaged in partnerships with the private sector to develop commercial systems capable of carrying humans to and from low Earth orbit, similar to the successful approach demonstrated for cargo resupply services to the International Space Station (ISS).

Extending human presence into deep space requires expansion of technical and scientific knowledge to tackle complex problems and devise creative new solutions to meet demands never before encountered by humans or machines. NASA must understand long-term human exposure to space, and address unanticipated effects before sending humans on deep space missions in the Orion crew vehicle. In the



## EXPLORATION

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future, complex missions may rely on technologies not yet developed. This research is underway in the Exploration Research and Development portfolio.

For more programmatic information, go to: <http://www.nasa.gov/directorates/heo/home/index.html>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

In preparation for Exploration Flight Test-1 (EFT-1) in FY 2014, the Orion test module successfully completed proof pressure testing and manufacture of its heat shield, demonstrating that the module can withstand the extremes of the space environment, including re-entry through the Earth's atmosphere. Data from EFT-1 will validate Orion crew vehicle design and operations in preparation for Exploration Mission (EM)-1 in FY 2018. NASA also completed negotiations with the European Space Agency to provide an Orion Service Module and necessary elements of its design for the EM-1 flight. In the summer of 2013, NASA successfully completed the technical Preliminary Design Review for SLS, and began installing tooling for the launch vehicle's large structure manufacturing at the Michoud Assembly Facility.

Advanced Exploration Systems scientists analyzed data gathered by the Radiation Assessment Detector instrument on the Mars Science Laboratory in order to understand radiation exposure, assess its effects on crew health and safety, and plan for future deep space crewed missions. In addition, engineers assembled elements for an advanced suit to replace the more than 30-year-old-design used on Space Shuttle flights. This portable system provides fresh air and cooling for astronauts during extravehicular activity, and will be able to support exploring a variety of destinations in space and on planetary bodies such as the Moon, near-Earth asteroids, and Mars.

NASA's industry partners made significant progress toward developing affordable commercial crew transportation systems to low Earth orbit. Space Exploration Technologies (SpaceX), Blue Origin, Sierra Nevada Corporation, and the Boeing Company completed nearly all of their Commercial Crew Development Round 2 milestones in FY 2013. SpaceX, Sierra Nevada Corporation, and Boeing also completed several significant design and testing milestones under Commercial Crew integrated Capability (CCiCap) agreements. In FY 2013, these companies provided, and NASA reviewed and provided feedback on, the first round of products under the Certification Products Contracts.

### WORK IN PROGRESS IN FY 2014

As an important step toward NASA's goal to extend human space exploration beyond low Earth orbit, the Orion program will finalize preparations and launch EFT-1, which will validate innovative approaches to reduce cost, demonstrate crew vehicle post-landing recovery procedures, and support development of a launch vehicle adapter. EFT-1 is a two-orbit, four-hour mission that will send an uncrewed Orion vehicle more than 3,600 miles above the Earth's surface, returning at a speed of 20,000 miles per hour. EGS modernization and compatibility efforts will continue to develop ground support capabilities required for EM-1, as well as future Orion and SLS missions.

## EXPLORATION

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Advanced Exploration Systems is developing two experiments for EFT-1. The first will measure the radiation environment inside the Orion crew vehicle, and the second is an advanced caution and warning system that will monitor the health of critical vehicle systems. Both experiments will test sensors and systems compatible for Orion to extend human space exploration beyond low Earth orbit.

NASA continues to plan for an initial Asteroid Redirect Mission to capture a small asteroid with a robotic spacecraft and redirect it into a stable orbit. Advanced Exploration Systems will begin developing multi-mission technologies needed for extravehicular activity, crewed systems, and capture systems that are applicable to the asteroid robotic and crewed missions.

CCiCap is advancing partner design and development efforts. Milestones completed to date in FY 2014 include Boeing's Pilot-in-the-loop demonstration, Sierra Nevada's engineering test article flight testing #1, and SpaceX's Dragon parachute test. Before the end of FY 2014, NASA plans to award Commercial Crew transportation Capability (CCtCap) contract(s), based on proposals and available budget. The Agency understands that competition is an important component of the commercial crew program.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2018, NASA will conduct EM-1, which includes launching an uncrewed vehicle to demonstrate the performance of an integrated SLS rocket and uncrewed Orion vehicle prior to EM-2, a crewed flight. In preparation for EM-1, Orion will continue fabrication of the crew module primary structure and start to assemble secondary structures and mechanisms. Additionally, SLS will complete assembly and test of the first of four flight RS-25 engines, finish booster avionics fabrication and test, and begin core stage flight hardware integration.

Commercial Crew industry teams will achieve significant milestones as part of their CCtCap contract(s). These milestones will demonstrate that commercial providers are continuing to mature their capabilities towards NASA's goal of having U.S. crew transportation capability to low Earth orbit and ISS by 2017. Details on the milestones are not available at this time as the contracts have not been awarded yet.

Advanced Exploration Systems activities will continue to support the Bigelow Expandable Activity Module, scheduled to launch on a SpaceX commercial cargo resupply flight to the ISS in 2015. This module will test inflatable structures technology for a deep space habitat on long-duration human missions beyond Orion's 21-day capability. To further enable future human exploration beyond Earth, Advanced Exploration Systems will continue to support the Resource Prospector Mission, which will demonstrate technologies to search for water and ice on the Moon's surface.

The Opportunity, Growth, and Security Initiative (OGSI), discussed elsewhere in this volume, offers opportunities for additional progress in Exploration Systems Development and Commercial Crew. For Exploration Systems Development, it provides an additional \$100.0 million to support and address long lead procurement challenges, reduce or retire technical and programmatic risks, and maintain concurrent development between Orion, SLS, and EGS. This investment will reduce life cycle cost and improve the likelihood of achieving current EM-1 and 2 launch dates. For Commercial Crew, OGSI provides \$250.0 million to enhance competition in the Commercial Crew program and reduce the risk of a schedule slip. Specifically, the OGSI funding will enable early investments in necessary testing and analysis, which, along with competition, will be important for astronaut safety as this crew transportation system is being developed. Please refer to the OGSI section for more detail.

# EXPLORATION

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## Themes

### **EXPLORATION SYSTEMS DEVELOPMENT**

Programs within the Exploration Systems Development theme are developing the core capabilities required to implement NASA's multi-destination strategy. The SLS program is developing the heavy lift vehicle that will launch the crew vehicle, other modules, and cargo for deep space missions. The Orion program is developing the vehicle that will carry the crew to orbit, provide emergency abort capability, sustain the crew while in space, and provide safe reentry from deep space return speeds. The EGS program is working to develop the necessary launch site infrastructure to prepare, assemble, test, launch, and recover the SLS and Orion flight systems. NASA Headquarters is integrating programs to streamline decision making processes, and enable an affordable long term human exploration program.

### **COMMERCIAL SPACEFLIGHT**

The Commercial Crew Program partners with the U.S. private sector to develop and operate safe, reliable, and affordable crew transportation to low Earth orbit. During the development phase of their crew transportation systems, NASA provides technical and financial assistance to industry partners. The program measures progress against fixed-price milestones, proposed by the commercial partners and negotiated with NASA. Once these capabilities mature, NASA will certify the systems and purchase services from these providers to transport crew to the ISS. This commercial approach will bolster American leadership, end U.S. reliance on foreign providers for crew transportation, and stimulate a new space transportation industry. Competition is an important component of the commercial crew program as it is a key to controlling costs over the long term and NASA's Aerospace Safety Advisory Panel has opined that competition should be maintained until safety confidence is achieved.

### **EXPLORATION RESEARCH AND DEVELOPMENT**

Exploration Research and Development consists of two programs, Advanced Exploration Systems and Human Research Program (HRP), which map directly to the U.S. Space Exploration Policy and the NASA Authorization Act of 2010. Advanced Exploration Systems develops exploration technologies applicable to multiple missions and destinations to reduce risk, lower lifecycle cost, and validate operational concepts for future human missions to deep space. Several of these technologies are applicable to NASA's planned Asteroid Redirect Mission. HRP researches the effects of space flight on humans and develops countermeasures to lessen the effects of the hostile space environment on human health and performance. HRP utilizes ground research facilities, the ISS, and analog environments to research issues and develop countermeasures for future missions to deep space destinations, including Mars.

## ORION MULTI-PURPOSE CREW VEHICLE

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Crew Vehicle Development	1089.9	--	<b>1042.3</b>	1085.8	1109.3	1112.4	1116.2
MPCV Program Integration and Support	23.9	--	<b>10.5</b>	10.5	10.5	10.5	10.5
<b>Total Budget</b>	<b>1113.8</b>	<b>1197.0</b>	<b>1052.8</b>	<b>1096.3</b>	<b>1119.8</b>	<b>1122.9</b>	<b>1126.7</b>
Change from FY 2014			<b>-144.2</b>				
Percentage change from FY 2014			<b>-12.0%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA astronauts Rick Linnehan and Mike Foreman experience what it will be like to launch into space aboard Orion, using prototype display and control systems in an ascent simulator at JSC in Texas.

When astronauts venture beyond low Earth orbit for the first time since the Apollo program in the 1960s and early 1970s, they will travel aboard NASA's new Orion Multi-Purpose Crew Vehicle. This capsule-shaped vehicle has a familiar look, but its crew and service modules, spacecraft adapter, and launch abort system incorporate numerous technology advancements and innovations. For example, Orion's revolutionary launch abort system can activate within milliseconds to pull the crew to safety and position the module for a safe landing. The spacecraft's unique propulsion, thermal protection, avionics, and life support systems will enable extended duration missions beyond low Earth orbit and into deep space. Due to the vehicle's modular design, additional new technical innovations can be integrated as they become available.

After uncrewed test flights planned for FY 2014 and FY 2018, Orion will be ready for crewed flights in FY 2021-2022. Test flights of the Space Launch System (SLS) and Orion crew vehicle will support the Agency's proposed mission to find, capture, redirect, and study a near-Earth asteroid. This series of activities will use the proving ground of cis-lunar space to develop the systems and procedures necessary for Mars-class missions.

For further programmatic information, go to: <http://www.nasa.gov/orion>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

Exploration Systems Development has reviewed the allocation of program integration and support activities across SLS, Orion, and Exploration Ground Systems (EGS). Beginning in FY 2015, NASA has

## **ORION MULTI-PURPOSE CREW VEHICLE**

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reallocated specific activities (e.g., general IT requirements, audit support, and long-range exploration studies) from SLS and Orion to EGS, to better balance the distribution of content across the three programs. Previously, only SLS and Orion funded these activities.

### **Program Elements**

#### **ORION MPCV PROGRAM INTEGRATION AND SUPPORT**

The Orion program integration and support activities manage the interfaces to the SLS and Exploration Ground Systems programs. This effort is critical to making sure the system's technical performance meets technical and safety specifications, and supports programmatic assessment, which results in integrated technical, cost and schedule management. In addition, the Orion integration effort is critical to managing interfaces with other HEO activities, including strategic studies, feasibility studies, and small scale research tasks that feed into future human exploration. This ensures coordination and timely integration to avoid potential design and cost issues.

#### **CREW VEHICLE DEVELOPMENT**

See the Crew Vehicle Development section.

## CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>1089.9</b>	<b>--</b>	<b>1042.3</b>	<b>1085.8</b>	<b>1109.3</b>	<b>1112.4</b>	<b>1116.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Technicians work inside the Orion crew module at KSC in Florida to prepare for initial power up of the capsule's avionics system in October 2013. This activity marks a major milestone in Orion's final year of preparations before its first mission, Exploration Flight Test-1, scheduled for September 2014.

### PROJECT PURPOSE

As NASA reaches beyond low Earth orbit to destinations across the solar system, the Orion Multi-Purpose Crew Vehicle will be capable of transporting humans to multiple destinations beyond our moon and into deep space, and sustaining them longer than ever before. Drawing from more than 50 years of spaceflight research and development, Orion's design will meet the evolving needs of our nation's space program, and push the envelope of human spaceflight for years to come.

For further programmatic information, go to:

<http://www.nasa.gov/orion>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PRELIMINARY PARAMETERS

Orion will be able to carry a crew of four astronauts beyond Earth orbit for 21 days. The spacecraft's three components include the crew module, service module, and launch abort system, with a separate adapter to connect the crew and launch vehicles. The crew module is a familiar capsule shape on the outside, but inside it contains state-of-the-art crew systems. During a mission, Orion will house the crew, providing a safe environment within which to live and work. Its advanced heat shield will protect the crew from reentry heating during a high-speed return from beyond Earth's orbit. The service module is comprised of a crew module adapter and a European Space Agency (ESA)-designed and developed service module, that together provide in-space services to the crew module, including power, propulsion, and other life

## CREW VEHICLE DEVELOPMENT

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Formulation	Development	Operations
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support systems. On a tower atop the crew module, sits the launch abort system, which, in the event of an emergency during launch or climb to orbit, will activate within milliseconds to propel the crew module away from the launch vehicle to safety. This system will also protect the crew module from dangerous atmospheric loads and heating. Once Orion is out of the atmosphere and safely on its way to orbit, the spacecraft will jettison the launch abort system.

### ACHIEVEMENTS IN FY 2013

During FY 2013, Orion made significant progress on manufacturing the Exploration Flight Test (EFT)-1 article, with nearly 10,000 drawings and almost 60,000 components delivered to KSC for installation on the vehicle. The crew module successfully completed proof pressure testing, demonstrating that the crew module is able to withstand the extremes of the space environment. Orion also completed the heat shield structure manufacturing and application of the protective coating. The heat shield will safeguard the crew and spacecraft from the thermal conditions it will experience from a high-energy re-entry through the Earth's atmosphere during EFT-1, which will fly in 2014.

In parallel with the significant work associated with the EFT-1 mission, NASA and ESA opened a new chapter in an ongoing partnership, with ESA committing to provide a service module for the Exploration Mission (EM)-1 spacecraft. In FY 2013, ESA worked closely with NASA to prepare the preliminary design of the European Service Module and its test plan. Orion also continued testing to ensure the safety and success of the first crewed flights. NASA performed ground testing at facilities across the country, and during the year, accomplishments included parachute, water impact and recovery, structural, and space environment testing on the crew module, as well as a spacecraft adapter jettison fairing separation test.

### WORK IN PROGRESS IN FY 2014

Orion will finalize flight preparations for EFT-1, an important pathfinder test to validate innovative approaches to space systems development that will reduce cost, demonstrate spacecraft post-landing recovery procedures, and develop the launch vehicle adapter, which will be flown on future Orion missions, as well. EFT-1 is a two-orbit, four-hour mission that will send the uncrewed module more than 3,600 miles above the Earth's surface, returning at a speed of 20,000 miles per hour. During the flight, Orion's instrumentation will gather data, which will inform the program on design decisions and validate existing computer models. The flight test will also significantly reduce or eliminate 10 of the top 16 risk design drivers; demonstrate 47 percent of the design, development, test and evaluation; and include 50 percent of the software required for the first crewed flight, scheduled for FY 2021-2022. Detailed EFT-1 mission planning with the JSC mission operations team will continue throughout the year, in support of Orion program and the prime contractor, Lockheed-Martin, activities. Orion's crew and service modules will be integrated and flight-ready by the summer of 2014. During that same time, the Delta IV launch vehicle will be ready for flight, and integration of all flight test components – including the launch abort system – will begin. The Delta IV launch vehicle will be delivered in two shipments, arriving at KSC in March and April 2014. The EFT-1 launch window at Cape Canaveral Air Force Station opens in September 2014, and extends into the first quarter of FY 2015.

## CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations
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Orion will also begin manufacturing components for EM-1, forging elements for the primary structure, building avionics kits, and procuring parts with a long lead time. In addition, the program will continue supporting ESA with Orion service module design and testing.

The program has rigorously focused on a campaign to validate the capabilities needed in the deep space environment, and improved its test and verification strategy to increase confidence in Orion's crew capability. The plan shifted from using flight hardware to designated test articles for structural and environmental testing. By utilizing test articles, the program will reduce schedule risk and the potential of damaging flight hardware during testing. In addition, Orion's ascent abort flight test moved from FY 2018 to FY 2019 to allow time to incorporate any potential changes required as a result of the EM-1 launch. This test will evaluate the launch abort system's ability to separate and maneuver the crew module out of the launch vehicle's flight path during an emergency in the initial ascent phase; this is crucial to assuring range safety for the first crewed flight in FY 2021-2022.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, the program will focus on preparing for Orion's first exploration mission. EM-1 is an uncrewed test flight to lunar orbit, and will be the first pairing of Orion with the Space Launch System. The multi-day flight will provide the program with data, which, combined with data gained from EFT-1, will validate spacecraft design and operations. Orion will continue fabricating the crew module primary structure, and start to assemble secondary structures and mechanisms such as propulsion systems, and environmental control and life support. Orion will also complete its series of parachute tests and begin testing spacecraft avionics. Finally, the program will complete key programmatic reviews, ensuring Orion's readiness to progress to the next phase of the development life cycle.

### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Key Decision Point (KDP)-A, Formulation Authorization	Feb 2012	Feb 2012
System Requirements Review (SRR)		Mar 2007
System Definition Review (SDR)		Aug 2007
PDR		Aug 2009
Resynchronization Review		Jul 2012
KDP-B	Q1 FY 2013	Jan 2013
"Delta" PDR	Q4 FY 2013	Q4 FY 2014
EFT-1 Launch		Q4 FY 2014



## CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations
Milestone	Formulation Authorization Document	FY 2015 PB Request
KDP-C, Project Confirmation	FY 2015	Q1 FY 2015
Critical Design Review (CDR)		Q3 FY 2015
EM-1 Launch		FY 2018
EM-2 Launch		FY 2021 - 2022

### **Formulation Estimated Life Cycle Cost Range and Schedule Range Summary**

KDP-B certifies that the proposed mission and system architecture are credible and responsive to program requirements and constraints, including resources. Additionally, the maturity of the project's mission and system definition and associated plans is sufficient to begin Phase B. Mission achievement is likely within available resources and acceptable risk.

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Jan 2013	\$8,534.1 to \$10,288.6	EM-2 Launch, plus one quarter	EM-2 Launch: Aug 2021

## CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### Project Management & Commitments

JSC manages Orion crew vehicle development, supported by many of the other NASA centers as shown in the table below.

Element	Description	Provider Details	Change from Formulation Agreement
Crew Module	The crew module is the transportation capsule that provides a safe habitat for the crew as well as storage for consumables and research instruments, and serves as the docking port for crew transfers.	Provider: JSC Lead Center: JSC Performing Center(s): ARC, GRC, JSC, and LaRC Cost Share Partner(s): N/A	None
Service Module	The service module supports the crew module from launch through separation prior to reentry.	Provider: JSC Lead Center: JSC Performing Center(s): ARC, JSC, LaRC, and GRC Cost Share Partner(s): ESA	None
Launch Abort System	The launch abort system maneuvers the crew module to safety in the event of an emergency during launch or climb to orbit	Provider: JSC Lead Center: LaRC Performing Center(s): JSC, LaRC, and MSFC Cost Share Partner(s): N/A	None

### Project Risks

Risk Statement	Mitigation
If: The existing barter agreement between NASA and ESA does not offset the cost of Orion's service module work package 2, for EM-2, Then: Funding offsets would need to be found or the schedule would slip.	Orion will continue to try to identify possible barter elements from the entire NASA portfolio to offset the cost of work package 2.
If: The Orion test and verification plan increases the reliance on spacecraft component and subsystem testing, Then: There is a potential of increased risk of technical issues in higher-level systems.	Orion will continue to develop guidelines to implement the component qualification approach, validate the proposed test campaign to the flight test objectives to identify gaps and risks, and assess and reduce risk to flight hardware.

## CREW VEHICLE DEVELOPMENT

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Formulation	Development	Operations
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### Acquisition Strategy

NASA is using a competitively awarded contract to Lockheed Martin Corporation for Orion's design development, test, and evaluation. The contract was awarded in 2006, and reaffirmed in 2011 as part of reformulating the Orion Crew Exploration Vehicle as the Orion program. In order to meet NASA and Human Exploration and Operations Mission Directorate requirements, Orion extended its design and development schedule by approximately six years. Because this extension is beyond the timeframe of the original contract with Lockheed Martin, Orion is in the process of definitizing a contract extension to account for design and development schedule and changes to mission requirements.

NASA signed an Implementing Arrangement with ESA to provide a service module for the Orion spacecraft's EM-1.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Orion Design and Development	Lockheed Martin	Littleton, CO

## CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
SRR	Standing Review Board (SRB)	Mar 2007	Evaluates the program's functional and performance requirements ensuring proper formulation and correlation with Agency, and Mission Directorate's strategic objectives; assesses the credibility of the program's estimated budget and schedule.	Program cleared to proceed to next phase.	N/A
SDR	SRB	Aug 2007	Evaluates proposed program requirements and architecture; allocation of requirements to initial projects; assesses the adequacy of project pre-formulation efforts; determines if maturity of the program's definition and plans are sufficient to begin implementation.	Program cleared to proceed to next phase.	N/A

## CREW VEHICLE DEVELOPMENT

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
PDR	SRB	2009	Evaluates completeness and consistency of the program's preliminary design, including its projects, is meeting all requirements with appropriate margins, acceptable risk, and within cost and schedule constraints; determines the program's readiness to proceed with the detailed design phase.	Program cleared to proceed to next phase.	N/A
Resynchronization Review	SRB	Jul 2012	Realign the program's preliminary design to the requirements of Exploration system development. NASA policies allow changes to a program's management agreement in response to internal and external events. An amendment to the decision memorandum signed at the KDP-B review held prior to the PDR if a significant divergence occurs.	Program cleared to proceed to next phase.	N/A

## CREW VEHICLE DEVELOPMENT

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
"Delta" PDR	SRB	TBD	Updates the program's preliminary design ensures completeness and consistency; determines the program's readiness to proceed with the detailed design phase.	TBD	Q4 FY 2014
CDR	SRB	TBD	This review evaluates the integrity of the program's integrated design. This includes its projects and ground systems, its ability to meet mission requirements with appropriate margins and acceptable risk, planned within cost and schedule constraints; determines if the integrated design is appropriately mature to continue with the final design and fabrication phase.	TBD	Q3 FY 2015

## SPACE LAUNCH SYSTEM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		FY 2015	Notional			
	FY 2013	FY 2014		FY 2016	FY 2017	FY 2018	FY 2019
Launch Vehicle Development	1376.4	--	1350.7	1313.5	1268.6	1332.8	1441.8
SLS Program Integration and Support	38.5	--	29.6	43.4	85.2	85.2	85.1
<b>Total in FY15 Budget Structure</b>	<b>1414.9</b>	<b>1600.0</b>	<b>1380.3</b>	<b>1356.9</b>	<b>1353.8</b>	<b>1418.0</b>	<b>1526.9</b>
Programmatic CoF in CECR Account	252.6	--	52.3	0.0	0.0	0.0	0.0
Exploration Ground Systems	355.1	318.2	351.3	410.1	432.3	441.2	453.0
<b>Total in FY12 Budget Structure</b>	<b>2022.6</b>	<b>--</b>	<b>1783.9</b>	<b>1767.0</b>	<b>1786.1</b>	<b>1859.1</b>	<b>1979.9</b>
Change from FY 2014	--	--	-219.7				
Percentage change from FY 2014	--	--	-13.7 %				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Change from FY 2014 and Percentage change from FY 2014 calculated against "TOTAL in FY15 Budget Structure" row.*



NASA finished welding the first "pathfinder" barrel section for the SLS core stage at Louisiana's Michoud Assembly Facility in July 2013. The core stage will consist of eight stacked barrel sections for a total height of 211 feet. While the launch system will be over three times more massive than the Space Shuttle external tank, advanced manufacturing techniques will reduce the number of major tools and labor by more than 50 percent.

The NASA Authorization Act of 2010 directed the Agency to develop a follow-on government-owned civil launch system developed, managed, and operated by NASA to serve as a key component to expand human presence beyond low Earth orbit. For the first time since the final Saturn V launch in 1973, the Space Launch System (SLS) will allow crews and equipment to travel farther into deep space than now possible. Crewed missions will explore the solar system's mineral-rich asteroids, and eventually, the mountains and canyons of Mars. Early SLS and Orion Multi-Purpose Crew Vehicle testing will support the Agency's proposed mission to find, capture, redirect, and study a near-Earth asteroid. The enhanced lift capability of SLS will enable robotic science missions in the decades ahead that were previously not possible.

SLS capability will evolve using a block upgrade approach, driven by exploration

mission requirements. Human exploration beyond low Earth orbit is simplified by using a launch vehicle like SLS with far greater payload lift capacity than any existing system. In the near term, SLS will

## **SPACE LAUNCH SYSTEM**

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achieve a 70-metric ton lift capability that will enable early system demonstrations such as test flights near the Moon. Follow-on upgrades will improve vehicle lift performance to 105 metric tons, expanding deep space mission capability, with an ultimate evolutionary capability to 130 metric tons.

NASA is leveraging a half-century of experience with heavy-lift vehicles like Saturn and the Space Shuttle, along with advances in technology and manufacturing practices, to build and operate SLS at less cost and risk than previous heavy lift designs.

For further programmatic information, go to: <http://www.nasa.gov/exploration/systems/sls/index.html>.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

Exploration Systems Development has reviewed the allocation of program integration and support activities across SLS, Orion, and Exploration Ground Systems (EGS). Beginning in FY 2015, NASA has reallocated specific activities (e.g., general IT requirements, audit support, and long-range exploration studies) from SLS and Orion to EGS, to better balance the distribution of content across the three programs. Previously, only SLS and Orion funded these activities.

## **Program Elements**

### **SLS PROGRAM INTEGRATION AND SUPPORT**

In addition to the launch vehicle development effort, SLS program integration and support manages the interfaces between the SLS, Orion, and EGS to ensure that all necessary cross-program activities occur. This effort is critical to assuring system performance meets technical and safety requirements, and supports the program assessment that results in integrated technical, cost and schedule management. Additionally, SLS integration is key to managing the program's interface with other mission directorate activities, including strategic studies, feasibility studies, and small-scale research tasks that enable future human exploration.

### **LAUNCH VEHICLE DEVELOPMENT**

See Launch Vehicle Development section.



## LAUNCH VEHICLE DEVELOPMENT

Formulation	Development				Operations			
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional					BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019			
Formulation	1480.0	1376.4	TBD	TBD	TBD	TBD	TBD	TBD		TBD	TBD
Development/Implementation	0.0	0.0	TBD	TBD	TBD	TBD	TBD	TBD		TBD	TBD
Operations/Close-out	0.0	0.0	TBD	TBD	TBD	TBD	TBD	TBD		TBD	TBD
<b>2015 MPAR LCC Estimate</b>	<b>1480.0</b>	<b>1376.4</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>		<b>TBD</b>	<b>TBD</b>
<b>Total Budget</b>	<b>1480.0</b>	<b>1376.4</b>	<b>1557.7</b>	<b>1350.7</b>	<b>1313.5</b>	<b>1268.6</b>	<b>1332.8</b>	<b>1441.8</b>		<b>TBD</b>	<b>TBD</b>
Change from FY 2014				-206.7							
Percentage change from FY 2014				-13.3%							



A technician performs a final check on the solid rocket booster avionics test article for in preparation for the second flight control test of NASA's Space Launch System at the ATK facility in Promontory, Utah. These avionics and boosters will be part of the first two flights of the Space Launch System – America's next heavy-lift launch vehicle managed by NASA's Marshall Space Flight Center in Huntsville, Alabama.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Once the SLS Key Decision Point (KDP)-C is completed (expected in April 2014), NASA will provide this data in a revision to the Congressional Justification.*

### PROJECT PURPOSE

As NASA expands its focus for human spaceflight to destinations across the solar system, the Launch Vehicle Development project will enable deep space exploration with the SLS launch vehicle. This massive rocket will have a lift capability more than two and half times that of any launch vehicle currently in operation. For the first time since the

Apollo program, American astronauts will be able to explore space beyond low Earth orbit. In addition, the vehicle's lift capability may enable robotic science missions that are not possible today.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

## LAUNCH VEHICLE DEVELOPMENT

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Formulation	Development	Operations
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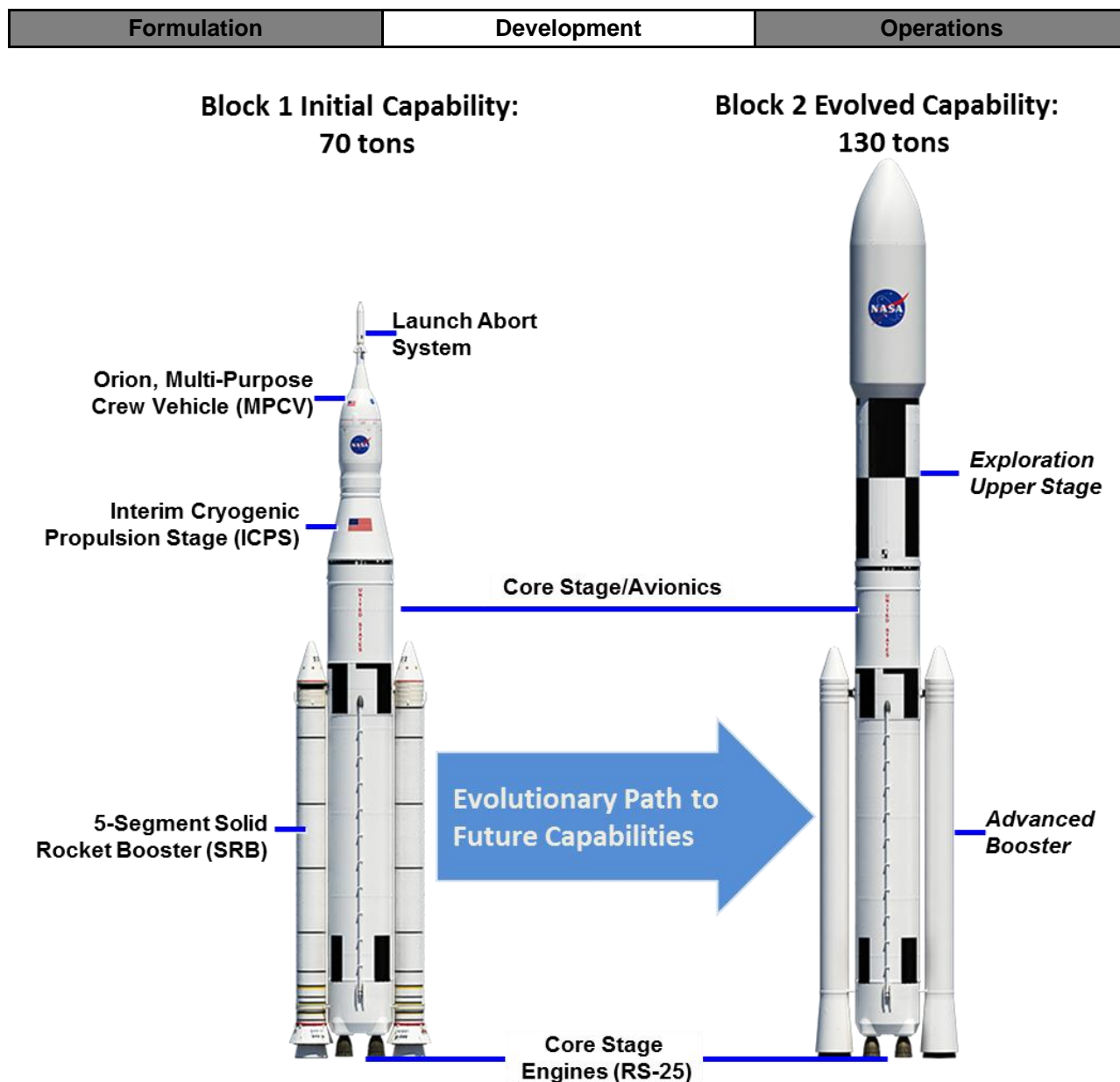
### PROJECT PARAMETERS

Launch Vehicle Development will work to achieve cost, schedule, and performance goals by utilizing hardware designed for previous projects, including Space Shuttle main engines, Constellation five-segment solid rocket boosters, and a Delta-IV design interim cryogenic propulsion stage. The program benefits from NASA's half-century of experience with liquid oxygen and liquid hydrogen heavy-lift vehicles, and from advances in technology and manufacturing practices.

The SLS vehicle design will be flexible and evolvable, based on mission requirements. Each evolution shares the same basic core stage to allow for different crew and cargo requirements as needed, in an effort to achieve efficiency, time, and cost savings. SLS will provide unique capabilities for human and robotic exploration missions beyond low Earth orbit, including travel to asteroids, Mars, and other destinations within our solar system.

The initial SLS will achieve a 70 metric ton initial lift capability that will enable early system demonstrations such as test flights near the Moon. Follow-on upgrades will improve vehicle lift performance to 105 metric tons, expanding deep space mission capability, with an ultimate evolutionary capability to 130 metric tons.

## LAUNCH VEHICLE DEVELOPMENT



### ACHIEVEMENTS IN FY 2013

In August 2013, SLS successfully completed the Preliminary Design Review (PDR), which evaluated whether the design met all requirements with appropriate margins, acceptable risk, and within cost and schedule constraints. Experts on 11 different review teams participated in the design review process; the analysis consisted of approximately 200 documents and 15 terabytes of data. As a result of this successful review, the program can now proceed with the detailed design.

Significant progress occurred in hardware development and facility readiness. In January, the program completed the final vertical weld on the first production Orion stage adapter, which will fly on

## LAUNCH VEHICLE DEVELOPMENT

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Formulation	Development	Operations
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Exploration Flight Test (EFT)-1 mission. In preparation for SLS core stage testing in the first quarter of 2016, refurbishment and facility buildup work continued on the B-2 test stand at SSC, with initial structural contracts awarded this year. Other test stand activity included demolition and restoration of the fixed and rolling decks. J-2X upper stage engine testing at SSC continued, with six tests completed for a total of 2,300 seconds on the A-2 test stand. Additionally, preparation began at Michoud Assembly Facility for production of SLS testing and flight articles. Other Michoud work included demolition, tool installation, liquid hydrogen 2 proof test construction, and roof repairs. Booster contract negotiations with Alliant Techsystems, Inc. were completed in July 2013. In addition, the program installed all tooling at Michoud Assembly Facility except for the Vertical Assembly Center, and completed production of eight full-scale models of the core stage for process checkout.

### WORK IN PROGRESS IN FY 2014

In January 2014, SLS completed all technical requirements associated with Key Decision Point (KDP)-C; the decision memo will be finalized in early April. Also in January, SLS completed handover of the Orion spacecraft adapter, which will support the EFT-1 launch later in the year. The program is also on track to complete integration of development avionics into the software integration test facility. This activity will help reduce overall program risk by enabling the start of integrated testing. Avionics and software are typically the highest risk areas for a development program, and early development and testing will buy down this risk. Booster and core stage elements will conduct Critical Design Reviews (CDRs) to determine if the current design is sufficiently mature to continue with final design and fabrication. Next, SLS will manufacture Exploration Mission (EM)-1 flight hardware including the interim cryogenic propulsion stage, boosters, major core stage flight components (tanks, engine structure, intertank, and forward skirt), as well as the launch vehicle stage adapter structural test article. The project will complete acceptance of the Vertical Assembly Center and modification of A-1 test stand at SSC, in support of testing the RS-25 engine that powers the core stage. SLS will complete contract actions for core stages and interim cryogenic propulsion stage. The program will also award the final work package for super structure and flame deflector repairs on the B-2 test stand.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

SLS will complete its CDR to evaluate the integrity of the program-integrated design. In addition, this review will determine if the project is appropriately mature to continue with the final design and fabrication phase. The spacecraft and payload integration office will conduct element level CDRs prior to the overall program review.

SLS will complete a significant amount of hardware, including the core stage liquid hydrogen tank, liquid oxygen tank, intertank, forward skirt, and engine structure. This includes completing structural test article facilities at MSFC and qualification avionics integrated into the software integration test facility. The project will also begin qualification testing of the liquid hydrogen tank, liquid oxygen tank, engine structure, intertank, and forward skirt. In support of EM-1, the project will complete assembly and test of the first flight RS-25 engine, finish booster avionics fabrication and test, begin integration of core stage flight hardware at the Michoud Assembly Facility, and start the booster thrust vector control assembly. In addition, they will complete final design analysis cycle and Vertical Assembly Center weld development.

## LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### SCHEDULE COMMITMENTS/KEY MILESTONES

Once the SLS KDP-C is completed (expected in April 2014), NASA will provide updated data in a revision to the Congressional Justification.

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	Nov 2011	Nov 2011
Systems Requirements Review (SRR) / Systems Definition Review (SDR)	Q2 FY 2012	Q3 FY 2012
KDP-B	Q4 FY 2012	Q4 FY 2012
PDR	Q1 FY 2014	Q4 FY 2013
KDP-C	Q1 FY 2014	Q2 FY 2014
CDR	Q2 FY 2015	Q2 FY 2015
KDP-D	Q1 FY 2016	Q3 FY 2017
EM-1 Launch	Dec 2017	FY 2018
EM-2 Launch	Aug 2021	FY 2021 - 2022

### Development Cost and Schedule

Once the SLS KDP-C is completed (expected in April 2014), NASA will provide this data in a revision to the Congressional Justification.

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

## LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### Development Cost Details

Once the SLS KDP-C is completed (expected in April 2014), NASA will provide this data in a revision to the Congressional Justification.

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>			
Aircraft/Spacecraft			
Payloads			
Systems I&T			
Launch Vehicle			
Ground Systems			
Science/Technology			
Other Direct Project Costs			

### Project Management & Commitments

Element	Description	Provider Details	Change from Baseline
Booster	Responsible for development, testing, production, and support for the five-segment solid rocket motor to be used on initial capability flights.	Provider: MSFC Lead Center: MSFC Performing Center(s): MSFC and SSC Cost Share Partner(s): N/A	None
Engines	Responsible for development and/or testing, production, and support for both core stage (RS-25) and upper stage (J-2X) liquid engines.	Provider: MSFC Lead Center: MSFC Performing Center(s): MSFC and SSC Cost Share Partner(s): N/A	None
Stages	Responsible for development, testing, production, and support of hardware elements for both the core and upper stages, including liquid engine and avionics integration.	Provider: MSFC Lead Center: MSFC Performing Center(s): MSFC, SSC, and KSC Cost Share Partner(s): N/A	None

## LAUNCH VEHICLE DEVELOPMENT

Formulation		Development	Operations
Element	Description	Provider Details	Change from Baseline
Spacecraft Payloads and Integration	Responsible for development, testing, production, and support of hardware elements for integrating the Orion and payloads onto SLS, including the interim cryogenic propulsion stage, Orion stage adapter, launch vehicle stage adapter, and payload fairings.	Provider: MSFC Lead Center: MSFC Performing Center(s): MSFC, SSC, and KSC Cost Share Partner(s): N/A	None

## Project Risks

Once the SLS KDP-C is completed (expected in April 2014), NASA will provide updated data in a revision to the Congressional Justification.

Risk Statement	Mitigation
<p>If: Significant design modifications are required to increase performance, increase structural margins, and/or human-rate the Interim Cryogenic Propulsion Stage (ICPS),</p> <p>Then: ICPS costs could increase and/or the development schedule could slip.</p>	<p>The SLS PDR will include performance, margin, and loads analyses that will envelope both Block 1 and planned upgrades. The PDR follows NASA best practices of utilizing various ground rules and assumptions to provide mass and performance margins for factors such as crew safety, booster performance variability, propellant loading uncertainty, engine performance variations, proper orbital disposal of stages, and in-space performance. In addition, prudent design practice requires payload reserves during development of systems to allow for mass growth from obsolesce to modern manufacturing to unknown integrated system interaction.</p>

## LAUNCH VEHICLE DEVELOPMENT

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Formulation	Development	Operations
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### Acquisition Strategy

Procurement for SLS launch vehicle development meets the Agency's requirement to provide an affordable and evolvable vehicle, within a schedule that supports various mission requirements. Procurements include use of existing assets to expedite development, as well as further development of technologies and future competitions for advanced systems and key technology areas specific to SLS vehicle needs. April 2013 saw the completion of the booster contract negotiations with Alliant Techsystems, Inc. In August 2013, the engine contract negotiations with Aerojet-Rocketdyne were completed. NASA is negotiating with the core stage and ICPS vendors to finalize contracts in FY 2014.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Boosters (qualification motors and first two test flights)	Alliant Techsystems, Inc.	Magna, UT
Core Stage Engine (RS-25)	Aerojet-Rocketdyne	Desoto Park, CA
Interim Cryogenic Propulsion Stage	Boeing Aerospace	Huntsville, AL
Core and Upper Stages	Boeing Aerospace	Huntsville, AL



## LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations
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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
SRR/SDR	Standing Review Board (SRB)	Jun 2012	<p>The purpose of the SRR is to evaluate whether the functional and performance requirements defined for the system are responsive to the program's requirements on the project and represent achievable capabilities.</p> <p>The purpose of the SDR is to evaluate the credibility and responsiveness of the proposed mission/system architecture to the program requirements and constraints, including available resources. To determine whether the maturity of the project's mission/system definition and associated plans are sufficient to begin Phase B.</p> <p>The SLS program combined the SRR and SDR into a single KDP-B review, as allowed by NASA NPR 7120.5.</p>	The SRB found the SLS program system architecture approach credible and responsive to program requirements and constraints, including resources. The maturity of the project's system definition and associated plans is sufficient to begin Phase B.	N/A

## LAUNCH VEHICLE DEVELOPMENT

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
PDR	SRB	Aug 2013	The purpose of the PDR is to evaluate the completeness/ consistency of the planning, technical, cost, and schedule baselines developed during formulation, assess compliance of the preliminary design with applicable requirements, and to determine if the project is sufficiently mature to begin Phase C.	The SRB evaluated the project and determined the project is sufficiently mature to begin Phase C.	N/A
CDR	SRB	TBD	The purpose of the CDR is to evaluate the integrity of the project design and its ability to meet mission requirements with appropriate margins and acceptable risk within defined project constraints, including available resources. To determine if the design is appropriately mature to continue with the final design and fabrication phase.	TBD	Q2-FY 2015

## EXPLORATION GROUND SYSTEMS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Exploration Ground Systems Development	355.1	318.2	320.6	390.9	417.1	425.9	437.7
EGS Program Integration and Support	0.0	0.0	30.7	19.1	15.3	15.3	15.3
<b>Total Budget</b>	<b>355.1</b>	<b>318.2</b>	<b>351.3</b>	<b>410.1</b>	<b>432.3</b>	<b>441.2</b>	<b>453.0</b>
Change from FY 2014			33.1				
Percentage change from FY 2014			10.4%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



An aerial view of Launch Pad 39B at KSC in Florida, where EGS is developing the necessary ground systems while refurbishing and upgrading infrastructure and facilities to process and launch next-generation vehicles and spacecraft designed to achieve the Agency's goals for space exploration.

The NASA Authorization Act of 2010 directed the Agency to develop an exploration-class rocket and crew vehicle to allow human exploration beyond low Earth orbit for the first time since the final Saturn V rocket launch in 1973.

At KSC in Florida, Exploration Ground Systems (EGS) is propelling this vision forward. The program's primary objective is to prepare KSC to process and launch next-generation vehicles and spacecraft designed to achieve NASA's goals for space exploration. To achieve this transformation, program personnel are developing the necessary ground systems while refurbishing and upgrading infrastructure and facilities to meet tomorrow's demands. Drawing on five decades of experience in processing and

launching missions, EGS is paving the way to transport humans and equipment farther into deep space than currently possible.

For further programmatic information, go to: <http://go.nasa.gov/groundsystems>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

Exploration Systems Development has reviewed the allocation of program integration and support activities across SLS, Orion, and EGS. Beginning in FY 2015, NASA has reallocated specific activities (e.g., general IT requirements, audit support, and long-range exploration studies) from SLS and Orion to

## **EXPLORATION GROUND SYSTEMS**

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EGS, to better balance the distribution of content across the three programs. Previously, only SLS and Orion funded these activities.

### **Program Elements**

#### **EGS PROGRAM INTEGRATION AND SUPPORT**

EGS program integration and support activities manage the interfaces to the SLS and Orion programs. This effort is critical to ensuring that ground systems performance meets technical and safety specifications, and supports programmatic assessment, which results in integrated technical, cost, and schedule management. In addition, the EGS integration effort is vital to managing interfaces with other HEO activities, including strategic studies, feasibility studies, and small scale research tasks that feed into future human exploration. This effort ensures coordination and timely integration across all three programs to avoid potential design overlaps, schedule disconnects, and cost issues.

#### **EXPLORATION GROUND SYSTEMS DEVELOPMENT**

See the Exploration Ground Systems Development section.

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	355.1	318.2	320.6	390.9	417.1	425.9	437.7
Change from FY 2014			2.4				
Percentage change from FY 2014			0.8%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Originally designed to carry the Space Shuttle from the Vehicle Assembly Building to the launch pad, NASA's crawler-transporter at Kennedy Space Center undergoes modifications to enable transport of launch vehicles currently in development, such as the Space Launch System. Here, technicians make steady progress on the installation of new bearings to help increase the crawler's lifting capacity from 12 million to 18 million pounds.

### PROJECT PURPOSE

As NASA enters a new era in human space exploration, space operations at KSC are evolving to support Space Launch System (SLS) and Orion integration and launch. The Exploration Ground Systems (EGS) is developing the necessary ground systems infrastructure to support the assembly, test, launch, and recovery of SLS and Orion elements.

For more programmatic information, go to: <http://go.nasa.gov/groundsystems>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### PROJECT PRELIMINARY PARAMETERS

EGS is modernizing and upgrading KSC ground systems and facilities required to integrate SLS and Orion, move the integrated vehicle to the launch pad, and successfully launch it into space. Many of the current ground systems and facilities date back to the Apollo era, so modernization is critical to the program's ability to assemble, test, launch, and recover SLS and Orion elements. For Exploration Mission (EM)-1 and EM-2, the EGS team is developing procedures and protocols to process the spacecraft, rocket stages, and launch abort system before assembly into one vehicle. Other work required to launch

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

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Formulation	Development	Operations
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astronauts into space includes modifying the mobile launcher and the crawler-transporters, preparing launch pad 39B, and modernizing computers, tracking systems, and other networks.

### ACHIEVEMENTS IN FY 2013

EGS continued modification to various KSC ground systems and facilities required to support EM-1 and EM-2 – NASA’s first test flights of the integrated SLS and Orion vehicles. The Agency awarded a contract to modify the mobile launcher to ensure that it is structurally sound and outfitted to meet both SLS and Orion requirements. The program finished refurbishing several Launch Complex 39B systems, including Pad B instrumentation, and continued development of ground support equipment. EGS also completed initial installation of command, control hardware installation, and implemented initial voice, video, and data infrastructure for the firing room. NASA also awarded the construction contract for phase II of the multi-payload processing facility, to enable Orion hazardous payload processing. In addition, the program completed design and began construction efforts to re-rock the crawlerway. Finally, the Agency signed a Memorandum of Agreement with the Department of Defense to provide a recovery ship for Exploration Flight Test 1 (EFT-1), scheduled to launch on a Delta IV rocket in September 2014.

### WORK IN PROGRESS IN FY 2014

Modernization and compatibility efforts will continue in FY 2014 to support the EM-1 launch. The program will enter the implementation phase of its life cycle, where final designs and initial fabrication take place. Major infrastructure enhancements will continue to prepare launch pad 39B for the EM-1 mission and future flights. Enhancements such as the flame trench, flame deflector, ignition overpressure, and sound suppression system, will safely channel the extraordinary energy released by the rocket away from critical systems. To provide ground crew access to the launch vehicle and Orion while on the mobile launcher, upgrades are underway to the aging ground support equipment and umbilical outfitting on the upper stage, core stage and crew access arm. Additionally, the team will finish designing new adjustable high-bay access platforms, and award the construction contract. Installing these platforms will assure maximum vehicle and spacecraft access in the vehicle assembly building, where vertical stacking of the SLS and Orion will occur.

EGS will recover the crew module during the EFT-1 mission, while ongoing landing recovery planning and design are underway in support of EM-1. End-to-end spaceport command and control system applications and displays will be in work, along with transmission, imagery, and voice communication. Integrated verification and validation activity will begin, in order to ensure mission success and seamless integration and launch site processing during EM-1.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, the program will complete its Critical Design Review (CDR) to evaluate the integrity of the ground system design, and its ability to meet mission requirements within available resources with appropriate margins and acceptable risk. This review will determine if the design is appropriately mature to continue to the final design and fabrication phase.

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations
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The program will continue structural and facility modifications on the mobile launcher, and complete ground support equipment installation. In the vehicle assembly building, construction of adjustable high-bay platforms will continue, providing access levels required to process the SLS vehicle. At Launch Complex 39B, EGS will complete demolition on the Pad B flame trench/flame deflector, as well as modifications for infrastructure and propellant and gas systems.

EGS will also continue installing and upgrading software to support end-to-end spaceport command and control system applications, and displays required to establish that capability in a majority of the ground processing facilities. Life extension modifications for the crawler transporter will continue in order to complete roller bearings, jacking, equalizing, and leveling cylinder replacement. These modifications will prepare NASA for future space exploration, beginning with EM-1 and EM-2, followed by missions beyond low Earth orbit.

### ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2015 PB Request
Formulation Authorization	Nov 2011	Nov 2011
Key Decision Point (KDP)-A	Q2 FY 2012	Jan 2012
Systems Requirements Review (SRR)/Systems Definition Review (SDR)	N/A	Aug 2012
Phase A	Q2 FY 2012	Q4 FY 2012
KDP-B	Q4 FY 2012	Jan 2013
Phase B	Q1 FY 2013	Q3 FY 2014
Preliminary Design Review (PDR)	N/A	Jan 2014
KDP-C	Q3 FY 2014	Feb 2014
CDR	N/A	May 2015
KDP-D	TBD	Jun 2017
KDP – E/Completion of Block 1	TBD	TBD
EM-1 Launch	Dec 2017	FY 2018
EM-2 Launch	Aug 2021	FY 2021 - 2022

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations
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### **Formulation Estimated Life Cycle Cost Range and Schedule Range Summary**

KDP-B certifies that the proposed mission and system architecture are credible and responsive to program requirements and constraints, including resources. Additionally, the maturity of the project's mission and system definition and associated plans is sufficient to begin Phase B. Mission achievement is likely within available resources and acceptable risk.

Life cycle cost estimates are preliminary. A baseline cost commitment does not occur until the project receives approval for implementation (KDP-C), which follows a non-advocate review and/or preliminary design review.

KDP-B Date	Estimated Life Cycle Cost Range (\$M)	Key Milestone	Key Milestone Estimated Date Range
Jan 2013	2,812 – 3,121	EM-1 launch (Dec 2017)	Dec 2017-Mar 2018

### **Project Management & Commitments**

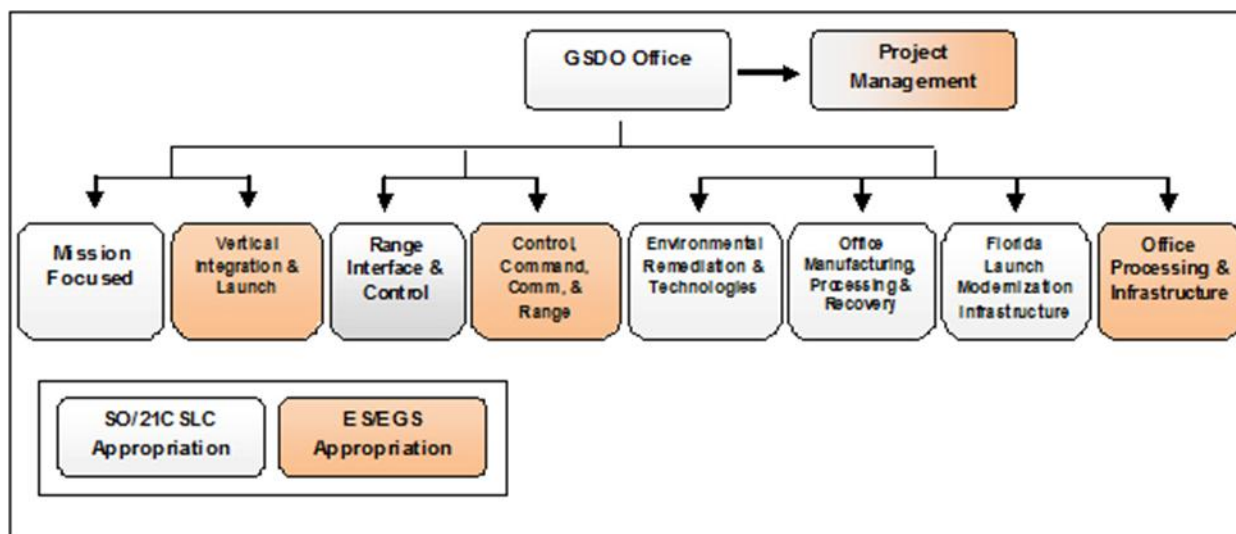
The Ground Systems Development and Operations Program Office (GSDO) manages EGS and 21st Century Space Launch Complex (21CSLC) activities. GSDO balances customer requirements between SLS, Orion, and other government and commercial users to provide synergy between EGS and 21CSLC. EGS is developing ground systems infrastructure necessary for assembly, test, launch, and recovery of SLS and Orion while 21CSLC is focusing on enabling NASA facilities to support multiple users.



## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations
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The following diagram shows the distinct break out of 21CSLC and EGS content, as managed under the GSDO program.



*Note: SO=Space Operations account. ES=Exploration account*

The following table displays the various EGS elements, lead and performing centers, and any cost share partners.

Element	Description	Provider Details	Change from Formulation Agreement
Vertical Integration and Launch	Performs facility modifications and upgrades to ground support equipment in support of launch vehicle stacking, launch vehicle and spacecraft integration, rollout, and pre-launch and launch operations at the pad	Provider: KSC Lead Center: KSC Performing Center(s): ARC Cost Share Partner(s): N/A	N/A
Offline Processing	Enables payload processing activity, manufacturing, testing, servicing and hazardous operations, and recovery in support of Orion MPCV	Provider: KSC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Command, Control, Communication and Range	Provides end-to-end command and control, weather, telemetry and tracking, communications, and customer interface systems	Provider: KSC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
Project Management	Includes project management, safety and mission assurance, logistics, systems engineering, utilities and facility operations and maintenance	Provider: KSC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A

### Project Risks

Risk Statement	Mitigation
<p>If: The Pad B LH2 system storage capability is not sufficient to support the 24 hour scrub turnaround requirement for the SLS launch vehicle,</p> <p>Then: Pad B operations will not support the 24-hour scrub turnaround requirement.</p>	EGS approved a mitigation strategy to build an additional storage tank, piping and control system based on an approved engineering design and final study submittal.
<p>If: There is insufficient time allotted to perform integrated testing activities at VAB and Pad B,</p> <p>Then: There is a possibility that the scheduled EGS operational readiness date will not be met.</p>	Systems integration and test activity schedule assumes six months for test execution, but analysis shows testing content may exceed this time. The mobile launcher to pad element integration team developed a mitigation strategy to address the risk, and incorporate an optimized timeline and task list. Systems integration and test established schedule products to improve vehicle integration and launch development along with systems integration, and test schedule activity. Mitigation activities include improved integrated validation and verification timelines and optimization of schedules.
<p>If: There is insufficient time allotted to perform integrated operations for EM-1 at the VAB and Pad B,</p> <p>Then: The scheduled launch date for EM-1 will not be met.</p>	EGS developed a coordinated approach to address the issue, and integrate a timeline and task list. EGS has a proposed schedule to optimize vehicle integration, launch development, systems integration and test schedule activities.

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations
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### Acquisition Strategy

To retain flexibility and maximize affordability, GSDO serves as its own prime contractor for EGS development activities. EGS executes SLS and Orion ground infrastructure and processing requirements by leveraging center and programmatic contracts. EGS also uses pre-qualified indefinite delivery indefinite quantity contractors for more routine work, while exercising full and open competition for larger or more specialized projects, such as the mobile launcher structural and facility systems construction contract, and associated ground support equipment fabrication firm-fixed-price contracts. The fixed-price contracting approach is the first choice whenever possible, as it provides maximum incentive for contractors to control costs, since they are subject to any losses incurred. In addition, it imposes a minimal administrative burden upon the contracting parties.

### MAJOR CONTRACTS/AWARDS

EGS development activities will encompass projects of varying content and size. Many are consistent with the type of architecture and engineering, construction, and programmatic support available within the scope of existing center and program support contracts. If the project size or scope falls outside existing center capabilities, then a competitively bid firm-fixed-price contract will be used. Major contracts are below.

Element	Vendor	Location (of work performance)
Mobile Launcher Structural and Facility Support Modification Contract	J.P. Donovan Construction Inc.	KSC
Vehicle Assembly Building High Bay Platform Construction	TBD (under NASA's Construction and Environmental Compliance and Restoration appropriation)	KSC

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
All	Standing Review Board (SRB)	Q1 FY 2013	Provides an independent assessment of the program's technical plan, cost estimates, schedules, and risks at KDP B.	Program cleared to proceed to next phase	N/A

## EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
PDR	SRB	TBD	Evaluates completeness and consistency of the program's preliminary design, including its projects, is meeting all requirements with appropriate margins, acceptable risk, and within cost and schedule constraints; determines the program's readiness to proceed with the detailed design phase.	TBD	Jan - May 2014
CDR	SRB	TBD	Demonstrates the program's design maturity is appropriate. The design supports proceeding to full-scale fabrication, assembly, integration, and test. It also meets overall performance requirements within the identified cost and schedule constraints	TBD	Q3 FY 2015

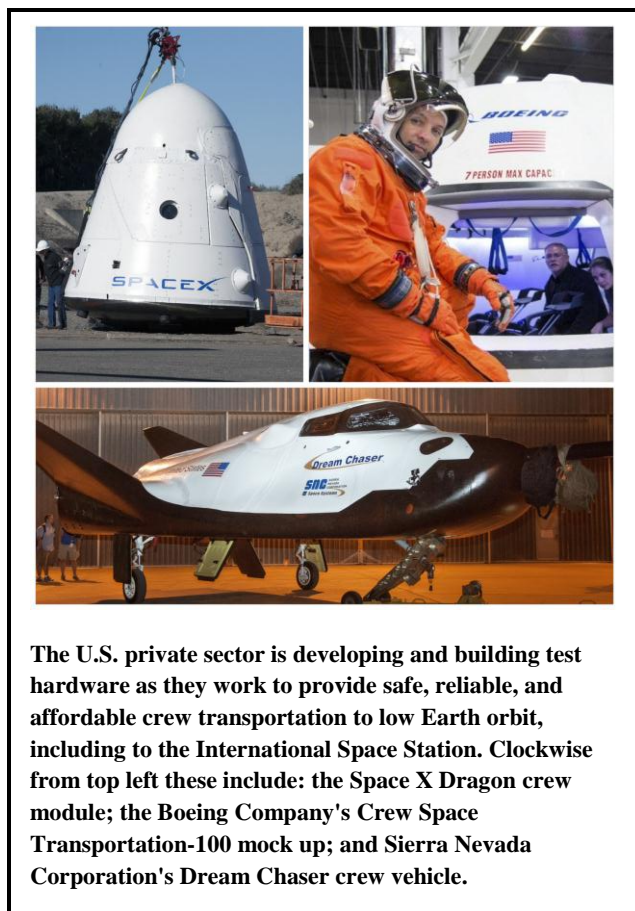
## COMMERCIAL CREW

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	Notional			
				FY 2016	FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>525.0</b>	<b>696.0</b>	<b>848.3</b>	<b>872.3</b>	<b>791.7</b>	<b>730.9</b>	<b>172.0</b>
Change from FY 2014			<b>152.3</b>				
Percentage change from FY 2014			<b>21.9%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



With an eye to the future of human spaceflight, NASA is looking to the US private sector to develop and operate safe, reliable, and affordable crew transportation to low Earth orbit (LEO), including to the International Space Station (ISS). Partnering with the commercial space industry for access to LEO and ISS will bolster American leadership, reduce our current reliance on foreign providers for this service, and help stimulate the American aerospace industry. As commercial crew providers focus on LEO, NASA is able to increase focus on developing systems that will expand the deep space exploration capabilities provided by the Space Launch System and Orion crew vehicle.

Through the Commercial Crew program, NASA is providing technical and financial support to industry providers during the development phase of their crew transportation systems, while certifying providers' transportation systems to carry NASA astronauts to and from ISS.

NASA currently measures progress against milestones proposed by the commercial partners and negotiated in Space Act Agreements, awarded in a fully competitive process. These milestones are fixed-price and based on

performance of agreed upon entrance and success criteria. Although they vary in content, milestones are designed as events that mature a partner's progress. Examples include risk reduction testing, design reviews, hardware development, flight tests, and partner investment reviews. If a partner fails to complete a milestone, the government owes nothing.

## COMMERCIAL CREW

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Concurrently with the Space Act Agreements, NASA awarded Certification Products Contracts to industry to begin the process of NASA certifying their crew transportation systems. The products provided under these contracts are proving to be very beneficial in honing industry designs to meet NASA requirements.

In the next phase, planned to begin by the end of FY 2014, NASA intends to award development and certification contracts to complete transportation system designs, and to finalize NASA certification of provider transportation systems. Contracts will also include initial service missions to the ISS.

This innovative approach will help stimulate development of a new space transportation industry available to all potential customers, enable U.S. companies to transport people to LEO and ISS, and end NASA's outsourcing of human space transportation to foreign providers. NASA's efforts will strengthen America's space industrial base, providing a catalyst for future business ventures to capitalize on affordable, globally competitive, US space access.

For more programmatic information, go to: <http://commercialcrew.nasa.gov> or <http://www.nasa.gov/exploration/commercial/crew/index.html>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

During FY 2013, NASA's industry partners made significant progress toward developing viable commercial crew transportation systems. Partners nearly completed the Commercial Crew Development Round 2 (CCDev2) initiative which began in FY 2011. Space Exploration Technologies (SpaceX) completed all 10 of their milestones, Blue Origin completed all 10 of their milestones, Boeing completed all 14 of their milestones, and Sierra Nevada Corporation (SNC) completed 12 of 13 milestones during FY 2013, and completed their final milestone in November 2013. NASA's unfunded CCDev2 partners, Alliant Techsystems, United Launch Alliance and Excalibur Almaz, Inc. all successfully satisfied the terms of their agreements. NASA and Blue Origin modified their CCDev2 Space Act Agreement to include additional unfunded milestones, allowing NASA and Blue Origin to continue working together to mature Blue Origin's crew transportation system. Completed milestones included accomplishments, such as Blue Origin's pad escape test, SNC's free flight approach and landing test of the Dream Chaser spacecraft, and Boeing's ground software preliminary design review.

Beginning in FY 2012, NASA's follow-on initiative, Commercial Crew Integrated Capability (CCiCap) also made significant progress completing planned milestones. This initiative is helping to advance partner design and development efforts. By the end of FY 2013, Boeing completed 10 milestones, including an integrated vehicle wind tunnel test to fully understand aerodynamic environments and reduce potential design risks. SNC completed four milestones, including the first integrated systems safety analysis review to assess potential safety hazards and controls for a variety of spacecraft and systems. SpaceX completed seven milestones, including a pad abort test plan review, proving that test articles are capable of meeting test requirements and schedule.

## **COMMERCIAL CREW**

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In December 2012, NASA awarded three Federal Acquisition Regulation (FAR) based fixed-price Certification Products Contracts. With a contract period of performance of January 22, 2013 through May 30, 2014, Boeing, Sierra Nevada, and SpaceX received individual awards valued between \$9.5 million and \$10.0 million each. The scope of the contracts includes the submittal and technical disposition of specific, early development certification products. All three partners began contract work, submitting initial hazard reports, alternative standards, verification and validation plans, and certification plan deliverables.

### **WORK IN PROGRESS IN FY 2014**

SNC completed its final CCDev2 milestone in early FY 2014 – a helicopter drop test of the Dream Chaser engineering test article to evaluate the vehicle’s aerodynamic properties. Blue Origin continued work with NASA on an unfunded basis, while the funded partners further matured their systems under the CCiCap initiative by completing milestones and advancing their spacecraft and launch vehicle designs. NASA is evaluating whether to extend CCiCap milestones through FY 2015. Competition is an important component of the commercial crew program. Competition is a key to controlling costs over the long term and NASA’s Aerospace Safety Advisory Panel has opined that competition should be maintained until safety confidence is achieved. Certification Products Contracts work is scheduled for completion in FY 2014.

NASA released the Commercial Crew transportation Capability (CCtCap) Request for Proposal on November 19, 2013. CCtCap initiates the final development, testing, and verification necessary to allow crewed demonstration flights by 2017, and also includes initial service missions to ISS. NASA plans to award CCtCap contracts before the end of FY 2014.

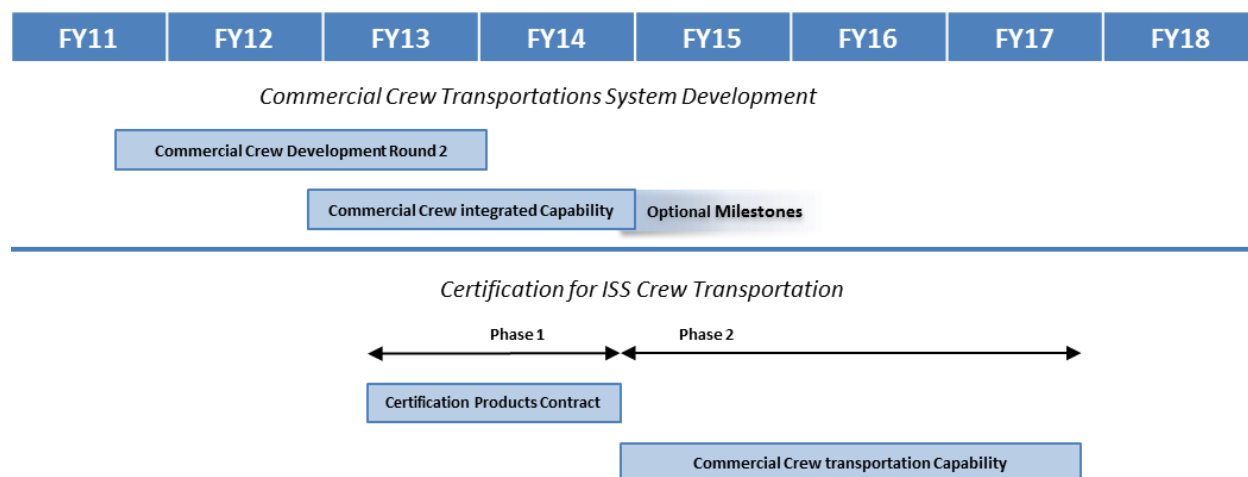
### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015, Commercial Crew industry teams will achieve significant milestones as part of their CCtCap contracts. Milestones in FY 2015 will demonstrate that commercial providers are continuing to mature their capabilities toward the program's goal of securing US crew transportation capability to LEO and ISS by 2017. Under CCtCap, NASA and our commercial providers will conduct detailed verification closure activities, ensuring crew transportation systems can and do meet NASA requirements for carrying crew to and from the ISS.

## COMMERCIAL CREW

### Program Schedule

Progression of Commercial Crew Development Efforts:



### Program Management & Commitments

The Human Exploration and Operations team at NASA Headquarters performs strategic management and oversight of Commercial Spaceflight, and KSC has responsibility for Commercial Crew program management, in collaboration with JSC. The Commercial Crew program partners with industry, utilizing a combination of Space Act Agreements and FAR-based fixed-price contracts to stimulate efforts to develop and demonstrate crew transportation capabilities.

Program Element	Provider
Commercial Crew Program	Provider: Blue Origin, Boeing, SNC, SpaceX Lead Center: KSC Performing Center(s): All Cost Share Partner(s): Industry Partners (providers above)

### Acquisition Strategy

The Commercial Crew program facilitates development of a US commercial crew space transportation capability with the goal of achieving safe, reliable, and cost effective access to and from LEO and ISS. In the early lifecycle stages, CCDev activities focused on stimulating industry efforts that successfully matured subsystems and elements of commercial crew spaceflight concepts, enabling technologies and capabilities. For this, NASA utilized Space Act Agreements, which provided maximum flexibility to the provider and maximum affordability to the government. Subsequently, NASA continued this effort with CCDev2 to address new concepts to mature the design and development of primary elements, such as launch vehicle or spacecraft. The current stage of the acquisition lifecycle includes the CCiCap Space Act



## COMMERCIAL CREW

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Agreements and Certification Products Contracts, which are fixed-price contracts. Certification Products Contracts provide a means for NASA and the partners to iterate standards and related certification documentation so that the partners can produce better proposals under CCtCap. Competition is an important component of the Commercial Crew program. Competition is a key to controlling costs over the long term and NASA's Aerospace Safety Advisory Panel has opined that competition should be maintained until safety confidence is achieved.

The next stage of the acquisition plan uses solely FAR-based fixed-price contracts for certification and services. NASA released a formal request for proposal for CCtCap. This includes award criteria that require proof of a credible integrated design maturity to achieve successful development, test, evaluation, and final NASA certification as well as a demonstration of at least one crewed ISS mission as early as possible, with a goal of 2017. During this phase, the Agency will verify whether providers achieve compliance with NASA requirements to ensure mission and safety objectives.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
CCiCap/CPC	Boeing	Houston, TX
CCiCap/CPC	SNC	Louisville, CO
CCiCap/CPC	SpaceX	Hawthorne, CA

## COMMERCIAL CREW

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	NASA Advisory Council	Dec 2013	To provide independent guidance for the NASA Administrator	No formal recommendations or findings were specified for CCP.	Apr 2014
Other	Aerospace Safety Advisory Panel	Jan 2014	To provide independent assessments of safety to the NASA Administrator	Recommended NASA use its oversight and insight capability under the CCtCap contract to ensure that competing providers do not shortchange safety in order to gain a competitive advantage in other dimensions, such as cost and schedule.	Apr 2014
Other	Booz Allen	Oct 2012 - Feb 2013	To provide an independent cost assessment	Found that CCP Government estimates are of high quality and follow standard cost estimating best practices. Made eleven findings and recommendations.	N/A

## COMMERCIAL CREW

### HISTORICAL PERFORMANCE

Through FY 2013

		Total Potential Value (in \$M)	No. Milestones Completed	Funding for Completed Milestones (in \$M)	% Milestones Completed	% Funding Completed	Status
Commercial Orbital Transportation System (COTS) Partner*	No. of Milestones						
SpaceX	40	396.0	40	396.0	100%	100%	Completed
Orbital	29	288.0	28	285.5	97%	99%	Active
Rocketplane-Kistler (RpK)	15	206.8	3	32.1	20%	16%	Terminated

		Total Potential Value (in \$M)	No. Milestones Completed	Funding for Completed Milestones (in \$M)	% Milestones Completed	% Funding Completed	Status
CCDev1 Partner	No. of Milestones						
Sierra Nevada Corporation (SNC)	4	20.0	4	20.0	100%	100%	Completed
Boeing	36	18.0	36	18.0	100%	100%	Completed
Blue Origin	7	3.7	7	3.7	100%	100%	Completed
Paragon Space Development Corporation	5	1.4	5	1.4	100%	100%	Completed
United Launch Alliance (ULA)	4	6.7	4	6.7	100%	100%	Completed

		Total Potential Value (in \$M)	No. Milestones Completed	Funding for Completed Milestones (in \$M)	% Milestones Completed	% Funding Completed	Status
CCDev2 Partner	No. of Milestones						
Sierra Nevada (SNC)	13	105.6	12	97.6	92%	92%	Active
Boeing	15	112.9	15	112.9	100%	100%	Completed
SpaceX	10	75.0	10	75.0	100%	100%	Completed
Blue Origin	10	22.0	10	22.0	100%	100%	Completed
United Launch Alliance (ULA)	5	N/A	5	N/A	100%	N/A	Completed
Alliant Techsystems Inc (ATK)	5	N/A	5	N/A	100%	N/A	Completed
Excalibur Almaz Inc (EAI)	5	N/A	5	N/A	100%	N/A	Completed

		Total Potential Value (in \$M)	No. Milestones Completed	Funding for Completed Milestones (in \$M)	% Milestones Completed	% Funding Completed	Status
CCiCap Partner	No. of Milestones						
SNC	11	227.5	4	107.5	36%	47%	Active
Boeing	20	480.0	10	339.0	50%	71%	Active
SpaceX	15	460.0	7	259.0	47%	56%	Active

## HUMAN RESEARCH PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>146.7</b>	<b>--</b>	<b>160.5</b>	<b>167.8</b>	<b>173.6</b>	<b>178.2</b>	<b>178.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**With the help of European Space Agency astronaut Luca Parmitano, NASA's Expedition 37 flight engineer Michael Hopkins performs ultrasound eye imaging in the Columbus laboratory of the International Space Station. This imaging is a part of the data gathered to better understand Visual Impairment Intracranial Pressure symptoms seen recently in astronauts.**

Sending astronauts into space involves many critical systems, the most complex of which is the human system. NASA has amassed more than fifty years of crew experience in low Earth orbit (LEO), and researchers continue to unravel the mysteries of how the space environment affects the human body. The Human Research Program (HRP) is responsible for understanding and mitigating the highest risks to astronaut health and performance to ensure that crews remain healthy and productive during long duration exploration missions beyond LEO. HRP works to develop countermeasures and technologies that will allow astronauts to complete their high-risk missions and preserve lifelong health.

Scientists have studied the effects of low gravity on the human body for decades, but certain significant changes have only been detectable since the International Space Station (ISS) has enabled crews to experience long-duration weightlessness. Effects such as muscle atrophy, bone loss, and motion sickness were widely known, but what was happening inside the heart and the skull was not. Researchers learned that

the heart seems to shrink and reduce its ability to fill completely in space, which could compromise exercise or temperature control. Increased intracranial pressure observed in returning astronauts can reshape the optic nerve and possibly result in permanent vision changes. These discoveries created high research priorities for HRP, in collaboration with other NASA programs.

HRP has identified risks that must be retired to enable human exploration beyond LEO, and approaches to retire those risks via research. Much of this will be accomplished aboard ISS. This deep space exploration research is one of the key factors in the Administration's decision in January 2014 to extend ISS operations through at least 2024.

Understanding the effects on astronauts' physiological systems is critical for mission planners and system developers charged with implementing NASA's long-duration space missions beyond LEO. As is the case

## **HUMAN RESEARCH PROGRAM**

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with many space-based medical investigations however, this research may also lead to significant advancements in treating patients on Earth.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

In order to investigate astronaut health and performance, HRP and the National Space Biomedical Research Institute (NSBRI) selected 23 research proposals representing 14 states and 18 institutions for funding, committing approximately \$17 million over the lifetime of the grants. A new NASA Research Announcement (NRA) – Human Exploration Research Opportunities (HERO) – was released to the national biomedical research community to address crew health and performance risks for long-duration exploration missions. Learning from the Science Mission Directorate’s implementation of the Research Opportunities in Space and Earth Science (ROSES) announcements, HRP has implemented a new process for NRA’s beginning with the HERO announcement. The HERO NRA will be one announcement with appendices rather than multiple announcements for each new research opportunity, providing HEO with a more efficient grant process.

Also in FY 2013, researchers developed and implemented ISS biomedical investigations on ocular surveillance to address the visual impairment that astronauts experience. These investigations will gather information on the visual changes that occur in crewmembers, determine their association with the fluid shifts while in space, and inform approaches to develop potential countermeasures.

Astronauts completed the ISS Integrated Cardiovascular study to quantify the extent, time course, and clinical significance of heart atrophy (decrease in size), as well as the functional consequences for crewmembers during extended spaceflight. Results will help ensure crew health on long-duration exploration missions, and aid in developing necessary countermeasures. The information has relevance for patients on Earth after prolonged bed rest or chronic reduction in physical activity, as well as those with cardiac problems.

NASA updated and implemented the space radiation cancer risk model with more accurate data on the amount of time that astronauts could safely remain in space. This helps ensure astronaut health and safety, resulting in a significant increase in the number of mission days that astronauts remain in space.

In preparation for the 2015 ISS one-year mission, HRP and NSBRI released a research announcement soliciting comparable investigations between astronaut Scott Kelly who will be living aboard the Station, and his identical twin brother, retired astronaut Mark Kelly, on Earth. These studies provide a unique opportunity for investigations into physiological and genetic aspects of spaceflight.

### **WORK IN PROGRESS IN FY 2014**

Throughout FY 2014, HRP will have approximately 13 ongoing ISS space biomedical research investigations during each mission increment. Researchers will complete a research plan for the US/Russian ISS one-year mission, and continue to work with the ISS program, the Crew Health and

## **HUMAN RESEARCH PROGRAM**

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Safety project, and international partners to better understand such risks as the visual impairment and intracranial pressure changes.

NASA is conducting a microbiome study to investigate the variety of microorganisms on, in, and around astronauts during spaceflight missions. The human body hosts millions of tiny organisms, called microbes. These organisms play a key role in human health and it is important to understand the changes to this microbial population during long duration space exploration. By sampling the astronaut's microbiome on Earth and in space during long-term spaceflight, researchers hope to define the signatures of human response to a variety of relevant aspects of space travel. Potential applications to human health include early detection of diseases, alterations in metabolic function, and immune system deficiency.

NASA expects to conclude the ISS "Pro K" experiment in 2014. This experiment investigates the astronauts' diet based on consuming a decreased ratio of protein (meat) to potassium (vegetables, fruit) as a countermeasure to bone loss during spaceflight. This method could lead to improvements in bone health, including the development of a virtually risk free countermeasure that requires no additional flight resources. The proposed research also has direct public health significance here on Earth: demonstrating the importance of diet and the value of fruits and vegetables over other food items, especially given the growing rate of obesity in the United States.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

FY 2015 marks the launch of astronaut Scott Kelly and cosmonaut Mikhail Kornienko to the ISS, where they will live for an entire year in a joint US/Russian mission. This will be the longest mission ever assigned to a US astronaut. During this year, HRP will develop and implement the biomedical research plan which will yield valuable information regarding medical countermeasures for bone, muscle, and cardiovascular deconditioning; behavioral health and performance; and medical operation challenges explorers may face as they venture to an asteroid, Mars, and beyond.

A key part of the one-year mission is the identical twins study, as astronaut Scott Kelly spends 12 months in orbit on the ISS, while retired astronaut Mark Kelly – his identical twin – remains on Earth. These experiments will provide an unprecedented opportunity to research the effects of spaceflight on the twin genetic makeup, and help scientists better understand the impacts of spaceflight on the human body. Research on the twins will incorporate cutting edge genetic "-omics" tools. Omics is the study of the entire complement of biomolecules, like proteins (proteomics), genes (genomics), etc. For the first time, scientists can observe things such as DNA and proteins in Scott Kelly while in space, and compare those results to his twin Mark to gain significant insight into the real-time genetic effects of spaceflight and its impacts on the human body at the molecular level.

## **Program Elements**

### **EXPLORATION MEDICAL CAPABILITY**

As NASA makes plans to extend human exploration beyond LEO, identifying and testing next-generation medical care and crew health maintenance technologies is vital. Health care options evolve based on past experience, anticipated needs, and input from flight surgeons and crew offices. Teams in this area draft

## **HUMAN RESEARCH PROGRAM**

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requirements for medical equipment and clinical care, develop remote medical technologies, and assess medical requirements unique to long-duration space missions.

### **HUMAN HEALTH COUNTERMEASURES**

Countermeasures are the procedures, medications, devices, and other strategies that help keep astronauts healthy and productive during space travel and their return to Earth. Researchers provide biomedical expertise; they are responsible for understanding the normal physiologic effects of spaceflight, and then developing countermeasures to those with harmful effects on human health and performance. These experts define health and medical standards, validate human health prescriptions and exercise system requirements, develop injury and sickness prevention standards, integrate physiological countermeasures, and establish criteria for NASA fitness for duty, as well as crew selection and performance standards.

### **BEHAVIORAL HEALTH AND PERFORMANCE**

Just as the space environment poses physical risks to crewmembers, space flight's unique stresses and challenges can also affect cognitive and mental performance. NASA must assess the impact of space travel on human behavioral health, and develop interventions and countermeasures to ensure optimal crew health and performance. Researchers in this area make extensive use of analogs, which are experimental environments created to simulate certain aspects of space travel. By duplicating space conditions, such as altered day and night cycles, heavy workloads, social isolation, and close living quarters, scientists gain insight into the impact of these circumstances on human behavior and performance. They then work to develop countermeasures, equipment, and other interventions to minimize these risks.

### **SPACE HUMAN FACTORS AND HABITABILITY**

Crew performance and well-being is affected by where they live, what they eat, and even what they wear. Considering external factors is essential when designing a spacecraft, a habitat, or a spacesuit. Human factors experts develop new equipment, procedures, and technologies designed to make the space environment more livable. Food scientists work to create nutritious and palatable meals that can withstand the rigors of spaceflight, are simple to prepare, and generate minimal waste. Other studies necessary for living and working in space include determining impacts and limits of environmental factors, such as chemicals, bacteria, fungi, and lunar dust.

### **SPACE RADIATION**

As NASA expands human presence through the solar system, it is critical that crews are able to safely live and work in a space radiation environment without exceeding exposure limits. Space radiation researchers determine standards for health and habitability, and define requirements for radiation protection. They also develop tools to assess and predict risks due to space radiation exposure, and strategies to mitigate exposure effects.

## HUMAN RESEARCH PROGRAM

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### ISS MEDICAL PROJECTS

The ISS provides a unique test bed for HRP activities. The medical projects team plans, integrates, and implements approved biomedical flight experiments on the ISS, as well as research studies that use ground experiments to accomplish program objectives. This includes pre and post-flight activities, coordinating flight or ground resources with our international partners, maintaining ISS biomedical research racks and flight hardware, and developing crew training for both flight and ground investigations. Teams also operate a telescience support center, which provides real-time support and data services to all HRP flight experiments. Strong interfaces with external implementing organizations, such as the ISS payloads office, analog coordination offices, and international partners are critical to maintaining a robust research program.

### Program Schedule

Date	Significant Event
Nov 2014	Complete First Clinical Test on Feasibility of Utilizing Ultrasound to Reposition Kidney Stones
Dec 2014	Determine the Suitability of the Vitted Two-Depth Transcranial Doppler for the Non-Invasive Assessment of Intracranial Pressure in Astronauts
Dec 2014	Deliver food system concepts and technology gaps to reach a five-year shelf life
Jan 2015	Receive ISS Functional Task Test Final Report
Feb 2015	2015 Investigator's Workshop
Feb 2015	2015 NASA Research Announcement in Space Radiation Release
Apr 2015	2014 Human Exploration Research Opportunity NRA Selections
Apr 2015	Deliver Multi-modal Neurodiagnostic Tool for Stress Monitoring
Apr 2015	Deliver Recommendations and Tools for Developing Resilient Teams
May 2015	Complete 2015 Mission X: Train Like an Astronaut Fitness Challenge
Aug 2015	2015 Human Exploration Research Opportunity NRA Release
Sep 2015	2015 NASA Research Announcement in Space Radiation Selections

### Program Management & Commitments

HRP is managed by a program office located at JSC with support from ARC, GRC, LaRC and KSC.

The Human Exploration and Operations Associate Administrator delegated the authority, responsibility, and accountability of the HRP manager to the Space Life and Physical Sciences Research and Applications (SLPSRA) Division at NASA Headquarters. Working closely with the Office of the Chief



## HUMAN RESEARCH PROGRAM

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Scientist and the Office of the Chief Health and Medical Officer, the SLPSRA Division establishes the overall direction, scope, budget, and resource allocation for the program, which the NASA centers then implement.

Program Element	Provider
Exploration Medical Capability	Provider: JSC Lead Center: JSC Performing Center(s): GRC, ARC, and LaRC Cost Share Partner(s): N/A
Human Health Countermeasures	Provider: JSC Lead Center: JSC Performing Center(s): ARC and GRC Cost Share Partner(s): N/A
Behavioral Health and Performance	Provider: JSC Lead Center: JSC Performing Center(s): ARC and GRC Cost Share Partner(s): N/A
Space Human Factors and Habitability	Provider: JSC Lead Center: JSC Performing Center(s): ARC Cost Share Partner(s): N/A
Space Radiation	Provider: JSC Lead Center: JSC Performing Center(s): ARC and LaRC Cost Share Partner(s): Department of Energy
ISS Medical Project	Provider: JSC Lead Center: JSC Performing Center(s): ARC and KSC Cost Share Partner(s): N/A

## Acquisition Strategy

NASA awards contracts and grants in HRP to further efforts in mitigating risks to crew health and performance by providing essential biomedical research and technologies for human space exploration, based upon National Academies studies and Agency roadmaps.

HRP uses peer reviews to assure a high-quality research program. Engaging leading members of the research community to competitively assess the merits of submitted proposals is essential for the quality of research. HRP uses NRAs to provide scientists the opportunity to develop complete flight experiments

## HUMAN RESEARCH PROGRAM

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and allow universities to participate in flight research by involving their scientists and engineering schools. HRP plans to announce two NRAs in 2015 in conjunction with the NSBRI.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Program Management	NSBRI	JSC

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Peer Review Panel	Jul 2013	Peer review of NASA Research Announcement	Selected grantees	Jul 2014
Quality	Standing Review Board/External Independent Review	Nov 2013	Review of research projects, gaps and tasks	Verifies project prioritization/reprioritization	Nov 2014
Quality	National Academies	Jun 2012	Review of NASA Research on Human Health Risks	Verifies project prioritization/reprioritization	Jun 2014
Quality	National Academies	Jun 2012	Review of Scientific Merit Assessment Processes	Verifies program review process	TBD
Quality	Independent Program Assessment Office	Sep 2012	Review of Program Management Policies and Practices	Verifies adherence to NASA Program Management Policies	Sep 2014
Quality	National Academies	Jul 2011	Decadal survey of life and physical sciences in microgravity	Establish a guide for research in the next decade.	Jul 2021

## ADVANCED EXPLORATION SYSTEMS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>150.0</b>	<b>--</b>	<b>182.9</b>	<b>176.5</b>	<b>178.2</b>	<b>216.6</b>	<b>216.6</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



AES performs extravehicular activity (EVA) suit testing in NASA's Neutral Buoyancy Laboratory at JSC with the modified advanced crew escape suit – a concept for capsule-based EVA. Advanced space suit development enables humans to conduct "hands-on" surface exploration and in-space operations outside habitats and vehicles, and advances technologies such as portable life support systems, thermal control, power systems, communications, avionics, information systems, and space suit garments.

Advanced Exploration Systems (AES) represents an innovative approach to developing foundational technologies and high-priority capabilities that will become the building blocks for future space missions. Using focused in-house activities coupled with public-private partnerships to rapidly develop and test prototype systems, AES is pioneering ways to drive a rapid pace of progress, streamline management, foster partnerships with external organizations, and more effectively utilize the NASA workforce as we transition to enabling human spaceflight beyond low Earth orbit. NASA-led teams of engineers and technologists across the country are engaged in rapid development activities, demonstrating key capabilities in flight or in flight-like environments, validating operational concepts, gaining valuable hands-on experience with hardware, and mastering the skills necessary for future space missions.

Through early integration of complex systems, testing those systems in the proper environments, and flying technology, AES works to uncover potential risks before new capabilities are planned for integration into more critical systems. This

methodology will reduce the risk of schedule and cost problems and improve the affordability of future space exploration.

AES activities focus on human spaceflight enabling systems for deep space and robotic precursor missions, that identify and fill in knowledge gaps about potential destinations in advance of flight missions. Major areas currently in work include systems development for more reliable life support, deep space habitats, crew mobility systems, advanced space suits – including concepts for astronaut extravehicular activity (EVA) with an asteroid, public-private partnerships for lander capabilities, developing the means to use space resources to support missions and allow human spaceflight to become Earth independent, and autonomous space operations. AES also collaborates with the Science Mission

## **ADVANCED EXPLORATION SYSTEMS**

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Directorate to explore innovative partnerships to advance Near Earth Object observation and target identification to enable additional discovery of asteroids to support human spaceflight missions and help protect our planet.

NASA develops and then tests prototype systems using ground-based facilities, the International Space Station (ISS), flight opportunities on such vehicles as Orion Multi-Purpose Crew Vehicle and the Space Launch System, or NASA's robotic missions to destinations in the solar system. FY 2015 will begin a new phase for many AES activities, which will involve taking successful accomplishments from previous years to start larger, integrated activities. AES will also complete final testing objectives for prototype systems still in development.

NASA's Space Technology Mission Directorate also contributes to the Human Exploration and Operations effort: AES infuses new Space Technology Mission Directorate-developed technologies into exploration missions as components integrated into prototype and flight systems. AES also works closely with NASA's Science Mission Directorate on a joint robotic precursor activity to develop instruments, support research and analysis efforts, and plan and conduct precursor missions.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

NASA engineers assembled a portable life support system for the first new space suit to be developed in over 30 years. This portable system is the backpack that provides fresh air and cooling for astronauts during an EVA. The new space suit will be able to support exploring a variety of destinations in space and on planetary bodies such as the Moon, near-Earth asteroids, and Mars.

AES successfully awarded a fixed price cost sharing contract to conduct an expandable habitat demonstration on the ISS with Bigelow Aerospace. This represented the first cost-sharing technology demonstration contract awarded by the Agency and will provide valuable in-orbit performance data to NASA and industry. In addition, AES awarded a fixed price contract for the passive common berthing mechanism that will enable the Bigelow module to connect to the ISS.

Scientists analyzing data gathered by the AES Radiation Assessment Detector (RAD) instrument on the Mars Science Laboratory published new findings on interplanetary radiation exposure in one of the May editions of the journal *Science*. Long-term population studies have shown that exposure to radiation increases a person's lifetime cancer risk; understanding the radiation environment in a spacecraft travelling to, and on the surface of Mars, is critical for planning future human spaceflight missions. This RAD data will benefit current spacecraft design as well as scientific models and theories on exposure limits for deep-space explorers. Five AES radiation flight sensors are currently operating on ISS in order to better understand crew radiation exposure.

The Goldstone radar, located in California's Mojave Desert and managed by JPL, imaged 17 near-Earth asteroids, nine of which are potential targets for human exploration. Goldstone measures asteroid size, shape, and spin rate as part of the planning for the Asteroid Redirect Mission (ARM), as well as any other potential future human spaceflight mission to visit asteroids.

## **ADVANCED EXPLORATION SYSTEMS**

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### **WORK IN PROGRESS IN FY 2014**

As NASA works to extend human space exploration beyond low Earth orbit, AES began developing the crew systems, EVA, and some initial asteroid capture system technologies needed for ARM. AES will release a Broad Agency Announcement for a capture mechanism and begin some pre-formulation concept studies on the mission. The initial mission concepts include the use of a robotic spacecraft to capture a small near-Earth asteroid, or remove a boulder from the surface of a larger asteroid, and redirect it into a stable lunar orbit. Once the asteroid is in this orbit, astronauts will launch aboard the Space Launch System/Orion to rendezvous with the asteroid, study it, and collect samples to return to Earth. AES is modifying existing pressure suits the crew wears during launch and landing for EVA use on the ARM crew mission(s). This single-suit approach could save weight by eliminating the need to bring a separate suit for an EVA. Astronauts will continue to test the modified suit in NASA's Neutral Buoyancy Laboratory to simulate ARM operations. Various concepts for an asteroid capture system will be in the study phase by the end of the fiscal year; AES will transfer study results on the initial capture mechanism to ISS In-Space Robotic Servicing in 2015 to proceed towards flight capabilities.

AES is developing two experiments for the Exploration Flight Test (EFT)-1 mission, planned to launch in FY 2014. The first includes solid-state detectors that will measure the radiation environment inside the Orion capsule as it passes through the Earth's radiation belts. The second is an advanced caution and warning system that will monitor the health of critical vehicle systems by using data transmitted to the ground. If successful, these tests will allow NASA to develop compatible sensors and systems for Orion, as well as other vehicles.

The Morpheus lander technology test bed will demonstrate an autonomous precision landing and hazard avoidance system that uses laser sensors to detect rocks and craters in a landing zone. Morpheus will take off from the ground, fly to an altitude of several hundred meters, and automatically land in terrain that simulates the surface of a planet. This capability will allow robotic missions to the Moon and Mars to land safely and closer to targets of scientific interest. The Morpheus lander is also demonstrating new propulsion system technology that uses liquid oxygen and methane for propellants.

In the spring of 2014, AES and the Space Technology Mission Directorate will jointly recommend an in-situ resource utilization experiment and a heat shield performance measurement experiment for the Mars 2020 rover mission for selection by the Science Mission Directorate.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

As AES concludes a majority of the work in development from FY 2012 - FY 2014, FY 2015 will bring a new set of activities with an emphasis on integrating current achievements. These new efforts include integrated life support, an advanced space suit, autonomous systems and operations, modular power systems, radiation sensors, avionics and software. In addition, an Exploration Augmentation Module will consolidate several existing activities into a prototype module to augment Orion's habitation and EVA capabilities for extended deep space missions.

Knowing that future human spaceflight missions are required to be more Earth independent, AES will make several investments in systems development and demonstrations for in-situ resource utilization. These will be in partnership with other NASA missions, international partnerships, and through public-private partnerships with commercial organizations in the lead. In addition, AES will begin new efforts related to in-space fabrication and synthetic biology, with applications for mining and food production.

## **ADVANCED EXPLORATION SYSTEMS**

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The Bigelow Expandable Activity Module (BEAM) is an inflatable habitat that is compacted for launch, and then expanded in orbit to give the crew additional living space. BEAM will launch aboard a SpaceX cargo resupply mission to ISS in 2015. Astronauts will attach the module to ISS to test inflatable structures technology that could be used for a deep space habitat on human missions to Mars. Sensors inside BEAM will measure the strength of its fabric walls, detect any pressure leaks caused by micrometeoroid punctures, and monitor the thermal and radiation environment during flight. After testing is complete, the module will be jettisoned and burn up during re-entry.

In support of other next generation habitat modules for long-term missions in orbit and beyond, AES will ramp up work within NASA and through public-private partnerships with academia and industry on promising areas to enable habitat capabilities. In FY 2015, as part of the integrated life support activity, AES will accelerate work on environmental control life support systems capabilities. AES will also develop concepts and continue to develop technologies for instruments and EVA tools that could be demonstrated on the ARM, to prospect for valuable asteroid resources such as metals and water.

In addition, AES plans to continue developing at least three secondary CubeSat payloads in 2015 in preparation to fly on the Space Launch System in 2017. Initial mission concepts include a “Lunar Flashlight” to look for lunar volatiles such as ice, a “Biosentinel” to further study the effects of the deep space radiation environment on simple organisms, and a “Near Earth Asteroid Scout” to characterize and visit candidate asteroids in support of ARM and future human exploration.

### **Program Elements**

Five technology elements called "domains" drive the AES effort. Each focuses on a specific technology required for future human space exploration.

#### **HABITAT SYSTEMS**

The focus of the Habitat Systems domain is enabling the crew to live and work safely in deep space. Activities include the BEAM inflatable habitat, deep space habitat capabilities, reliable life support systems, logistics reduction, radiation measurements, and protection. Experiments to improve spacecraft safety are also underway to better understand how fire spreads, and how to recover from fire events in microgravity.

#### **CREW MOBILITY SYSTEMS**

The Crew Mobility Systems domain encompasses capabilities that will enable the crew to conduct “hands-on” exploration and in-space operations. Current EVA and space suit advancements will lead to a next generation space suit and portable life support system that will give astronauts improved dexterity and mobility in space environments, as well as mission kits, and general crew tools and mobility aids.

#### **VEHICLE SYSTEMS**

Within the Vehicle Systems domain are efforts to develop technologies needed for advanced in-space propulsion stages and small robotic landers. Morpheus activities will benefit future robotic missions by improving autonomous precision landing on planetary surfaces, as well as potential new propellants

## ADVANCED EXPLORATION SYSTEMS

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and/or propulsion systems. The Lunar Cargo Transportation and Landing by Soft Touchdown initiative will share these landing capabilities through public-private partnerships with industry. Other ongoing initiatives include studies of reactor fuel elements and engine concepts for nuclear thermal propulsion systems, and modular power for multiple exploration vehicles and systems.

### OPERATIONS

The Operations domain focuses on systems that will enable more efficient mission and ground operations. Current activities include mission simulations to test systems and operational concepts, software for autonomous mission operations such as an advanced caution and warning system to fly on EFT-1, advanced ground systems to automate propellant handling, next generation autonomous networking technology, and common avionics and software for use in multiple systems. These technologies will make mission and ground operations more efficient and cost effective.

### ROBOTIC PRECURSOR ACTIVITIES

Robotic Precursor activities focus on developing robotic missions and instruments to provide data and information for analyzing the feasibility of potential destinations for human missions. Current activities include the ground-based radar Goldstone that images near-Earth asteroids, the RAD instrument to measure the radiation environment on the Mars surface, and work on in-situ resource utilization.

### Program Schedule

Date	Significant Event
Apr 2014	Demonstrate autonomous landing and hazard avoidance in flight test of Morpheus lander
Apr 2014	Determine potential for commercial industry led lunar lander partners and select initial partnerships to be conducted under space act agreements
May 2014	Select Mars 2020 payload to demonstrate oxygen production from atmosphere
Jun 2014	Demonstrate software for autonomous mission operations on ISS
Jun 2014	Deliver 3D printer for launch to ISS
Jul 2014	Human in the loop testing of EVA portable life support system
Aug 2014	Demonstrate EVA asteroid exploration capabilities in a ground test
Aug 2014	Test cascade distillation system to recycle wastewater
Aug 2014	Determine potential for international partner to develop robotic lunar lander
Aug 2014	Complete mission concept reviews for Exploration Mission (EM)-1 secondary payloads

## ADVANCED EXPLORATION SYSTEMS

Sep 2014	Complete studies on asteroid capture system and proof-of-concept laboratory demonstration
Sep 2014	Launch radiation environment monitors and test advanced caution and warning system on EFT-1
Dec 2014	Complete testing and down selection of reactor fuel element materials for nuclear thermal propulsion
May 2015	BEAM to ISS

### **Program Management & Commitments**

The Human Exploration and Operations Mission Directorate executes AES activities, and the Directorate's Associate Administrator has delegated management authority, responsibility, and accountability to the AES Division at NASA Headquarters. The AES Division establishes overall direction and scope, budget, and resource allocation for activities implemented by the NASA centers.

AES and the Planetary Science Division within the Science Mission Directorate jointly fund the Joint Robotic Precursor Activities (JRPA), developing instruments to include on NASA science and international missions. AES has overall management responsibility for this effort, and coordinates with the Science Mission Directorate on JRPA planning and execution.

Program Element	Provider
Crew Mobility Systems	Provider: NASA Centers Lead Center: HQ Performing Center(s): JSC and GRC Cost Share Partner(s): N/A
Habitat Systems	Provider: NASA Centers Lead Center: HQ Performing Center(s): MSFC and JPL Cost Share Partner(s): Bigelow Aerospace
Vehicle Systems	Provider: NASA Centers Lead Center: HQ Performing Center(s): GRC, JSC, and MSFC Cost Share Partner(s): Department of Energy
Operations	Provider: NASA Centers Lead Center: HQ Performing Center(s): ARC, JSC, KSC, and MSFC Cost Share Partner(s): N/A



## ADVANCED EXPLORATION SYSTEMS

Program Element	Provider
Robotic Precursor Activities	Provider: NASA Centers Lead Center: HQ Performing Center(s): ARC, JPL, and KSC Cost Share Partner(s): Science Mission Directorate

### Acquisition Strategy

AES selected initial activities through an internal competitive process in which NASA centers submitted proposals specifically to address the highest priority capabilities for human exploration beyond low Earth orbit, which are represented through the AES domains. Each year, AES evaluates how the portfolio aligns with human exploration priorities and technology gaps, and either terminates activities that do not demonstrate adequate progress or realigns them, and/or adds new activities to the portfolio as appropriate. Teams are provided limited procurement funding to purchase materials, equipment, and test facilities. AES strives to maximize the specialized skills within the civil service workforce but may also utilize a small amount of contractor workforce in areas where NASA can cost effectively leverage their skills and knowledge.

In FY 2013, AES awarded a fixed price cost sharing contract with Bigelow Aerospace to conduct an expandable habitat demonstration on the ISS. The agreement represents the first cost sharing technology demonstration contract awarded by the Agency; this effort will provide valuable in-orbit performance data to NASA and industry.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Crew Mobility Systems: Space Suit	ILC Dover	JSC
Habitat Systems: Life Support System Components	Hamilton Sundstrand	MSFC and JSC
Habitat Systems: Inflatable Module	Bigelow Aerospace	JSC
Habitat Systems: Inflatable Module Passive Common Birthing Mechanism	Sierra Nevada Development Corporation	JSC
Vehicle Systems: Reactor Fuel Elements	Department of Energy	MSFC

## **ADVANCED EXPLORATION SYSTEMS**

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### **INDEPENDENT REVIEWS**

AES undergoes quarterly Directorate Program Management Council reviews, and periodically, representatives from the Office of Chief Engineer, the Office of Safety and Mission Assurance, and the Office of Chief Financial Officer will assess AES performance during Agency-level Baseline Performance Reviews.

# SPACE OPERATIONS

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Space Shuttle	38.8	--	0.0	0.0	0.0	0.0	0.0
International Space Station	2775.9	--	3050.8	3126.5	3266.9	3290.3	3818.6
Space and Flight Support (SFS)	910.2	--	854.6	825.4	795.9	795.3	783.2
<b>Total Budget</b>	<b>3724.9</b>	<b>3778.0</b>	<b>3905.4</b>	<b>3951.9</b>	<b>4062.8</b>	<b>4085.6</b>	<b>4601.8</b>

## Space Operations.....SO-2

### International Space Station

INTERNATIONAL SPACE STATION PROGRAM.....	SO-6
ISS Systems Operations and Maintenance.....	SO-8
ISS Research.....	SO-14
ISS Crew and Cargo Transportation .....	SO-25

### Space and Flight Support (SFS)

21ST CENTURY SPACE LAUNCH COMPLEX.....	SO-32
SPACE COMMUNICATIONS AND NAVIGATION .....	SO-40
SN Ground Segment Sustainment(SGSS).....	SO-42
Space Communications Networks .....	SO-49
Space Communications Support .....	SO-57
HUMAN SPACE FLIGHT OPERATIONS.....	SO-62
LAUNCH SERVICES.....	SO-68
ROCKET PROPULSION TEST .....	SO-76

# SPACE OPERATIONS

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Space Shuttle	38.8	--	0.0	0.0	0.0	0.0	0.0
International Space Station	2775.9	--	3050.8	3126.5	3266.9	3290.3	3818.6
Space and Flight Support (SFS)	910.2	--	854.6	825.4	795.9	795.3	783.2
<b>Total Budget</b>	<b>3724.9</b>	<b>3778.0</b>	<b>3905.4</b>	<b>3951.9</b>	<b>4062.8</b>	<b>4085.6</b>	<b>4601.8</b>
Change from FY 2014			127.4				
Percentage change from FY 2014			3.4%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**In 2013, NASA and its global partners celebrated 15 years of International Space Station operations and research. This world class orbiting laboratory has established a continuous human presence in space and paves the way for future exploration with Orion, the Space Launch System, and commercial crew vehicles.**

NASA's exploration of deep-space is rooted in an operational experience base a half century long. As it prepares once again to stretch human exploration beyond low Earth orbit, the Agency is drawing from the best that five decades of human space flight has to offer.

Space Operations spans NASA's space and ground infrastructure, capabilities that: enable rocket propulsion testing; assure safe, reliable and affordable access to space; and maintain secure and dependable communications between ground stations and platforms across the solar system. Programs in the Space Operations portfolio promote full utilization of the International Space Station (ISS) for conducting research and sustain a mission-ready astronaut corps. This activity

includes all aspects of ISS operation and resupply, including on-orbit operations, crew training and transfer, and cargo replenishment.

For further programmatic information, go to: <http://www.nasa.gov/directorates/heo/home/index.html>.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

The Administration recently announced the decision to extend operations of the ISS through at least 2024.

Extension of ISS operations is essential to achieve the goals of sending humans to Mars in the 2030s, develop and establish a robust U.S. crew transportation capability to low Earth orbit, achieve a self-sustaining commercial use of space in low Earth orbit, return benefits to humanity through ISS research

## SPACE OPERATIONS

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and technology development, provide a platform to host NASA and non-NASA Earth and space science instruments, and lead spacefaring nations in the exploration of space. A unique facility, ISS offers enormous scientific and societal benefits and this extension will allow us to maximize its potential, deliver critical benefits to our Nation and the world, and maintain American leadership in space.

### ACHIEVEMENTS IN FY 2013

Future long-duration human spaceflight and exploration activities require research that can only be accomplished on the ISS. These activities are integral to understanding and mitigating the impacts of long-duration spaceflight on human health. In FY 2013, NASA updated and implemented the space radiation cancer risk model with better and more accurate data on the amount of time that astronauts could safely remain in space. This helps ensure crew health and safety, resulting in an increase in the number of mission days that astronauts can remain in space.

ISS requires a dependable supply line to continue vehicle operations and science investigations. In FY 2013, two SpaceX commercial cargo resupply missions delivered over a ton and a half of supplies to the ISS, and returned two and a half tons. Orbital Sciences Corporation (Orbital) accomplished a demonstration flight of its Antares/Cygnus cargo resupply system, marking the successful completion of NASA's Commercial Orbital Transportation System program. Two commercial providers are now qualified to deliver cargo to the ISS.

In FY 2013, the Launch Services Program managed the successful launch of three major payloads, and acquired launch services for two more. Networks managed by the Space Communication and Navigation (SCaN) program provided data download and operations commands for a range of NASA and international missions, including the Curiosity rover on Mars, Voyager 1 (now nearly 12 billion miles from Earth), Cassini in orbit around Saturn, the Hubble Space Telescope, and the ISS. The Rocket Propulsion Test (RPT) program provided test stand facilities for the Space Launch System (SLS) program testing of the J-2X engine – a candidate upper stage engine for NASA's new heavy-lift vehicle. SLS is a critical component of the Agency's deep-space exploration development activity, and is the first human-rated liquid oxygen and liquid hydrogen rocket engine to be developed in 40 years.

### WORK IN PROGRESS IN FY 2014

Safely operating ISS in the severe conditions of space and ensuring that the crew always has a sufficient supply of food, water and oxygen available requires careful planning and logistics. Orbital successfully launched a cargo resupply mission to the ISS in January 2014, and plans another later in the year. SpaceX plans three cargo resupply flights to ISS in FY 2014, carrying critical investigations, experiments, and supplies.

ISS crewmembers and ISS Research project staff will continue and complete Pro K, a human diet investigation in which astronauts eat a decreased ratio of protein (meat) to potassium (vegetables, fruit) as a countermeasure to bone loss during spaceflight. This investigation has potential impacts to life on Earth, possibly demonstrating diet as a countermeasure to growing rates of osteoporosis and obesity in the United States.

Approximately 10 innovative investigations studying the potential impacts of long duration spaceflight will be selected to prepare for a one year, U.S./Russia mission in 2015. Researchers will complete a

# SPACE OPERATIONS

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research plan for the mission, and continue to work with the ISS program, the Crew Health and Safety project, and International Partners to better understand such risks as visual impairment and intracranial pressure changes.

The programs in Space Flight Support will continue to provide the capabilities required for the success of NASA's missions and goals. The Launch Services Program will continue to provide expertise and launch management services for three missions launching in FY 2014. The SCaN program will provide data download and operations command upload services for a range of NASA and international missions. Also this year, the RPT program will provide test facilities for the SLS program's J-2X and RS-25 engine testing in support of deep space exploration missions.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

The ISS will continue to host the research required for future long-duration deep space missions. Crew and cargo transportation activities will enable continued research and technology development by carrying crew and payloads to the ISS. In FY 2015, SpaceX will launch the Bigelow Expandable Activity Module (BEAM) – an expandable habitat for ISS. BEAM will demonstrate inflatable technology and applications for human spaceflight and exploration activities, possibly in combination with SLS and Orion Multi-Purpose Crew Vehicle.

Also in FY 2015, the US/Russian one-year mission to ISS will investigate genetics and effects of long-duration spaceflight on humans, with the assistance of astronaut Scott Kelly on-orbit, and his identical twin, retired astronaut Mark Kelly on the ground. The 2013 astronaut class will complete their two-year training course this year, and become eligible for flight assignments, including commercial crew vehicle flights to the ISS.

Space Flight Support programs will continue to provide the capabilities needed for NASA's missions and goals, including affordable launch services, propulsion testing facilities, and reliable space communication.

The Opportunity, Growth and Security Initiative (OGSI) provides an additional \$100.6 million for transportation to and from ISS, which will prevent additional Commercial Resupply Service (CRS) flight deletions. Maintaining an adequate number of CRS flights is critical to operating ISS and conducting research. These flights provide ISS with critical supplies (such as food and water), maintenance hardware, and research experiments; enable the return of science samples and hardware to Earth; and facilitate waste disposal. Not having an adequate number of resupply flights significantly reduces the amount of research that can be brought to and conducted on ISS, possibly threatening NASA's ability to safely fly long-duration missions on Orion. Please refer to the OGSI section for more detail.

## Themes

### INTERNATIONAL SPACE STATION

The ISS is a unique technological achievement: the result of an international effort to conceive, plan, build, operate, and utilize a research platform in space. It is a key step in the human endeavor to explore and live in space, providing a laboratory and crew in orbit to conduct research to advance biology and

## **SPACE OPERATIONS**

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biotechnology, materials and physical science, and the effects of long-duration spaceflight on the human body. The ISS enables researchers to identify risks to crew, and then develop and test countermeasures to reduce those risks. The results of the research completed on ISS advance many areas of science, enabling benefits here on Earth. Many of these advances hold the promise of next-generation technologies in fields such as health and medicine, robotics, manufacturing, and propulsion.

The ISS program also includes on-orbit vehicle operations, crew transfer via Russian Soyuz vehicles, and cargo resupply by U.S. commercial vehicles and International Partner vehicles. Without adequate operations, crew transfer, and cargo resupply, ISS cannot deliver the research needed to enable future long-duration human missions in deep space.

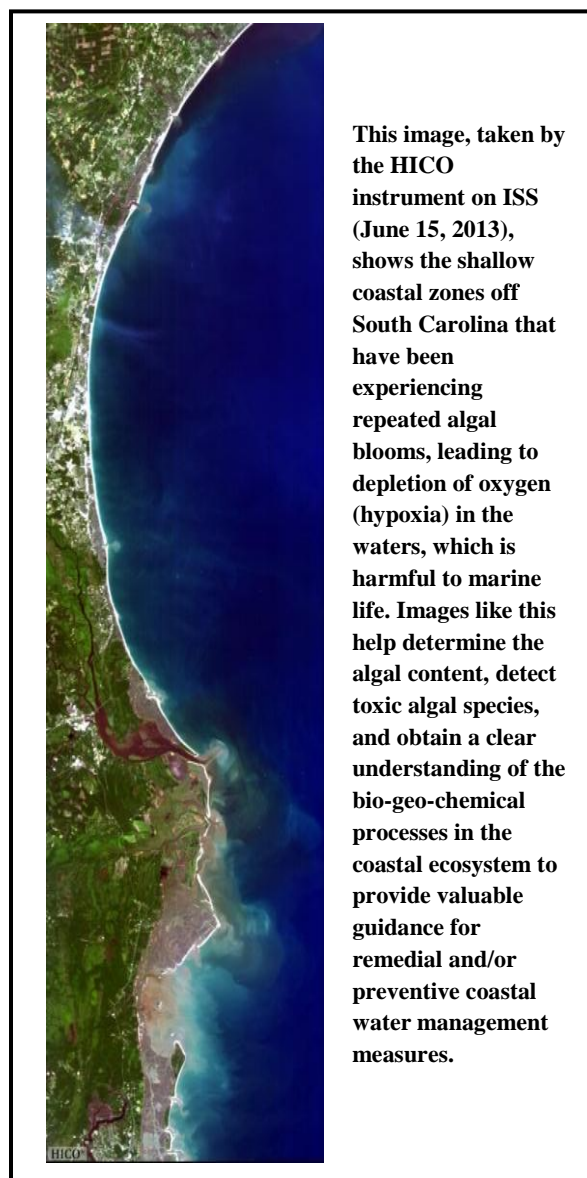
## **SPACE AND FLIGHT SUPPORT**

Space and Flight Support consists of multiple programs providing Agency-level capabilities critical to the success of NASA missions and goals. The Human Space Flight Operations program ensures NASA's astronauts are fully prepared to safely carry out current and future missions. The Launch Services Program assures reliable access to space by providing leadership, expertise, and cost-effective expendable launch vehicle services for NASA missions. The SCaN program downloads the science data payoff from NASA's robotic spacecraft and human missions through an extensive network of ground-based and orbiting communications nodes, and associated hardware and software. The RPT program maintains a wide variety of test facilities that enable NASA, other agencies, and commercial partners to advance their rocket development efforts in a cost-effective manner.

## INTERNATIONAL SPACE STATION PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
ISS Systems Operations and Maintenance	1418.2	--	<b>1207.9</b>	1211.9	1337.7	1347.2	1347.3
ISS Research	317.5	--	<b>312.2</b>	312.2	312.2	312.2	312.2
ISS Crew and Cargo Transportation	1040.3	--	<b>1530.7</b>	1602.4	1617.0	1630.9	2159.1
<b>Total Budget</b>	<b>2775.9</b>	<b>--</b>	<b>3050.8</b>	<b>3126.5</b>	<b>3266.9</b>	<b>3290.3</b>	<b>3818.6</b>



*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

The International Space Station (ISS) is a highly complex facility that provides an unparalleled capability for human, space-based research. A crew of six aboard ISS – three on the US operating segment, and three on the Russian segment – orbits the Earth about every 90 minutes. The US operating segment is the portion of ISS operated by the US and its Canadian, European, and Japanese partners; the Russian segment is operated by Russia.

Including its solar arrays, ISS spans the area of a US football field (with end zones) and weighs over 860,000 pounds, excluding visiting vehicles. Orbiting Earth 16 times per day at a speed of 17,500 miles per hour, ISS maintains an altitude that ranges from 230 to 286 miles. The complex has more livable room than a conventional five-bedroom house, with two bathrooms, a fitness center, a 360-degree bay window, and state of the art scientific research facilities. In addition to external test beds, ISS houses three major science laboratories (US Destiny, European Columbus, and Japanese Kibo).

As the world's only multinational space-based research facility and technology testbed, ISS is critical to the future of human space activities. The

facility enables scientists to identify and quantify risks to human health and performance and to develop and test countermeasures and technologies to protect astronauts during extended human space exploration. It is also a perfect testbed for evolving critical technologies needed to venture farther into



## **INTERNATIONAL SPACE STATION PROGRAM**

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space, such as long-duration life support, navigation systems, advanced lightweight structures, propulsion, and power generation and storage.

ISS offers unique opportunities for research and development, allowing scientists to investigate biological and physical processes in an environment very different from that on Earth. Observing from and experimenting aboard the ISS provides the chance to learn about Earth, life, and the solar system from a very different frame of reference. NASA and its partners use this unique “reference point” to advance science, technology, engineering, and mathematics efforts to inspire youth to pursue those fields. The results of the research completed on ISS can be applied to many areas of science, improving life on this planet, and furthering the experience and increased understanding necessary to journey to other worlds.

This international partnership is transforming space exploration from an effort for the advancement of individual nations, to an endeavor that seeks to advance humankind. ISS aims to provide direct research benefits to the public through its operations, research, and technology development activities. The designation of ISS as a National Laboratory enables partners in government, academia, and industry to use the unique environment and advanced facilities aboard ISS to perform investigations. ISS research continues to result in health solutions and lead to technologies that improve our capabilities in space and on Earth. Additionally, ISS supports NASA’s effort to develop a low Earth orbit space economy, as the demand for access to low Earth orbit provides a customer base for commercial crew and cargo system providers.

For additional information on the ISS program, go to:

[https://www.nasa.gov/mission\\_pages/station/main/index.html](https://www.nasa.gov/mission_pages/station/main/index.html)

For specific information on the many experiments conducted on ISS, go to:

[https://www.nasa.gov/mission\\_pages/station/research/experiments\\_category.html](https://www.nasa.gov/mission_pages/station/research/experiments_category.html)

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The Administration recently announced the decision to extend operations of the ISS through at least 2024.

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	1418.2	--	1207.9	1211.9	1337.7	1347.2	1347.3



NASA astronaut Michael Hopkins, Expedition 37 flight engineer, performs routine in-flight maintenance on the Advanced Resistive Exercise Device in the Tranquility node of the International Space Station. Exercising in weightlessness poses unique challenges; the device simulates free-weight exercises in normal gravity to work all the major muscle groups through squats, dead lifts, and calf raises. It also allows for personalized training and automated, privacy protected, exercise data collection. Through this investigation, astronauts, engineers, and medical professionals work to help mitigate the loss of muscle mass crewmembers have experienced while in space – up to 15%, and some of it permanently.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

The International Space Station (ISS) is a complex research facility and human outpost in low Earth orbit, developed in a collaborative, multinational effort to advance exploration of the solar system, enable unique scientific research, and promote commerce in space.

Many things taken for granted on Earth are not available in space. Safely operating ISS in the severe conditions of space and ensuring that the crew always has a sufficient supply of food, water and oxygen available requires precise planning and logistics. Much like a home, ISS needs routine maintenance and is subject to unexpected mechanical failures. However, the systems on ISS are much more complex than those in an average home. Resolving problems can be challenging, often requiring the crew to make repairs in space with support from ground teams on Earth. Astronauts on the Station cannot go to the local hardware store to buy materials. Support teams on Earth monitor and painstakingly plan replacement parts and "consumables" such as filters, to make sure they are available when needed.

The planning and support needed to allow crew to live and work comfortably in space requires intensive Earth-based mission operations. Ground teams continually monitor ISS performance, provide necessary vehicle commands, and communicate with crew. Even before the astronauts leave Earth, the Systems Operations and Maintenance project provides crew training to prepare them for their stay aboard ISS.

When developing operations plans to meet ISS program

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

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objectives, all aspects of the mission are considered. These include scheduling crew time, coordinating docking and undocking of visiting crew and supply ships, evaluating consumables supply, and managing stowage issues. The ISS Systems Operations and Maintenance project ensures that the Station is operational and available to perform its research mission at all times.

Because ISS is an international partnership, these program decisions are not made in isolation, but require coordination with multiple countries to ensure that all technical, schedule, and resources supply considerations are taken into account. The experience that NASA is gaining through integration with its ISS partners is helping the Agency better prepare for future partnerships in human exploration endeavors.

A critical component of the Systems Operations and Maintenance project is immediate, emergency services and analyses conducted by mission control teams on Earth, known as vehicle and program anomaly resolution. Engineers and operators diagnose system failures and develop solutions, while program specialists respond to changing program needs and priorities through replanning efforts. Without this anomaly resolution capability, the ISS cannot function as a safe, human-occupied, Earth-orbiting research facility.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA has proposed renaming Satellite Servicing to In-Space Robotic Servicing, and will move the associated funding and content from ISS Systems Management and Operations to ISS Research. The Agency is refocusing this activity to multi-use technology development efforts that could enable multiple NASA missions, including servicing potential science satellites, non-NASA users, and providing robotic tools for an Asteroid Redirect Mission, as well other applications for use and/or testing on ISS. This refocusing synergistically supports In-Space Robotic Servicing's current objectives.

### ACHIEVEMENTS IN FY 2013

Throughout the year, NASA ground teams continued to monitor overall vehicle health, and oversee general maintenance and performance of all ISS vehicle systems such as environmental control and life support, electrical power, propulsion, thermal control, and guidance, navigation and control. They supported real time in-flight anomaly resolution, which included extravehicular activities (EVA) to address the issues. This was the case in May 2013, when NASA quickly planned EVA to repair an external thermal control system fluid leak that could have shut down a portion of the Station's power system. Two months later, specialists investigated a water leak inside the helmet of a spacewalking astronaut, and developed solutions to restore contingency EVA capability while analysis continued. This allowed NASA to conduct a pair of contingency EVAs in December, to replace a malfunctioning component in an external thermal control system ammonia loop.

Successful operation and maintenance leads to an environment conducive to research. During FY 2013, ISS was host to 286 experiments. These included 58 in biology and biotechnology, 34 in Earth and space science, 38 educational activities, 41 in human research, 44 in physical science, and 71 in technology.

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

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### WORK IN PROGRESS IN FY 2014

The ISS Systems Operations and Maintenance project continues to maintain resources on-orbit and on the ground to operate and utilize ISS. NASA expects continued success in providing all necessary resources (including power, data, crew time, logistics, and accommodations) to support research while operating safely with a crew of six astronauts. Four crew rotation and eleven cargo resupply missions are planned in FY 2014, including both international partner and US commercial cargo flights.

Throughout the year, NASA ground teams continue to monitor overall vehicle health, and oversee general maintenance and performance of all ISS vehicle systems, including command and data handling, communication and tracking, crew health care, environmental control and life support, electrical power, EVA, extravehicular robotics, flight crew equipment, guidance navigation and control, propulsion structures and mechanisms, and thermal control.

The team has supported three Russian EVAs and two US EVAs to date, and will support two additional US EVAs, and one from the Russian segment. In addition, Robotic Refueling Mission phase 2 hardware will be flown to ISS in FY 2014. This hardware includes a new tool and task board, which will be used to demonstrate additional refueling tasks, including robotic operations associated with cryogenic fluid transfer. In-Space Servicing is also developing a tool to detect external ammonia leaks on ISS. This device will be critical in monitoring and determining leak locations on ISS, and serve as generic tool to assist in satellite repair.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, the Systems Operations and Maintenance program will work with the international partners to maintain a continuous six crew member capability on ISS by coordinating and managing resources, logistics, systems, and operational procedures. The program will continue to manage requirements and changes in ISS resources, including vehicle traffic, cargo logistics, stowage, and crew time. In addition to planning and real-time support for activities such as EVA and visiting vehicles, the team will provide anomaly resolution and failure investigation as needed. Robotic refueling mission operations and data analysis will proceed, as NASA continues to engage private industry and other government agencies to determine their interest in these capabilities. A one-year crew expedition for one Russian cosmonaut and one NASA astronaut, beginning in the spring of 2015, will help scientists to better understand the impacts of long-duration spaceflight on the human body, and will aid in the development of effective countermeasures.

### Project Schedule

The table below provides a schedule for potential EVAs. However, ISS conducts near term, real-time assessments of EVA demands along with other program objectives, to efficiently plan all required ISS activities. NASA remains postured to conduct EVAs on short notice in response to specific contingency scenarios. In addition, routine maintenance EVAs are planned when the list of tasks fulfills an EVA and the activity can be accommodated within the program objectives for the increment, while maintaining focus on utilization and research.

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

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Date	Significant Event
Nov 2013	Russian EVA 36
Dec 2013	Russian EVA 37
Dec 2013	US EVAs 24, 25
Jan 2014	Russian EVA 37A
Aug 2014	Two US EVAs
Aug 2014	Russian EVA 38
Feb 2015	Two US EVAs
Apr 2015	One US EVA
TBD 2015	Russian EVA(s) TBD

### Project Management & Commitments

While NASA maintains the integrator role for the entire ISS, each partner has primary authority for managing and operating the hardware and elements they provide. Within NASA, the Johnson Space Center in Houston, Texas leads project management of ISS Systems Operations and Maintenance.

### Acquisition Strategy

The current Boeing US on-orbit segment sustaining engineering contract extends through September 30, 2015. It is a cost plus award fee contract that provides sustaining engineering support, end-to-end subsystem management, and post production hardware support.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
US on-orbit segment Sustaining Engineering Contract	The Boeing Company	Johnson Space Center

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Implementation Review	Standing Review Board	May 2013	The Sustainment and Utilization Program Implementation Review will assess the ISS Program's ability to safely operate and maintain the ISS and to provide for a continuous human presence on-orbit. In addition, the Program Implementation Review will assess ISS utilization activities across Agency programs and the National Laboratory.	ISS Program is technically strong, well-managed, proactive, and has an excellent demonstrated technical capability. ISS needs to resolve transportation vulnerabilities, extend the life of ISS, focus and fund mandatory and critical technology research and demonstrations, increase crew time available for utilization, and fully utilize ISS.	N/A
Other	NASA Advisory Council	Dec 2013	Provides independent guidance for the NASA Administrator	No formal recommendations or findings for ISS	Apr 2014
Other	NASA Aerospace Safety Advisory Panel	Jan 2014	Provides independent assessments of safety to the NASA Administrator	ISS continued safe transport and operations during 2013. Significant progress has been made in Micrometeoroid and Orbital Debris avoidance. Recommend NASA develop de-orbit plan commensurate with ISS life expectancy timeline.	Apr 2014

### HISTORICAL PERFORMANCE

The table below provides the historical health assessment of each ISS system in FY 2013. As the table indicates, most systems had acceptable performance for the year. The thermal control system was yellow

## ISS SYSTEMS OPERATIONS AND MAINTENANCE

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in October 2012 due to an ammonia leak in a photovoltaic radiator. On November 1, 2012, astronauts conducted a spacewalk to reroute the ammonia flow through a spare radiator so the photovoltaic thermal control system could continue operation. The electrical power system was yellow in October 2012 due to a circuit breaker trip that caused a temporary reconfiguration of the power system. The crew health systems were briefly yellow in November 2012 while a software problem inside the US treadmill was investigated and resolved. EVA systems were red beginning in July 2013 after a spacesuit water leak during US EVA 23 spawned an investigation of the suits. EVA systems status improved to yellow by September 2013 when contingency EVA capability was restored.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
SUBSYSTEM	2012	2012	2012	2013	2013	2013	2013	2013	2013	2013	2013	2013
Command and Data Handling (C&DH)	G	G	G	G	G	G	G	G	G	G	G	G
Communications & Tracking (C&T)	G	G	G	G	G	G	G	G	G	G	G	G
Crew Health Systems (CHCS)	G	Y	G	G	G	G	G	G	G	G	G	G
Environmental Control and Life Support Systems (ECLSS)	G	G	G	G	G	G	G	G	G	G	G	G
Electrical Power System (EPS)	Y	G	G	G	G	G	G	G	G	G	G	G
Extra-Vehicular Activity (EVA)	G	G	G	G	G	G	G	G	G	R	R	Y
Extra-Vehicular Robotics (EVR)	G	G	G	G	G	G	G	G	G	G	G	G
Flight Crew Equipment (FCE)	G	G	G	G	G	G	G	G	G	G	G	G
Guidance & Navigation (GN&C)	G	G	G	G	G	G	G	G	G	G	G	G
Propulsion	G	G	G	G	G	G	G	G	G	G	G	G
Structures & Mechanisms (S&M)	G	G	G	G	G	G	G	G	G	G	G	G
Thermal Control Systems (TCS)	Y	G	G	G	G	G	G	G	G	G	G	G
Payload Facilities	G	G	G	G	G	G	G	G	G	G	G	G

**Purpose:** To provide a sense of the availability and functional status of the on orbit systems.

### Definitions:

(G) Acceptable performance. Degraded performance of any subsystem may be deemed acceptable, dependent on other mitigating factors such as redundancy, spares availability, or criticality level.
(Y) Degraded system performance with some operations being impacted.
(R) System performance is degraded and there is a significant impact to operations

## ISS RESEARCH

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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>317.5</b>	<b>--</b>	<b>312.2</b>	<b>312.2</b>	<b>312.2</b>	<b>312.2</b>	<b>312.2</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**NASA Expedition 37 flight engineer Karen Nyberg works with a plant experiment in the Destiny Laboratory aboard the International Space Station. Growing plants in space will provide the necessary food as well as aesthetics for future long-duration missions, and has important applications for increasing crop yield here on Earth.**

The International Space Station (ISS) is an orbiting platform that provides an unparalleled capability for space-based research and a unique venue for developing technologies for future human space exploration. As a research and development facility, ISS enables scientific investigation of physical processes in an environment very different from that of Earth. A range of science laboratories, external testbeds, and observatory sites are available aboard the ISS, enabling astronauts to conduct a wide variety of experiments in the unique environment of low Earth orbit.

ISS supports research across a diverse array of disciplines, including physics, Earth science, space science, biology and biotechnology, human physiology, agricultural science, chemistry, and materials science. In addition, ISS is a platform for educational activities that

allow the public to connect with NASA and inspire students to excel in science, technology, engineering, and mathematics (STEM) academic disciplines.

As the name implies, the International Space Station is not strictly a NASA endeavor, but a collaborative venture with our international partners, including the Canadian, European, Japanese, and Russian space agencies. Although each partner has distinct national goals for ISS research, all participating agencies share a unified goal to extend the resulting knowledge for future exploration and to benefit humanity. Within NASA, mission directorates prioritize their research investments based on decadal studies from the National Academies and the Decadal Survey on Biological and Physical Sciences in Space.

The ISS Research project funds fundamental research in biological and physical sciences to enable future human exploration and add to our existing body of knowledge. Also funded is multi-user systems support (MUSS), which provides strategic, tactical, and operational support to all NASA sponsored and non-



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NASA sponsored payloads (including those of the five international partners), as well as operation of on-orbit research facilities. Research-enabling activities are included, as well as support to the Center for the Advancement in Space (CASIS) – a non-profit management organization that determines commercial and other non-NASA research priorities for the ISS National Laboratory.

Research and development conducted aboard ISS holds the promise of next-generation technologies in health and medicine, robotics, manufacturing, and propulsion. As NASA's only long-duration flight testbed, ISS is critical to developing plans to extend human space exploration beyond low Earth orbit. Aboard ISS, researchers study the effects of long-duration exposure to the space environment on the crew, devising and testing countermeasures that can offset risks to crew. Additionally, researchers evaluate extended performance of hardware critical to long-duration flight, by testing the ability of hardware to survive in the space environment, determining life limiting issues and repair capabilities, and evaluating upgrades to improve performance. For example, a thermal protective coating that withstood long-term exposure to the space environment as part of the ISS materials testbed is now being used to protect the Space-X Dragon commercial cargo resupply vehicle.

With the conclusion of Expedition 36 in September 2013, more than 1,600 principal investigators from 69 countries around the world have performed over 1,500 research investigations utilizing ISS and over 700 research and development results have been published in scientific journals and magazines. ISS will continue to provide research opportunities to scientists, engineers, and technologists through at least 2024.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA renamed the Satellite Servicing project "In Space Robotic Servicing," and the Agency has transferred the budget from ISS Systems Operations and Maintenance to ISS Research. This change better aligns this content, which is research and development in nature.

### ACHIEVEMENTS IN FY 2013

Scientific accomplishments on ISS continue to increase, as do the quantity of data returned from automated research instruments, and astronaut crew time dedicated to research. During FY 2013, ISS was host to 286 experiments. These included 58 in biology and biotechnology, 34 in Earth and space science, 38 educational activities, 41 in human research, 44 in physical science, and 71 in technology.

As NASA looks forward to expanding human exploration of the solar system, work aboard ISS continued efforts to enable long-duration space flight. NASA initiated studies to better understand the causes for vision changes experienced by many astronauts on ISS. Early studies indicate that this change in vision could be linked to alterations in how the cardiovascular system handles fluid shifts to the brain when in space. This leads to increased pressure on the eyes, and associated structures within the brain. As a result, some astronauts experience problems with their vision, sometimes temporary, and sometimes permanent. While critical to astronaut health, understanding the role of the cardiovascular system in these vision changes could also provide information for advanced treatments of cardiovascular disease in certain populations here on Earth.

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Researchers also continued using the ISS to investigate the behavior of “smart fluids.” These are fluids that can change from liquid to solid when an electromagnetic field is applied. Understanding smart fluid behavior without the masking effects of gravity holds promise to improve current materials and structures, ranging from automobile brake and suspension systems to the design of buildings and bridges to better withstand earthquakes.

Here on Earth, a new commercial system called “mWater” began providing an innovative, mobile, and inexpensive global clean water testing resource for governments, health workers and the public by using an ISS technology-based water sampling kit and new smartphone application. The “app” allows users from around the world to input water quality data from different locations in the field. They can also scan the mWater database for nearby potable water locations. This kind of technology is critical for managing health globally, especially in developing countries.

The Environmental Protection Agency (EPA) uses data from the Hyperspectral Imager for the Coastal Ocean on ISS to help monitor and protect the nation’s water supplies as required by the Clean Water Act. Findings have allowed EPA scientists to monitor water quality in near real time, resulting in new models to identify the presence of algal blooms that endanger public health and sea life. The Hyperspectral Imager for the Coastal Ocean is now widely available for use by other institutions through CASIS National Laboratory pathways.

In April 2013, researchers announced exciting Alpha Magnetic Spectrometer science results collected on the ISS, which possibly indicates the existence of either a dark matter particle, or a near-by spinning neutron star (pulsar). Subsequent Alpha Magnetic Spectrometer science data collection will help to determine which possibility is correct.

Educational activities aboard ISS have inspired roughly 43 million students worldwide by involving them in research and demonstrating the science and engineering principles behind space exploration. FY 2013 marked the 10-year anniversary of the “High School Students United with NASA to Create Hardware” program. This is an instructional partnership between NASA, high school and intermediate/middle school students. Students build cost-effective hardware and soft goods for use on the ISS and for training NASA astronauts and flight controllers. The program’s popularity has grown to include 53 schools across 18 different states, and curriculum areas include video editing, sewing and soft goods design, computer electronics, engineering design, and 3-D printing for rapid prototype development, machine shop and welding.

CASIS continued to make progress toward its goal to expand utilization of the ISS by the wider, non-NASA sponsored, research community, connecting with high technology business “ecosystems” in Houston, Denver and Boston. CASIS established new partnerships with organizations such as Novartis, Cobra Puma Golf, MD Anderson Cancer Center, the Boston Museum of Science, and the Massachusetts Institute of Technology. The CASIS team released three Requests for Proposals, and began funding research on advancing protein crystal growth in microgravity to improve drug design, and on materials science to study how exposure to space influences the physical and chemical properties of materials. At the end of the fiscal year, CASIS saw their first funded payloads – all education related – successfully delivered to the ISS.

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For a more comprehensive list of research achievements on the ISS, go to:

[http://www.nasa.gov/mission\\_pages/station/research/index.html](http://www.nasa.gov/mission_pages/station/research/index.html).

### WORK IN PROGRESS IN FY 2014

In FY 2014, astronauts will use new hardware on ISS to perform plant research and investigate gravity effects on physiology and biology. The first phase of a new fruit fly lab will launch in FY 2014, enabling study of micro- and fractional-gravity effects on animals. The fruit fly is a complex organism that has been extensively studied on Earth. At first glance, fruit flies do not seem to be a good analog for humans, but on the molecular level, we share many of the same basic genes and signal transactions. Research on insects is opening up new avenues for development of prevention and therapy against infections, cancer, and inflammatory disease. The new fruit fly lab could also enable greater knowledge of human genetic responses to long-term stays in space.

NASA biological and physical sciences kicked off a new approach to NASA research called “open source science,” which is entering implementation this year. Open source science is a way to maximize return on investment in ISS research by greatly increasing numbers of investigations and development of translational applications. The approach augments the current traditional approach to NASA Research Announcements. Open source experiments will generate large amounts of data which will be stored in a NASA-developed database, available for analysis by anyone. Additional research can be performed using current infrastructure and hardware. The first database being developed is for geneLAB, which will be used to expand upon the growing field of “-omics,” which is a broad area of biological and molecular research. It is the study of the entire complement of biomolecules, like proteins (proteomics), genes (genomics), etc. This particular data will also incorporate the effects and differences that microgravity induces in living organisms.

In FY 2014, the new Rodent Research habitats will provide critical life sciences research capabilities to study physiological changes in space. SpaceX-4 will launch the first rodent investigation using this habitat. An active animal research program is critical to improve our understanding of the adaptive response of several physiological systems. This helps better define risks and countermeasures to the health of humans in prolonged spaceflight.

New externally mounted payloads on ISS will study Earth’s atmosphere, cosmic rays, high energy astrophysics, and the origin of the universe. One of these payloads is the Cloud-Aerosol Transport System, which uses a Light Detection and Ranging (LIDAR) remote sensing instrument to provide measurements of atmospheric clouds and aerosols such as pollution, dust, and smoke. The investigation will perform long duration observations of up to three years beginning in 2014, providing continuity in data acquired on previous missions. Observations of the Earth’s changing atmosphere enable researchers to understand formative and ongoing processes, and ultimately model and predict future climate changes. The orbit of ISS is particularly suited to measurements of this kind because of the geographic areas it passes over, and because it permits study of day-to-night changes, which other Earth science satellites cannot offer, due to their orbits.

Reusing hardware originally built to test parts of NASA's QuikScat satellite, NASA will launch the RapidScat instrument to ISS in 2014 to measure ocean-surface wind speed and direction. As an

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Formulation	Development	Operations
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autonomous externally-mounted payload to the Columbus laboratory, the ISS-RapidScat instrument will help improve weather forecasts, including hurricane monitoring, and understanding of how ocean-atmosphere interactions influence Earth's climate. ISS-RapidScat will help fill the data gap created when QuikScat, which was designed to last two years but operated for 10, stopped collecting ocean wind data in late 2009. Current scatterometer orbits pass the same point on Earth at approximately the same time every day. Since the Station's orbit intersects those of each of these satellites about once every hour, ISS-RapidScat can serve as a calibration standard and help scientists stitch together the ocean-surface wind data from multiple sources into a long-term consistent record. A SpaceX Dragon cargo spacecraft will deliver the instrument, and the instrument is expected to operate for two years.

The ISS program has begun work to support hardware development, such as a new Cold Atom Laboratory that will take advantage of the microgravity environment to create the coldest matter in the universe – just a trillionth of a degree above absolute zero. At these temperatures, individual atoms, following the laws of quantum mechanics, approach fractions of a millimeter in effective size, making it possible to visually observe the quantum interactions of clouds of atoms. In 2014, the Cold Atom Laboratory is scheduled to complete the critical design review phase, in preparation for delivery to ISS in 2016. The laboratory could enable significant discoveries in atomic physics, which could have applicability to next generation communications, navigation, timekeeping, and computing.

Under a new Executive Director, former astronaut Gregory H. Johnson, CASIS started off the fiscal year at a rapid pace. They announced a partnership with the Naval Research Laboratory to use ISS for observational research on factors that contribute to harmful ocean algal bloom. CASIS and Kentucky Space LLC will examine effects of the space environment on enhanced healing abilities in microgravity on ISS. They will study regeneration in planarians, which are flatworms capable of rebuilding damaged body organs and nervous systems. CASIS will also fund several new awards in microgravity stem cell research to study tissue engineering/regeneration, cell replacement therapy and cell reprogramming.

New CASIS investigations in protein crystal growth will leverage the microgravity environment for growing ideal crystal structures of proteins critical in the progression of Huntington's disease and cystic fibrosis. Understanding these protein structures can lead to new forms of treatment and perfecting these methods are critical to explaining structures of other difficult proteins here on Earth.

In addition, the ISS MUSS payload integration function will support over 300 on-orbit payload investigations and 500 investigators in FY 2014.

Robotic Refueling Mission phase 2 hardware will be flown to ISS in FY 2014. This hardware includes a new tool and task board, which will be used to demonstrate additional refueling tasks, including robotic operations associated with cryogenic fluid transfer. In Space Robotic Servicing is also developing a tool to detect external ammonia leaks on ISS. This device will be critical in monitoring and determining leak locations on ISS, and serve as generic tool to assist in satellite repair.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Although ISS crew visits are currently limited to six months, two astronauts will remain aboard for a full year of research starting in spring 2015. This 12 month study will investigate the effects of long-term

## ISS RESEARCH

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Formulation	Development	Operations
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stays in space on bone density, muscle mass, strength, vision and human physiology. While critical for future exploration missions, NASA anticipates that this study and other investigations will also have application on Earth. As a growing senior population faces a myriad of age-related health concerns, NASA's research advances knowledge of bone and muscle health, immunology, and innovative diagnostic systems, all of which hold promise for medical treatments on Earth.

NASA plans to launch the Bigelow Expandable Activity Module in May 2015. This expandable habitat for ISS will be used to prove inflatable technology for future human spaceflight and exploration activities. Also ahead for space exploration advancements are the Zero Boil-Off Tank fluids investigation, and 3-D Printing in Zero-G technology. The Zero Boil-Off Tank aims to reduce propellant launch mass and decrease space mission risk by improving existing models for development of cryogen storage systems. The 3-D Printing in Zero-G technology will be the first step in demonstrating a “machine shop” capability of creating new components in space, a critical enabling element of future exploration class missions.

NASA and CASIS teams are already coordinating to maximize available resources for rodent science in FY 2015. Other than the academic community, early candidates for research opportunities include the pharmaceutical industry and the US Army. Rodent research is particularly valuable because of the similarity of many aspects of rodents’ anatomy, physiology, and genetics to those of humans. They allow for more efficient research and drug therapy development because they are small and have a short generation time and accelerated lifespan (one mouse year equals about 30 human years). By studying rodents on ISS, researchers can observe spaceflight-induced changes to tissues and cells, muscles and bones, cardiovascular and reproductive systems, and even behavior.

The ISS Research project continues to develop hardware that supports research such as a large plant chamber planned for deployment in 2015. This facility is key to studying what happens to plants in space, and to determine whether humans can successfully grow food in microgravity during long-duration exploration missions. Plants are not only a source of food, but they provide oxygen, building material, and water recycling. This research may also lead to innovations that allow people on Earth to grow more food using less land, and to regenerate lost forest areas more quickly.

The Stratospheric Aerosol and Gas Experiment (SAGE) Earth observation facility planned for FY 2015 will record changes in the properties of the Earth's ozone layer, such as fluctuations in concentrations of greenhouse gases and thinning of the ozone layer. Scientists do not yet understand how this affects the climate; accurate long-term measurements such as those provided with SAGE are crucial for understanding the processes controlling climate change.

In addition, Robotic Refueling Mission phase 2 hardware will be flown to ISS in FY 2014. This hardware includes a new tool and task board, which will be used to demonstrate additional refueling tasks, including robotic operations associated with cryogenic fluid transfer. In Space Robotic Servicing is also developing a tool to detect external ammonia leaks on ISS. This device will be critical in monitoring and determining leak locations on ISS, and serve as generic tool to assist in satellite repair.

## ISS RESEARCH

Formulation	Development	Operations
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### Project Schedule

An increment is a period of time for ISS operations that spans from one Soyuz undock to the next Soyuz undock. There are four increments per year that consist of cargo ship arrivals and departures, as well as activities performed on board, including the research performed. The table below outlines start dates of the upcoming increments to ISS.

Date	Significant Event
Nov 2013	Increment 38
Mar 2014	Increment 39
May 2014	Increment 40
Sep 2014	Increment 41
Nov 2014	Increment 42
Mar 2015	Increment 43
May 2015	Increment 44

### Project Management & Commitments

The Space, Life and Physical Sciences Research and Applications Division (SLPSRAD) at NASA Headquarters manages biological and physical sciences research. The division, working closely with the Office of the Chief Scientist, establishes the overall direction and scope, budget, and resource allocation for the project, which the NASA centers implement, and acts as the liaison with CASIS. The ISS Program Office manages other ISS Research activities such as MUSS and National Laboratory enabling activities.

Element	Description	Provider Details	Change from Formulation Agreement
Biological and Physical Sciences	This element includes all NASA-sponsored biological and physical research.	Provider: NASA Centers, contractors, and principal investigators Lead Center: HQ Performing Center(s): ARC, GRC, JPL, MSFC, JSC Cost Share Partner(s): N/A	N/A

## ISS RESEARCH

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Multi-user systems support (includes National Laboratory enabling activities)	Multi-user systems support activities support all research on ISS, both NASA sponsored and non-NASA sponsored.	Provider: ISS program and contractors Lead Center: JSC Performing Center(s): MSFC Cost Share Partner(s): N/A	N/A

### Acquisition Strategy

NASA awards contracts and grants for conducting research on ISS. SLPSRAD manages NASA-sponsored biological and physical research. NASA selected CASIS to manage non-NASA ISS Research activities. This independent non-profit will further develop national uses of the Station.

Peer review is the means to ensure a high-quality research program. Engaging leading members of the research community to competitively assess the merits of submitted proposals is essential to assuring the productivity and quality of ISS Research. In FY 2014, SLPSRAD began implementing a new approach to research, termed “open source science”, to maximize return on investment on research dollars. Open source science will make greater quantities of flight experiment data available to larger scientific communities. SLPSRAD will continue to use NRAs to provide researchers selected by peer-review the opportunity to develop complete flight experiments and continue to allow universities to participate in flight research by involving their scientists. ISS Research will announce two biological and physical sciences NRAs in 2014, and the first open source science NRA is planned for FY 2015.

NASA prioritizes ISS research based on recommendations from the National Research Council and the Decadal Survey on Biological and Physical Sciences in Space. In FY 2013, NASA established a HEO Research Subcommittee within the NASA Advisory Council to advise NASA on the direction of basic research within HEO. The National Research Council has agreed to add a committee in FY 2014 to its Space Studies Board to provide independent advice on strategy and priorities in the physical and life sciences at NASA. Major technology demonstrations require significant cooperative funding and NASA is developing an approach for cross-Agency prioritization of ISS technology initiatives.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Vehicle Sustaining Engineering Contract	The Boeing Company	Houston, TX
Huntsville Operations Support Center	COLSA Corporation	Huntsville, AL

## ISS RESEARCH

Formulation	Development	Operations
Element	Vendor	Location (of work performance)
ISS National Laboratory Management Entity	CASIS	Tallahassee, FL

## INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Peer Review Panel	May 2013	Peer review of space biology NASA research announcement	Selection of grantees	Jul 2014
Quality	Peer Review Panel	July 2012	Peer review of physical sciences NASA research announcement	Selection of grantees	Dec 2013
Quality	National Academies	Jul 2011	Decadal survey of life and physical sciences in microgravity	Establish a guide for research in the next decade.	Jul 2021
Program Implementation Review	Standing Review Board	May 2013	The Sustainment and Utilization Program Implementation Review will assess the ISS Program's ability to safely operate and maintain the ISS and to provide for a continuous human presence on-orbit. In addition, the Program Implementation Review will assess ISS utilization activities across Agency programs and the National Laboratory.	ISS Program is technically strong, well-managed, proactive, and has an excellent demonstrated technical capability. ISS needs to resolve transportation vulnerabilities, extend the life of ISS, focus and fund mandatory and critical technology research and demonstrations, increase crew time available for utilization, and fully utilize ISS.	N/A
Other	NASA Advisory Council	Dec 2013	Provides independent guidance for the NASA Administrator.	No formal recommendations or findings for ISS	Apr 2014



## ISS RESEARCH

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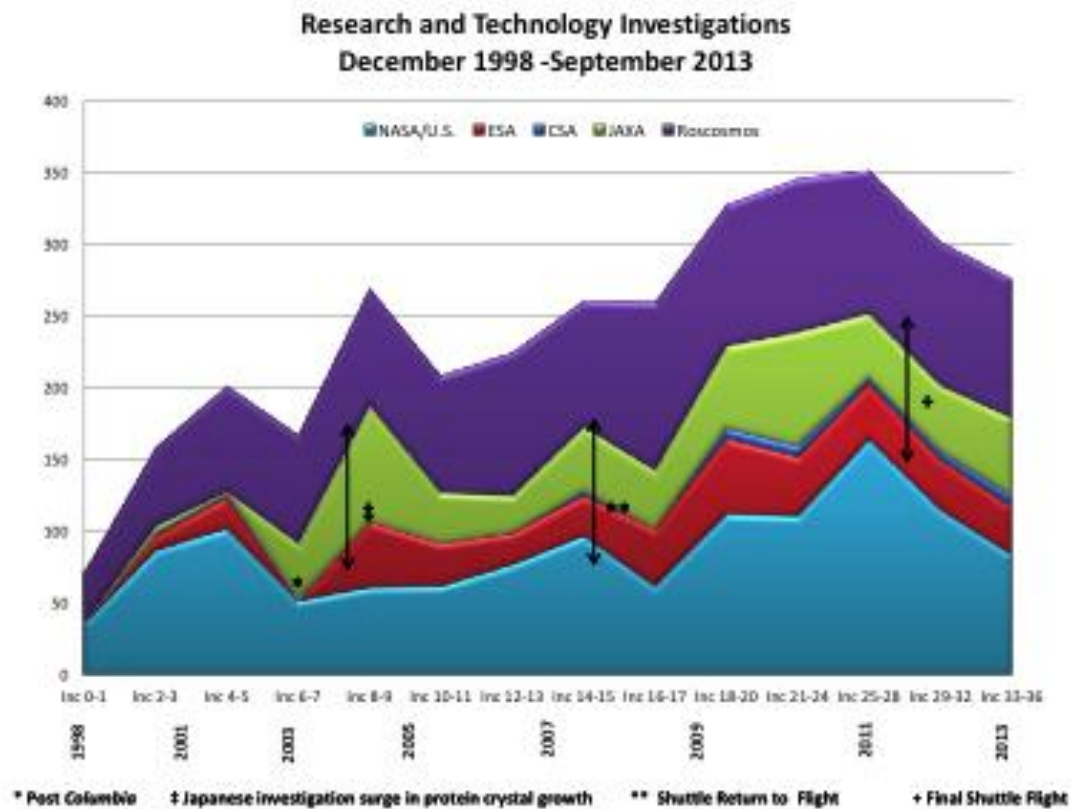
Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	NASA Aerospace Safety Advisory Panel	Jan 2014	Provides independent assessments of safety to the NASA Administrator	ISS continued safe transport and operations during 2013. Significant progress has been made in Micrometeoroid and Orbital Debris avoidance. Recommend NASA develop de-orbit plan commensurate with ISS life expectancy timeline.	Apr 2014

## ISS RESEARCH

Formulation	Development	Operations
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### HISTORICAL PERFORMANCE

In FY 2013, NASA estimates ISS performed over 284 research and technology investigations. The chart below displays historical data by partner agency for research investigations performed on ISS since 1998.



## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>1040.3</b>	<b>--</b>	<b>1530.7</b>	<b>1602.4</b>	<b>1617.0</b>	<b>1630.9</b>	<b>2159.1</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**In September 2013, the Orbital Sciences Corporation Antares rocket, carried the Cygnus cargo spacecraft from the Mid-Atlantic Regional Spaceport at NASA's Wallops Flight Facility in Virginia. This was the first launch of the Cygnus cargo spacecraft into low Earth orbit – an important step that enabled berthing with the International Space Station 11 days later.**

Maintaining the International Space Station (ISS) requires a fleet of vehicles and launch locations to rotate crewmembers; replenish propellant; provide science experiments, critical supplies, and maintenance hardware; and dispose of waste. These deliveries sustain a constant supply line crucial to ISS operations and research. The ISS Crew and Cargo Transportation project funds transportation services provided by both international partners and domestic commercial providers.

NASA purchases cargo delivery to ISS under the Commercial Resupply Services (CRS) contracts with Orbital Sciences Corporation (Orbital) and Space Exploration Technologies (SpaceX). The FY 2015 budget supports these contracted flights, as well as future flights to provide for cargo transportation, including National Laboratory research payloads.

The Russian Space Agency, Roscosmos, currently provides ISS crew transportation. NASA plans to continue purchasing crew transportation services from Roscosmos until a domestic capability is available.

ISS Crew and Cargo Transportation also funds activities supporting visiting vehicles that provide transportation for ISS, such as the system to support crew communications and provide backup capability for existing cargo transportation providers.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA has eliminated one previously planned FY 2015 cargo flight from the manifest as the agency balances ISS requirements with appropriated funding. NASA is currently updating cargo requirements as part of the FY 2016 budget planning process, and assessing the full impacts of the FY 2014 appropriations.

## ISS CREW AND CARGO TRANSPORTATION

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Formulation	Development	Operations
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### ACHIEVEMENTS IN FY 2013

FY 2013 marked the successful completion of the Commercial Orbital Transportation Services program, resulting in two domestic supplier vehicles to deliver cargo to the ISS. Cargo services are now procured commercially through the CRS contracts.

SpaceX completed ten milestones for performance on seven commercial resupply flights, including milestones for successful completion of two flights. SpX-1 launched on October 7, 2012, delivering a total of 882 pounds of supplies to the orbiting laboratory, including crew supplies, scientific research hardware, and miscellaneous supplies. SpaceX's Dragon spacecraft returned a total of 1,673 pounds of cargo, including crew supplies, scientific research, vehicle and other hardware. SpX-2 launched on March 1, 2013, delivering over 1,200 pounds of supplies to support continuing space station research experiments, and returning with more than a ton of science samples from human research, biology and biotechnology studies, physical science investigations, and education activities.

Orbital completed five milestones for performance on five commercial resupply flights. Under the CRS contract, NASA procured capability on the Orbital COTS demonstration flight launched on September 18, 2013, which delivered approximately 1,300 pounds of cargo, including food, clothing and student experiments. Prior to its departure from the Station, Cygnus, Orbital's spacecraft, was loaded with items no longer needed aboard the Station. After Cygnus was released from ISS, it successfully completed its planned destructive re-entry into the Earth's atmosphere.

The project also supported five Russian Soyuz launches in FY 2013, providing crew transportation and rescue services to ISS for six US operating segment crewmembers.

### WORK IN PROGRESS IN FY 2014

In FY 2014, ISS Crew and Cargo Transportation continues to provide a stable cargo flight plan, which includes CRS flights to deliver research and logistics hardware to the Station. In total, NASA expects SpaceX to launch three CRS flights, and complete 16 performance milestones on eight commercial resupply flights. NASA expects Orbital to launch two CRS flights, and complete eleven performance milestones on eight commercial resupply flights.

Also in FY 2014, the project will support a crew flight plan that includes four Soyuz launches carrying a total of six US operating segment crewmembers to ISS.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

ISS Crew and Cargo Transportation will enable continued research and technology development by providing a stable crew and cargo flight plan. These flight plans include approximately four Soyuz launches carrying a total of six US operating segment crewmembers to ISS, and commercial resupply flights to deliver research and logistics hardware. NASA expects Orbital to launch three CRS flights, and complete ten performance milestones on six flights; SpaceX plans include three commercial resupply flights, and completing 15 performance milestones on eight flights.

## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
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The Opportunity, Growth, and Security Initiative contains an additional \$100.6 million for ISS cargo transportation. This funding would support the current manifest and offset potential future flight reductions, which would enhance NASA's efforts to fully utilize ISS as a national laboratory and orbiting research facility.

### **Project Schedule**

Maintaining a regular rate of cargo delivery on a mix of NASA and partner vehicles ensures that nominal operations and maintenance are sustained, while allowing the program to respond to any anomalies that might occur. The table below shows the scheduled ISS flight plans for FY 2014 and FY 2015. NASA funds the SpaceX and Orbital missions, as well as Soyuz seats related to US operating segment crew requirements. The planned spacing of the Soyuz crew rotation flights assures a continuous six-crew presence on ISS, as well as smooth transitions between crews.

Date	Significant Event
Nov 2013	Soyuz 37S
Nov 2013	Progress 53P
Jan 2014	Orb-1
Feb 2014	Progress 54P
Mar 2014	SpX-3
Mar 2014	Soyuz 38S
Apr 2014	Progress 55P
Jun 2014	SpX-4
May 2014	Orb-2
May 2014	Soyuz 39S
Jun 2014	ATV-5
Jul 2014	Progress 56P
Jul 2014	HTV-5
Sep 2014	SpX-5
Sep 2014	Soyuz 40S
Oct 2014	Orb-3
Oct 2014	Progress 57P
Nov 2014	Soyuz 41S

## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
Dec 2014	SpX-6	
Jan 2015	Orb-4	
Feb 2015	Progress 58P	
Mar 2015	Soyuz 42S	
Apr 2015	SpX-7	
Apr 2015	Progress 59P	
May 2015	Soyuz 43S	
Jun 2015	SpX-8	
Jul 2015	Orb-5	
Jul 2015	Progress 60P	

### Project Management & Commitments

Johnson Space Center (JSC) is responsible for project management of ISS Crew and Cargo Transportation.

Element	Description	Provider Details	Change from Formulation Agreement
Crew transportation	Roscosmos will provide crew transportation to ISS via the major contract described below until a domestic capability is available.	Provider: Roscosmos Lead Center: JSC Performing Center(s): N/A Cost Share Partner(s): CSA, ESA, and JAXA	N/A
Cargo transportation	Orbital and SpaceX will provide cargo transportation to ISS via the major contracts described below. ESA and JAXA will provide additional cargo transportation as part of the ISS partnership. Roscosmos will also provide nominal cargo transportation via Soyuz purchased for crew transportation.	Provider: Orbital, SpaceX, ESA, JAXA, and Roscosmos Lead Center: JSC Performing Center(s): GSFC, KSC Cost Share Partner(s): CSA, ESA, and JAXA	N/A

## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
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### Acquisition Strategy

NASA competitively awarded CRS contracts to SpaceX and Orbital on December 23, 2008. These are milestone based fixed-price indefinite delivery, indefinite quantity contracts. Cargo transportation services began in 2012, with the current contracts running through 2016. NASA plans to competitively procure any future cargo transportation services, excluding services obtained via barter with our international partners or nominal cargo transportation provided by Soyuz.

In 2006, NASA modified the Roscosmos contract to include crew transportation, rescue, and related services. The agreement is a sole source contract under FAR 6.302-1 (only one responsible source and no other supplies or services will satisfy Agency requirements). NASA is in discussions with Roscosmos for crew launches through 2017, and crew rescue and return through mid-2018. As domestic crew transportation service providers are certified (by the end of 2017), NASA will competitively procure those services.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Crew transportation	Roscosmos	Moscow, Russia
Cargo transportation	Orbital	Dulles, VA
Cargo transportation	SpaceX	Hawthorne, CA

## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
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### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Implementation Review	Standing Review Board	May 2013	The Sustainment and Utilization Program Implementation Review will assess the ISS Program's ability to safely operate and maintain the ISS and to provide for a continuous human presence on-orbit. In addition, the Program Implementation Review will assess ISS utilization activities across Agency programs and the National Laboratory.	ISS Program is technically strong, well-managed, proactive, and has an excellent demonstrated technical capability. ISS needs to resolve transportation vulnerabilities, extend the life of ISS, focus and fund mandatory and critical technology research and demonstrations, increase crew time available for utilization, and fully utilize ISS.	N/A
Other	NASA Advisory Council	Dec 2013	Provides independent guidance for the NASA Administrator.	No formal recommendations or findings for ISS.	Apr 2014
Other	NASA Aerospace Safety Advisory Panel	Jan 2014	Provides independent assessments of safety to the NASA Administrator.	ISS continued safe transport and operations during 2013. Significant progress has been made in Micrometeoroid and Orbital Debris avoidance. Recommend NASA develop de-orbit plan commensurate with ISS life expectancy timeline.	Apr 2014



## ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations
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### HISTORICAL PERFORMANCE

#### Flights to ISS from Inception Through FY 2013:

Vehicle	Provider	Number of Launches	Successful Launches	Unsuccessful Launches
Shuttle	NASA	37	37	0
Soyuz	Roscosmos	36	36	0
Progress	Roscosmos	54	53	1
Proton	Roscosmos	2	2	0
ATV	ESA	4	4	0
HTV	JAXA	4	4	0
Falcon9/Dragon	SpaceX	3	3	0
Antares/Cygnus	Orbital	1	1	0

## 21ST CENTURY SPACE LAUNCH COMPLEX

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>39.0</b>	<b>39.6</b>	<b>25.9</b>	<b>25.9</b>	<b>11.8</b>	<b>11.8</b>	<b>0.0</b>
Change from FY 2014			-13.7				
Percentage change from FY 2014			-34.6%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The range safety system at Cape Canaveral Air Force Station in Florida supports all launches from the Cape and the Kennedy Space Center. It is part of the Eastern Range modernization effort funded by NASA's 21st Century Launch Complex, in partnership with the US Air Force. Planned upgrades to the range safety system will provide a sophisticated launch network that enables faster transfer of data, making launches from the Eastern Range more beneficial to commercial and government customers.

In order to enable future exploration of the solar system and new commercial opportunities in low Earth orbit, the Agency created the 21st Century Space Launch Complex (21CSLC) activity. Its primary purpose is to modernize and transform the Florida launch and range complex into a more robust launch capability at Kennedy Space Center (KSC) that can support multiple users. This initiative supports current and future NASA programs, other US government agencies, and commercial industry.

For more information, go to <http://go.nasa.gov/groundsystems>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

In FY 2013, the Agency completed extensive infrastructure enhancements at KSC, aimed at enabling the launch complex to support multiple users. In the Vehicle Assembly Building (VAB), the project team removed heritage electrical cables, completed upgrades to the fire suppression system, and refurbished the overhead bridge cranes. At the Shuttle Landing Facility, they installed new security gates and fences to accommodate horizontal launch and landing customers. Replacing the old rock surface on the launch pad crawler-way continued, as did repairs to approximately 40 miles of gaseous nitrogen pipeline. These efforts improve system dependability, and reduce operations and maintenance costs. To enable NASA to monitor commodity usage per facility, the team installed meters at multiple ground processing facilities. The team also conducted several concept studies, assessments, and design reviews. Examples of these

## **21ST CENTURY SPACE LAUNCH COMPLEX**

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concept studies include a Shuttle Landing Facility vertical launch/vertical landing concept study, a Launch Complex-39B rocket propellant-1 capability concept study, a converter compressor facility preliminary engineering review, and Launch Complex-39B universal flame deflector/flame trench design.

### **WORK IN PROGRESS IN FY 2014**

During FY 2014, NASA continues to establish and develop partnerships with government and commercial entities. The team plans to finalize design of the critical system upgrade for the VAB utility annex. Design work will be finished on a multi-user flame deflector to support different vehicle configurations at Pad 39-B. The team will upgrade the interface with the new timing system installed on Cape Canaveral Air Force Station, and complete functional fault modeling of the cryogenic testbed lab. Both planned enhancements enable horizontal launch and landing capabilities. Work also continues on the crawler transporter 20-year life extension project, and completion of design studies for the mobile launcher extensible column, multi-use launch mount interface, and medium class launch capability at Launch Complex-39B.

The 21CSLC Mission-Focused Modernization product line, in addition to supporting the modernization of the Florida Launch and Range Complex, will continue to work with Wallops Flight Facility (WFF) in support of those ISS Commercial Resupply Services launches that originate from WFF.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The team will perform environmental remediation and technology upgrades to the LC-39 shoreline and the waste management facility. These improvements will reduce potential seawater intrusion into the launch complex, and expand the Center's waste management capabilities. Upgrades to the Eastern Range mechanical and lighting systems will be performed at commercial facilities, required due to increased facility usage and to remedy deferred maintenance. Prior to leasing Launch Pad 39A to commercial customers, 21CSLC will perform soil and groundwater assessments that allow the Agency to document any/or remediate any potential hazardous or environmental issues.

In partnership with the US Air Force, NASA will continue efforts to modernize combined range interface and control services such as installing a new Doppler radar wind profiler and improving the capability of the far field antenna range. To predict hardware failure, minimize repair cost, and avoid launch delays, 21CSLC activities will demonstrate and test interfaces with the end-to-end command and control system. In addition, activities will continue to perfect fault isolation and anomaly detection on ground support equipment, facilities, and other flight hardware, resulting in minimized costs and time for repairs.

### **Program Elements**

The 21CSLC initiative has a multi-user focus and targets investments to develop and implement effective and efficient ground systems designs. This will meet the needs of commercial and/or government future users of the KSC and WFF. 21CSLC consists of five product lines to guide these investments:

## 21ST CENTURY SPACE LAUNCH COMPLEX

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Project/Element	Element Content
Offline Manufacturing, Processing and Recovery Systems	Repair and upgrade systems and facilities associated with payload processing, servicing, hazardous operations, and recovery in support of commercial customers
Range Interface and Control Services	Develops capability for communications, range systems, customer interface systems, and advanced ground systems maintenance
Mission Focused Modernization	Provides multi-user facility capabilities to support a variety of vehicles, processed and launched in the horizontal or vertical configuration
Florida Launch Modernization Infrastructure	Modernizes power, utility and facility systems, waste management systems, and safety and security systems throughout the KSC launch infrastructure so that it can maximize the number of potential users
Environmental Remediation and Technologies	Ensures energy conservation, environmental planning and regulatory requirements, natural resource mitigation, and environmental research, including materials replacement and technology development are being addressed

### **Program Schedule**

The following table highlights the major 21CSLC activities with their estimated completion timeframes:

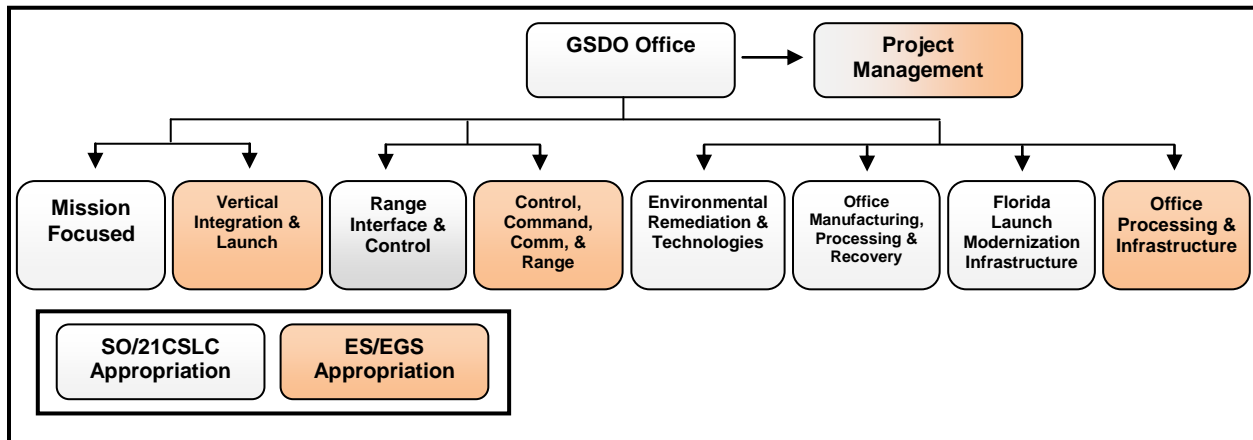
Date	Significant Event
Oct 2013	Pad B Flame Trench refurbishment design complete
Mar 2014	Environmental impact mitigation for Shuttle Landing Facility development complete
May 2014	Eastern Range Lightning System upgrade complete
Aug 2014	Advanced Ground System Maintenance Interface to End to End Command and Control System demonstration
Apr 2015	50 megahertz Doppler project complete
May 2016	Crawler Transport jacking, equalization and leveling system cylinders complete

### **Program Management & Commitments**

The Ground Systems Development and Operations Program Office (GSDO) manages both Exploration Ground Systems (EGS) and 21CSLC activities. GSDO manages customer requirements between the Space Launch System, Orion, and multiple other government and government and commercial users to ensure implementation of cost-effective, synergistic design solutions.

## 21ST CENTURY SPACE LAUNCH COMPLEX

The following diagram breaks out the 21CSLC and EGS content.



The following table addresses the various elements within 21CSLC, lead and participating centers, and any cost share partners.

Program Element	Provider
Offline Manufacturing, Processing and Recovery Systems	Provider: 21CSLC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A
Range Interface and Control Services	Provider: 21CSLC Lead Center: KSC Performing Center(s): ARC, JPL, GRC Cost Share Partner(s): US Air Force
Mission Focused Modernization	Provider: 21CSLC Lead Center: KSC Performing Center(s): WFF Cost Share Partner(s): N/A
Florida Launch Modernization Infrastructure	Provider: 21CSLC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A
Environmental Remediation and Technologies	Provider: 21CSLC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A

## 21ST CENTURY SPACE LAUNCH COMPLEX

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### **Acquisition Strategy**

To maintain flexibility and maximize affordability, NASA serves as its own prime contractor for implementation of the 21CSLC activities. GSDO executes customer ground infrastructure and processing requirements by leveraging center and programmatic contracts. It also uses pre-qualified indefinite delivery indefinite quantity contractors for routine work, while exercising full and open competition for larger or more specialized projects. Firm-fixed-price contracting provides maximum incentive for contractors to control costs, and imposes a minimum administrative burden upon the contracting parties.

### **MAJOR CONTRACTS/AWARDS**

21CSLC include activities of varying size and content. Several of the activities are within the scope of existing center contracts. If the activity is not within the scope of an existing agreement, the contract is competitively bid.

Element	Vendor	Location (of work performance)
50 megahertz Doppler Radar Wind Profiler	QinetiQ, North America	KSC
Jacking, equalization and leveling cylinder (crawler transporter)	QinetiQ, North America	KSC

### **INDEPENDENT REVIEWS**

The 21CSLC activity is not required to manage with the same formal independent reviews NASA requires for traditional programs and projects. In accordance with Agency policy, initiatives and activities are not subject to the independent review process. In addition, the total funding for 21CSLC falls below the threshold required to initiate a review.

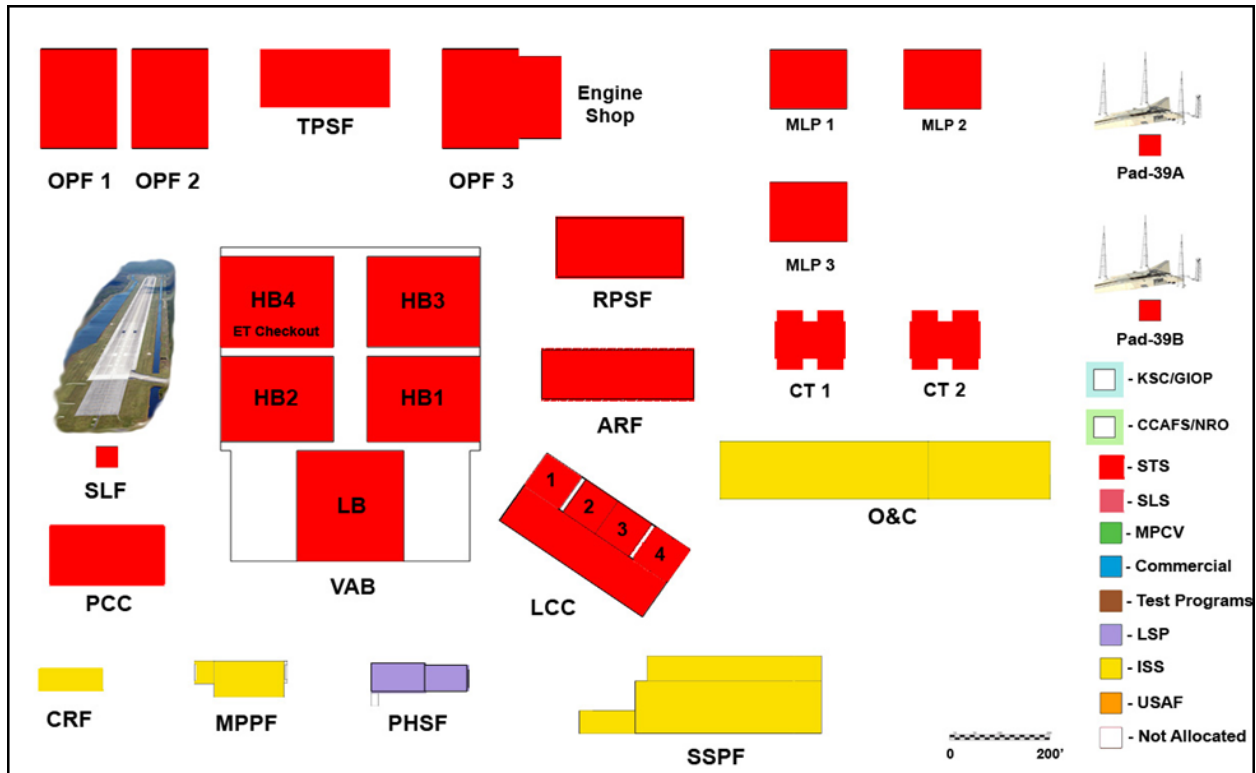
### **HISTORICAL PERFORMANCE**

NASA is evolving to meet the changing needs of America's space program by providing efficient facilities and services capabilities. These facilities support payload processing and integration, launch, and landing services for manned and unmanned missions. NASA is modernizing KSC to reconfigure from a Space Shuttle and ISS-centric complex to a robust launch architecture that is capable of supporting a multitude of commercial and government customers. The figures below illustrate this progression over the last several years. In the first chart, Figure 1, the major facilities at KSC were almost completely utilized by Space Shuttle and ISS. Over the last several years, as new NASA programs (including GSDO, Orion, and SLS) and commercial users have assumed responsibility for various facilities, the spaceport has now evolved to its current state, as shown in Figure 2. NASA is continuing to pursue opportunities for the remaining available assets.

## 21ST CENTURY SPACE LAUNCH COMPLEX

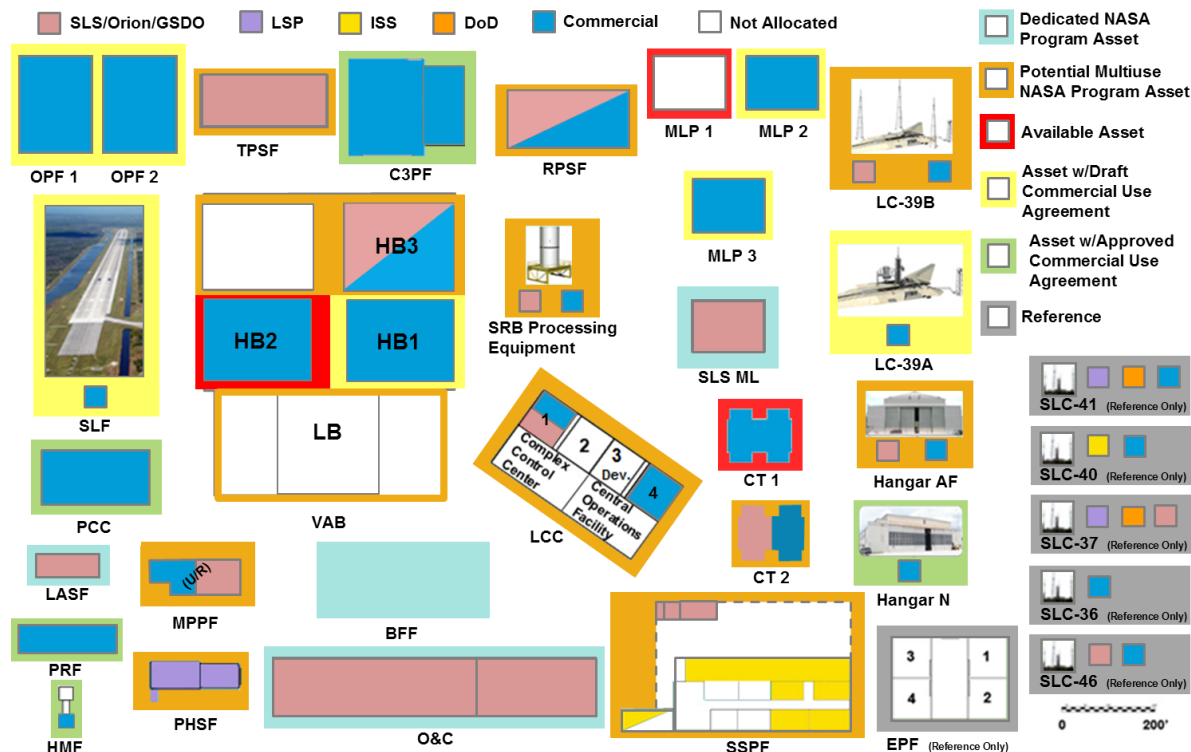
### Current 21st CSLC and Exploration Ground Systems Utilization at KSC

Figure 1: NASA Shuttle and International Space Station Historical Utilization at KSC



## 21ST CENTURY SPACE LAUNCH COMPLEX

Figure 2: NASA Current Utilization at KSC



BFF	Booster Fabrication Facility	MLP	Mobile Launch Platform
CCAFS	Cape Canaveral Air Force Station	MPPF	Multi-Payload Processing Facility
CRF	Canister Rotation Facility (now LASF)	NRO	National Reconnaissance Office
C3PF	Commercial Crew and Cargo Processing Facility	O&C	Operation & Checkout
CT	Crawler Transporter	OPF	Orbiter Processing Facility
DoD	Department of Defense	PCC	Processing Control Center
EPF	Eastern Processing Facility	PHSF	Payload Hazardous Servicing Facility
ET	External Tank	PFR	Parachute Refurbishment Facility
GIOP	Ground Integration and Operations Program (GSDO precursor)	RPSF	Rotation, Processing, and Surge Facility
GSDO	Ground Systems Development and Operations	SLC	Space launch Complex
HB	High Bay	SLF	Shuttle Landing Facility
HMF	Hypergol Maintenance Facility	SLS	Space Launch System
ISS	International Space Station	SRB	Solid Rocket Booster
KSC	Kennedy Space Center	SSPF	Space Station Processing Facility



## 21ST CENTURY SPACE LAUNCH COMPLEX

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LASF	Launch Abort System Facility (formerly CRF)	STS	Space Transportation Program
LB	Low Bay	TPSF	Thermal Protection System Facility
LC	Launch Complex	USAFU/R	Under Review
LSP	Launch Services Program	VAB	Vehicle Assembly Building
ML	Mobile Launcher		

## SPACE COMMUNICATIONS AND NAVIGATION

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		FY 2015	Notional			
	FY 2013	FY 2014		FY 2016	FY 2017	FY 2018	FY 2019
Space Communications Networks	574.3	--	<b>532.1</b>	415.5	416.3	416.5	507.5
<i>Space Network Ground Systems Sust.</i>	<i>106.4</i>	<i>122.6</i>	<i>97.7</i>	<i>94.1</i>	<i>66.3</i>	<i>17.1</i>	<i>0.0</i>
Space Communications Support	67.0	--	<b>59.7</b>	94.5	140.7	151.6	151.2
<b>Total Budget</b>	<b>641.4</b>	<b>--</b>	<b>591.8</b>	<b>553.5</b>	<b>535.4</b>	<b>534.8</b>	<b>534.5</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



SCaN's Near Earth Network recently installed an 11 meter (36 foot) antenna at the Alaska Satellite Facility, housed at the University of Alaska-Fairbanks. This new antenna joins two other SCaN antennas at the facility, which is part of the Near Earth Network composed of NASA-owned and commercially operated ground stations and antennas all over the world. The new antenna will provide on-orbit operations to missions that use orbits over the North and South Poles. It is currently undergoing testing and will be ready for use in the summer of 2014.

The Space Communications and Navigation (SCaN) program provides mission-critical communications and navigation services required by all NASA space missions. SCaN retrieves science and spacecraft health data, uploads commands, and sends data to individual mission control centers. Navigation services accurately determine where a satellite is and where it is going to enable plans for course changes, interpret science data, and position the spacecraft for communication opportunities.

Without SCaN services to move data and commands between spacecraft and Earth, customer missions and space hardware worth tens of billions of dollars would be little more than orbital debris. A communications or navigation failure on the spacecraft or in SCaN network systems could result in complete loss of a mission.

SCaN mission customers range from high altitude balloons at the edge of Earth's atmosphere, to science satellites in low Earth orbit, to the most distant manmade object,

Voyager 1, which has left the solar system and is now nearly 12 billion miles from our planet. Other SCaN customers include the Hubble Space Telescope in Earth orbit, the Curiosity rover on the surface of Mars, and New Horizons on its way to Pluto. SCaN supports the International Space Station (ISS) as well

## **SPACE COMMUNICATIONS AND NAVIGATION**

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as its commercial and international servicing vehicles, and will support commercial crew providers and NASA's Orion crew vehicle when they launch in the future. SCA<sub>N</sub> also supplies services to foreign governments, International Partners, and non-NASA US missions on a reimbursable basis.

SCA<sub>N</sub> provides customer missions with the required communications and navigation services at the lowest practical cost. Customer requirements include the mission's orbit, navigation needs, data rate, and how often communication opportunities occur. SCA<sub>N</sub> networks and the customer spacecraft must match technical parameters such as radio frequency, data coding, modulation scheme, polarization, and error correction. SCA<sub>N</sub> supports new spacecraft which are increasingly powerful, complex, and capable of acquiring ever increasing amounts of mission data, as well as missions launched over 30 years ago that are still returning valuable science data.

SCA<sub>N</sub>'s three space communications networks provide these critical services to customer missions. The Space Network communicates with missions in Earth orbit, and provides constant communication with ISS; it will also support future commercial crew and Orion missions. The Near Earth Network communicates with suborbital missions and missions in low Earth, highly elliptical Earth, and some lunar orbits. The Deep Space Network communicates with the most distant missions, such as inter-planetary probes.

The three networks require maintenance, replenishment, modernization, and capacity expansion to ensure service for existing and planned missions. SCA<sub>N</sub> also purchases ground communications links from the NASA Integrated Services Network to move data between SCA<sub>N</sub> ground stations, NASA centers, and mission operation and data centers.

The Tracking and Data Relay Satellite (TDRS) Replenishment project is purchasing three third-generation TDRS spacecraft for the Space Network. These spacecraft will ensure adequate Space Network services to customers into the early 2020s. Two are currently on-orbit, and one is nearing completion of development.

The Space Network Ground Segment Sustainment project is replacing aging ground hardware and data systems in the Space Network. These ground systems operate the TDRS fleet and route customer mission data between TDRS and the ground.

Space Communications Support provides several functions to efficiently integrate and plan current and future network capabilities to meet customer mission needs while reducing costs. These functions include systems engineering, architecture planning, communications data standards, technology development, testbeds for future capabilities, and radio frequency spectrum management.

For more information, go to: [www.nasa.gov/scan](http://www.nasa.gov/scan)

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual		Enacted	Request	Notional				BTC	Total
	Prior	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019		
Formulation	106.4	19.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	125.9
Development/Implementation	0.0	79.3	TBD	TBD	TBD	TBD	0.0	0.0	0.0	TBD
Operations/Close-out	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>2015 MPAR LCC Estimate</b>	<b>106.4</b>	<b>98.7</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>	<b>TBD</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>TBD</b>
<b>Total Budget</b>	<b>106.4</b>	<b>122.6</b>	<b>97.7</b>	<b>94.1</b>	<b>66.3</b>	<b>17.1</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>397.8</b>
Change from FY 2014				-3.6						
Percentage change from FY 2014				-3.8%						



Technicians maintain and configure electronics in the ground control equipment room at the Tracking and Data Relay Satellite ground terminal in White Sands, New Mexico. A new digital, flexible, and scalable system is being developed to replace outdated equipment from the 1970's shown above. The Space Network receives and transmits data to and from the International Space Station, Hubble Space Telescope, and other low Earth orbiting spacecraft 24 hours a day, 7 days a week, 365 days a year. The new system will provide operations at a reduced lifecycle and customer cost, and reduce operations risk while meeting or exceeding current mission support performance.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*The SGSS project will update the budget after completion of the re-plan in June 2014.*

### PROJECT PURPOSE

NASA's science and human missions such as the Hubble Space Telescope, the International Space Station (ISS), and the future Orion crew vehicle require communication and navigation services to send commands to the spacecraft, and move data to the ground terminal. NASA's Space Network provides these services with a fleet of Tracking and Data Relay Satellites (TDRS), and ground stations in New Mexico

and Guam. Customer missions send data to the TDRS spacecraft in geosynchronous orbit, and the satellites relay those signals to the ground stations, which include a mix of 10 meter, 18.3 meter, and 19 meter dish antennas; transmitters, receivers, amplifiers; and enough scheduling and control software to execute more than 145,000 mission passes per year.

## **SN GROUND SEGMENT SUSTAINMENT(SGSS)**

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Formulation	Development	Operations
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The Space Network's vintage 1980's ground stations are becoming more difficult to maintain and assure nearly 100 percent availability for users. Manufacturers no longer support much of the equipment and software currently in use. To keep some of the outdated equipment running, NASA has had to buy similar used parts on eBay, and modify them to work in the network ground stations. Beyond the increased costs for maintenance and repair, the age and wear of systems increase the risk that ground system failures will disrupt services to customers. If such disruptions occur, customers could lose critical science data, or even a spacecraft.

In order to maintain reliable communications services to customer missions, the Space Network Ground Segment Sustainment (SGSS) project is replacing outdated and expensive-to-maintain equipment and systems at the ground terminals. SGSS is a ground sustainment project that will incrementally upgrade the current space network. New equipment and software based on up-to-date technology will be more reliable, and cost less to maintain and operate. Due to the operational nature of the networks, these sustainment activities are performed while communications are ongoing, with no loss of service.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

In February 2013, SGSS successfully completed Preliminary Design Review, which confirmed the project had achieved stable design requirements. Ending FY 2013 and entering FY 2014, contractor efficiencies and management performance declined. As a result, overall SGSS status including the final budget estimate, scheduled completion date, and the path to success are under review.

### **PROJECT PARAMETERS**

SGSS will replace nearly all the electronics and software at Space Network ground stations. This includes high-power transmitters and receivers on the ground antennas, low-noise amplifiers, digital signal processors, TDRS fleet management software, tracking pass scheduling software, and numerous other components. Integrating the various exotic and high-power electronics, digital switchgear, and controlling software into a functional, reliable, and low-cost system is a major part of the project. Once complete, any Space Network ground terminal will be able to support any first, second, or third generation TDRS.

### **ACHIEVEMENTS IN FY 2013**

The SGSS project began major procurements, completed final system design, and concluded the technical portion of the Critical Design Review in June 2013. As part of this effort, the project worked closely with prime contractor, General Dynamics, to validate technical specifications and compliance with systems design review requirements. In addition, SGSS began assessing system level risks, threats, requirements, schedule, and cost to complete. Post Critical Design Review, evaluations revealed that cost and schedules were likely to exceed current planning estimates for this activity. Congress was notified of this concern via both the FY 2014 operating plan and unique letter. NASA is in the process of defining this effort as sustainment activity and not a project. In addition to this notification, SGSS is developing a go-forward plan that controls and defers delivery of specific capabilities. Less time critical activities will be deferred, and there is an option to stagger implementation rather than upgrade all facilities at once. When a facility

## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations
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is upgrading, its hardware is available for use in other older facilities. This staggered approach controls costs and provides for robust support to users. The updated delivery and cost plan is scheduled for completion in June 2014.

### WORK IN PROGRESS IN FY 2014

The management portion of the Critical Design Review, including budget to complete, schedule, and final capability, is planned for the second quarter of FY 2014. The SGSS project will continue to manage the prime contractor's technical, schedule, and cost performance, as well as validate that system requirements meet Space Network needs. As part of these activities, the project will oversee hardware and software component integration and testing at the contractor's plant. SGSS systems integration is expected to start in FY 2015, with some installation and transition activities starting in FY 2016. A detailed upgrade plan will be complete in June 2014.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The SGSS project will continue to monitor activity at the contractor's plant, prior to system deployment and transition activities planned to begin in FY 2016. In preparation for placement at ground station sites, the contractor will perform end-to-end testing of hardware and software elements. After successful testing, teams will deploy the systems to domestic and international Space Network ground station sites.

Beyond FY 2015, the project will verify data communications and tracking using TDRS space segments. This is an important step towards achieving the new modernized Space Network, which will enable state-of-the-art communications capability with the ISS, Space Launch System, Orion, and other orbiting spacecraft well into the 21st century.

### SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2015 PB Request
Formulation Authorization (complete)	Nov 2011	
Preliminary Design Review (complete)	Jul 2012	Jul 2012
Key Decision Point-C	Oct 2012	Mar 2013
Deployment of first elements to Space Network ground stations begins	N/A	TBD pending budget and schedule replan
System-level integration and test of last elements complete	N/A	TBD pending budget and schedule replan

## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations
Milestone	Confirmation Baseline Date	FY 2015 PB Request
Deployment at all ground stations complete	N/A	TBD pending budget and schedule replan
Full Operational Capability, Space Network Ground Segment Sustainment Complete	Dec 2015 - Sep 2017	TBD pending budget and schedule replan

### Development Cost and Schedule

The cited development cost is for SGSS.

Base Year	Base Year Development Cost Estimate (\$M)	JCL (%)	Current Year	Current Year Development Cost Estimate (\$M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	463.4	70	2014	TBD		CDR (cost and schedule)	Q3 FY 2013	Q2 FY 2014	7 months

*Note: The confidence level estimates reported reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as JCL (joint confidence level); all other CLs (confidence levels) reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.*

### Development Cost Details

Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
<b>TOTAL:</b>	<b>463.4</b>	<b>TBD pending budget and schedule replan</b>	
Pre-Formulation not included in LCC	21.1	21.1	
Phase A	32.8	32.8	
Phase B	71.9	71.9	

## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation		Development	Operations
Element	Base Year Development Cost Estimate (\$M)	Current Year Development Cost Estimate (\$M)	Change from Base Year Estimate (\$M)
Ground Systems	337.6	TBD pending budget and schedule replan	

## Project Management & Commitments

The SGSS Project Office at Goddard Space Flight Center manages the project.

Element	Description	Provider Details	Change from Baseline
Space Network Ground Segment Sustainment	Replace outdated and deteriorating ground systems at Space Network ground terminals	Provider: Space Network Ground Segment Sustainment Project Office Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): Non-NASA US government partners	Replan pending, including new cost and schedule

## Project Risks

Risk Statement	Mitigation
If: Space Network Ground Segment Sustainment operational delivery is delayed, Then: The Space Network will continue to use existing, high-risk ground systems that are costly to operate. The Deep Space and Near Earth Networks will be unable to use Space Network Ground Segment Sustainment elements to replace elements of their ground systems.	The SCaN program and SGSS project office will carefully manage effort to deliver Space Network products on time, balancing requirements, technical content, budget, and schedule. On-time delivery will allow the Space Network to replace aging and costly ground systems. The Deep Space and Near Earth Networks will be able to replace parts of their ground systems with Space Network Ground Segment Sustainment elements.



## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations
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### Acquisition Strategy

NASA used a full and open competition to select the SGSS prime contractor in FY 2011. The contract is cost-plus-incentive-fee. No additional major awards are planned.

### MAJOR CONTRACTS/AWARDS

Insert Text (if appropriate)

Element	Vendor	Location (of work performance)
Space Network Ground Segment Sustainment	General Dynamics C4 Systems	Scottsdale, AZ

### INDEPENDENT REVIEWS

NASA established a Standing Review Board to perform the independent reviews of the Space Network Ground Segment Sustainment project that are required by NPR 7120.5.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
System Requirements Review	Standing Review Board	Aug 2011	Determine if functional and performance requirements are properly formulated. Determine if estimated budget and schedule are credible.	Passed; recommended changes incorporated into new baseline	None
Key Decision Point-B	Standing Review Board	Feb 2012	Determine if requirements definition and associated plans are sufficient to begin project implementation	Complete	None
Technical Preliminary Design Review	Standing Review Board	Jul 2012	Determine if project is ready to proceed with detailed design of hardware and software elements	Complete	None

## SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Key Decision Point-C	Standing Review Board	Mar 2013	Determine if project is ready to proceed with formal development	Complete	None
Critical Design Review (technical only)	Standing Review Board	Aug 2013	Determine if project is ready to proceed with production of hardware and software elements	Pending	Pending budget and schedule replan

### CORRECTIVE ACTION PLAN AS REQUIRED BY SECTION 1203 OF NASA 2010 AUTHORIZATION ACT

2013 Issues	Corrective Action Plan
<p>Issue 1: While architecture and top level requirements were approved by the SRB, lower level requirements, cost, and schedule were deemed inadequate for assessment.</p> <p>Current Status: The program office, project office, and prime contractor have convened an in-depth review to certify that lower level requirements lead to a reliable cost estimate and schedule completion date</p>	<p>(Plan TBD depending on the results of the in-depth review scheduled for completion April/May 2014.)</p>

## SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	697.8	--	596.1	484.2	397.0	384.2	383.3

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Operators manage Space Network ground and space assets at the White Sands, New Mexico complex, where data from orbiting satellites and the International Space Station are received and forwarded. Commands and other services such as voice and video are also transmitted from the complex to orbiting spacecraft. The Space Network operates 24 hours a day, 7 days a week to ensure continuous communication with the Station.

The Space Communication and Navigation (SCaN) program manages three space communications networks: Space, Near Earth, and Deep Space. Each has a different set of customer requirements for spacecraft orbit, signal strength, and real-time coverage, and each requires maintenance, modernization, and capacity expansion.

The Space Network provides continuous global coverage to NASA missions in low Earth orbit, and during the vehicle launch and ascent phase. It is the primary US communications link to ISS, as well as for ground and balloon research in remote locations such as the South Pole. The Space Network consists of NASA's Tracking and Data Relay Satellite (TDRS) system of communications satellites in geosynchronous orbit, a set of space-to-ground link terminals at White Sands, New Mexico, and remote space-to-ground terminals at Guam and Blossom Point, Maryland. Customer

missions communicate with the TDRS spacecraft, which relay signals to and from the ground terminals.

NASA's current TDRS fleet consists of three first-generation satellites placed into orbit 18 to 24 years ago and three second-generation satellites that have provided services for more than a decade. The original first-generation satellites are showing signs of age-related battery and electronics failures. Three new third generation satellites, TDRS-K, L, and M are prepared to join the fleet. Two satellites, TDRS-K and L have launched and TDRS-M is in production.

## SPACE COMMUNICATIONS NETWORKS

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Formulation	Development	Operations
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The Space Network Ground Segment Sustainment effort replaces obsolete ground terminal equipment that is nearing the end of its life cycle.

The Near Earth Network services missions in low Earth, geosynchronous, lunar, and highly elliptical Earth orbits, as well as from certain suborbital launch locations. The network's ground stations are located at White Sands, New Mexico, the US McMurdo Antarctic Station, and Wallops Flight Facility in Virginia. The network also purchases services from commercial providers in Alaska, Hawaii, Norway, Sweden, Australia, and Chile.

The Deep Space Network services missions from beyond low Earth orbit to the edge of the solar system. The network's ground stations are spaced about 120 degrees apart on the globe in Spain, Australia, and California, to maintain continuous communications to distant spacecraft as the Earth rotates. NASA owns these stations, and the Deep Space Network Project Office at JPL manages operations, maintenance, and upgrades.

The Deep Space Network Aperture Enhancement effort modernizes and upgrades the Deep Space Network's ground stations to enhance capacity, improve flexibility to support customer missions, and reduce operations and maintenance costs. Much of the network's hardware is over 30 years old and has become difficult and costly to maintain. This is true of antenna structures, exotic electronics such as high-power transmitters, cryogenically cooled low noise amplifiers, and support elements. Construction efforts, such as new 34-meter antennas, use Construction of Facilities funds appropriated in NASA's Construction and Environmental Compliance and Remediation account.

The SCaN program purchases services from the NASA Integrated Services Network (NISN) to move information between the three space communications network ground stations and NASA centers, customer mission operations, and data centers. NISN is a centralized commercial service that provides point-to-point communication services between ground sites. NASA's Office of the Chief Information Officer manages the NISN service.

For more information, go to: [www.nasa.gov/scan](http://www.nasa.gov/scan)

### EXPLANATION OF MAJOR CHANGES IN FY 2015

With the recent successful launches of TDRS K and L, the production costs for TDRS-M will be transferred from the stand-alone TDRS budget line to the Space Communication Networks budget line.

### ACHIEVEMENTS IN FY 2013

During FY 2013, the Space Network supported 25 customer missions with 168,901 hours of tracking over 145,186 passes. This included a European Space Agency resupply mission to the ISS, which involved docking the Automated Transfer Vehicle to the station. The vehicle was then loaded with disposable trash, undocked, and steered into a destructive Earth atmospheric reentry on October 28, 2013.

## SPACE COMMUNICATIONS NETWORKS

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Formulation	Development	Operations
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The Space Network provided primary US communications link with the ISS throughout the year, and supported 13 launches, including NASA's Radiation Belt Storm Probes and two SpaceX Dragon missions to the ISS. The Radiation Belt Storm Probes are two robotic spacecraft studying the Van Allen radiation belts that surround Earth. These probes provide NASA with critical data regarding radiation belt effects on spacecraft operations. Dragon is a reusable commercial spacecraft developed by SpaceX that has been successfully utilized for ISS resupply through NASA's ISS program.

The Near Earth Network supported 35 missions, as well as launch and early orbit operations for the Radiation Belt Storm Probes. The Deep Space Network supported 37 missions, including checkout and early surface operations of the Mars Science Laboratory Curiosity rover, deep space communications for the Juno spacecraft, and lunar impact and end of mission for the Gravity Recovery and Interior Laboratory (GRAIL) spacecraft. The success of these missions required challenging operations that could not have been performed without a robust and reliable network to transmit commands and receive data.

Following the successful launch of TDRS-K on January 30, 2013 from Cape Canaveral, the contractor completed initial on-orbit testing and the Space Network assumed control of TDRS-K (now TDRS-11), and began operational testing with users. The replenishment contractor also completed TDRS-L preflight testing and reviews. As part of NASA's environmental testing, engineers and technicians shook, baked, and froze TDRS-L and assessed its performance to make sure it could not only survive the rocket ride to orbit and the harsh environment of space, but its ability to function perfectly for years to come. The contractor started TDRS-M assembly after completing a successful Production Readiness Review; production is approximately 60 percent complete.

### WORK IN PROGRESS IN FY 2014

During the current fiscal year, the Space Network plans to support 25 to 30 missions, with over 175,000 hours of tracking and more than 145,000 passes. The Space Network will accept TDRS-K as an operational asset when it completes on-orbit checkout started in FY 2013. TDRS-L launched in January 2014 and on-orbit check out will commence. If TDRS-L performs as expected, NASA will accept the satellite as an operational part of the Space Network. TDRS-M will undergo environmental testing after the System Integration Review. All three spacecraft are critical to ensuring the Space Network's capacity and reliability to support NASA's missions into the foreseeable future.

In addition, both the Space and Near Earth Networks will support the Interface Region Imaging Spectrograph (IRIS) and the Landsat Data Continuity Mission (Landsat 8). IRIS was successfully launched and became operational in 2013, to study the sun's chromosphere. This mission will enable the capability to predict extreme and dynamic space conditions to order to maximize safe and productive human and robotic exploration. Landsat 8 became operational in May 2013, and is operated by the United States Geological Survey. The satellite collects valuable data and imagery for use in agriculture, education, business, science, and government. The Near Earth Network plans to support about 30 missions, with over 35,000 hours of tracking and more than 45,000 tracking passes; customers will include commercial cargo resupply missions to the ISS. In FY 2014, the Network will also complete a new antenna at the Alaska Satellite Facility ground station and perform acceptance testing. The new

## SPACE COMMUNICATIONS NETWORKS

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Formulation	Development	Operations
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antenna will provide the Near Earth Network with coverage to collect data from NASA's polar orbiting satellites.

The Deep Space Network plans to support approximately 35 missions, providing over 100,000 hours of tracking spread over more than 18,000 passes. The network will support launch and orbit insertion of the Indian Space Agency Mars Orbiter Mission, Mars Atmosphere, and Volatile Evolution mission, and the Lunar Atmosphere and Dust Environment Explorer. The Deep Space Network is supporting Curiosity on the surface of Mars and the European Space Agency's Rosetta mission, which recently awoke from hibernation.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

The three space communications networks will provide a level of service similar to those provided in FY 2013 and FY 2014, which included over 208,000 tracking passes totaling more than 310,000 hours. Customer mission highlights planned for FY 2015 include the arrival of Dawn at Ceres – a dwarf planet believed to have accreted early in the history of the solar system, Japan's Hayabusa-2 asteroid explorer launch and Earth flyby, and the New Horizons Pluto encounter – a dramatic flight past the icy dwarf planet and its moons in July 2015. The networks will support key human spaceflight programs such as Orion's Exploration Flight Test-1, as well as ISS and its commercial cargo missions.

NASA will continue to replenish the networks by addressing ongoing obsolescent equipment issues in order to maintain critical services for current and future missions. As part of the Deep Space Network modernization program, NASA will continue to upgrade and replace existing antennas around the world. These network tracking sites include Canberra, Australia; Madrid, Spain; and Goldstone, California. Part of NASA's long-term plan is to upgrade and replace earlier generation 70-meter antennas with 34-meter antennas. In 2015, the 34-meter antenna DSS-35 will become operational at Canberra, Australia. This new antenna will be able to transmit and receive across a wide range of radio frequencies for deep space communication with interplanetary robotic spacecraft to support the expected growth of deep space missions launching over the next decade.

Spacecraft like the new TDRS-L and TDRS-M expand NASA's communications capabilities while replacing existing on-orbit spacecraft when they reach end-of-life. TDRS-M will undergo preflight testing similar to that performed on TDRS-K and L. Vibration and thermal-vacuum testing will confirm the spacecraft can survive the stresses of launch, the vacuum, and alternating heat and cold temperature in space—ensuring the spacecraft functions for years to come. TDRS-M will be stored at the contractor's facility until funding is available to purchase a launch vehicle. Depending on the launch vehicle selected, changes may be required to integrate the satellite with the vehicle and prepare it for launch. Once all three spacecraft are accepted, the Space Network will have adequate capacity until the second-generation TDRS begin retiring in the early 2020s.

## SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations
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### Project Schedule

NASA's space communications networks provide ongoing services to Agency and customer missions, averaging about six hundred tracking passes a day. Providing this routine, daily service is the key function of the three space communications networks. Without these services, customer missions like Voyager, Hubble, ISS, New Horizons, and Opportunity would fail. In order to assure continuation of this service, NASA is replenishing the networks; below are some key network replenishment events.

Date	Significant Event
Q2 FY 2014	TDRS-K acceptance into the SN for operational use
Q2 FY 2014	TDRS-L launch
Q2 FY 2014	ASF-3 antenna acceptance into the NEN for operational use
Q3 FY 2014	TDRS-L acceptance into the SN for operational use
Q1 FY 2015	DSS-35 antenna acceptance into the DSN for operational use
Q3 FY 2015	TDRS-M completed development and placed in storage

### Project Management & Commitments

Element	Description	Provider Details	Change from Formulation Agreement
Space Network	Communication and navigation services to customer missions in low Earth orbit and launch vehicles	Provider: Space Network Project Office Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): Non-NASA customers	N/A
Near Earth Network	Communication and navigation services to customer missions in low Earth, highly elliptical, and lunar orbits	Provider: Near Earth Network Project Office Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): Non-NASA customers	N/A

## SPACE COMMUNICATIONS NETWORKS

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Deep Space Network	Communication and navigation services to customer missions in deep space	Provider: Deep Space Network Project Office Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): Non-NASA customers	N/A
NASA Integrated Services Network	SCaN purchases ground communication services from NASA Integrated Services Network	Provider: NISN, through NASA Chief Information Officer Lead Center: NASA HQ Performing Center(s): MSFC, GSFC Cost Share Partner(s): N/A	N/A
TDRS Replenishment	Purchase third-generation TDRS-K, -L, and -M to maintain Space Network communications services to customer missions into the 2020s	Provider: Boeing Space Systems Lead Center: GSFC Performing Center(s): N/A Cost Share Partners: Other US government agencies	Development cost reduced. TDRS-M added to purchase

## Acquisition Strategy

The major acquisitions for the networks are in place. NASA uses reimbursable, international, and barter agreements; and competitive procurements. NASA's Jet Propulsion Laboratory provides the Deep Space Network.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Deep Space Network	JPL	Pasadena, CA
Space Network Operations	ITT Excelis	McLean, VA
Near Earth Network Operations	ITT Excelis	McLean, VA



## SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations
<b>Element</b>	<b>Vendor</b>	<b>Location (of work performance)</b>
TDRS Replenishment, including TDRS-K, -L, and -M and modifications to Space Network ground systems to support these spacecraft	Boeing Space Systems	El Segundo, CA

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Integrated Review	Standing Review Board	Sep 2012	Assess the goals, approach, and performance of the SCaN program, including space communications networks.	Passed	None
TDRS-K ORR/FRR	Standing Review Board	Oct 2012	Assess if all systems are operationally ready for the spacecraft and if the spacecraft is ready for flight	Passed	Launch Readiness Date (LRD)
TDRS-K ORR/FRR	Standing Review Board	Oct 2012	Assess if all systems are operationally ready for the spacecraft and if the spacecraft is ready for flight	Passed	LRD
TDRS-K LRD	Flight Board	Jan 2013	Assess if all systems are ready for launch	Passed	On-orbit Acceptance
TDRS-K On-Orbit Acceptance Review	Standing Review Board	Aug 2013	Assess if TDRS-K is ready to be accepted by the Government	Passed	

## SPACE COMMUNICATIONS NETWORKS

Formulation		Development		Operations	
Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
TDRS-K On-Orbit Acceptance Review	Standing Review Board	Aug 2013	Assess if TDRS-K is ready to be accepted by the Government	Passed	
TDRS-L ORR/FRR	Standing Review Board	Nov 2013	Assess if all systems are operationally ready for the spacecraft and if the spacecraft is ready for flight	Passed	LRD
TDRS-L LRD	Flight Board	Jan 2014	Assess if all systems are ready for launch	Passed	On-orbit Acceptance
TDRS-L On-Orbit Acceptance Review	Standing Review Board	Under review			

## SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Total Budget	67.0	--	59.7	94.5	140.7	151.6	151.2

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The SCA testbed, installed on the International Space Station last year, is seen here in the integration and test facility at the Glenn Research Center in Ohio. The testbed is demonstrating new radio technologies and navigation techniques using software-defined radios. Through a joint effort with the Department of Defense to monitor new Global Positioning System navigation messages, the testbed has already led to improvements in the system.

When one wakes up in the morning and flips the switch, the lights go on. Much like electricity from a utility company, Space Communications and Navigation (SCaN) services have to be there when the customer needs them. The SCaN program provides critical communication services to customers such as the International Space Station, the Hubble Space Telescope, and the Mars Curiosity rover. For them, a service outage is far more than an inconvenience, because it impacts the safety and mission success.

SCaN has a long history of service reliability, but that success does not come easily – it requires the planning, management, and technology efforts of the Space Communication Support project. Activities that contribute to SCaN's success include architecture planning and systems engineering, standards definition and management, spectrum management, and technology development.

The architecture planning and systems engineering group ensures communication and navigation capabilities are integrated, interoperable, and standardized. This activity enables customer missions and SCaN networks to operate together by defining technical parameters, capacity, and performance. In addition, this group coordinates with NASA customer missions and SCaN networks to eliminate duplication across networks, minimize mission-unique requirements, and lower development costs by providing “off-the-shelf” communications solutions and standards.

The standards definition and management group is responsible for international standardization that focuses on interoperability with other space agencies. This group works to ensure NASA missions are

## SPACE COMMUNICATIONS SUPPORT

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Formulation	Development	Operations
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compatible with other agencies' space communication equipment and services, while minimizing mission cost and risk.

SCaN manages the Spectrum Management program for the Agency, and is deeply involved with other space-faring nations in this area. Spectrum Management ensures that all NASA activities comply with national and international laws applicable to the use of the electromagnetic spectrum. The program advocates for radio frequencies to remain available for communication with NASA missions, as well as radio astronomy and remote sensing applications. In this way, NASA continues to address competing interests for use of the electromagnetic spectrum, including emerging commercial broadband services.

New SCaN communication technology efforts have the promise of reducing costs, increasing the amount of data returned from science missions, and reducing science spacecraft weight and power. An example of technology development is the SCaN testbed onboard the ISS, which develops and demonstrates new radio frequency and navigation technology. The testbed will lead to new capabilities such as cognitive radios and improved Global Positioning System (GPS) aided navigation for Earth orbiting satellites. Already the testbed has led to improvements in the GPS system through a joint effort with DoD to monitor new GPS navigation messages. In addition, SCaN is collaborating with the Space Technology Mission Directorate on two technology development initiatives. The Deep Space Atomic Clock will demonstrate an increase in timing accuracy of precision space communications, and the Laser Communication Relay Demonstration will demonstrate higher speed communication. Both of these initiatives have the potential to improve deep space communication and enable the return of more science data to Earth.

For more information, go to: <https://www.nasa.gov/scan/>

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

In September 2013, NASA launched the Lunar Atmosphere and Dust Environment Explorer spacecraft from Wallops Flight Facility, which carried the Lunar Laser Communication Demonstration (LLCD) optical terminal as a technology hosted payload. This experiment tests optical (laser) communications between the Earth and the Moon at data rates over six times higher than current radio frequency based systems. The optical communications system transmits data using near-infrared light rather than radio wave, and will allow future missions to transmit at higher data rates, free from the encroachment and congestion plaguing current radio frequencies. In addition, optical communications systems consume less mass, volume, and power compared with similar radio frequency systems. As the technology evolves, transition to optical systems will reduce mission costs and enable opportunities for new science payloads. In October 2013, the LLCD space terminal was successfully activated with test results demonstrating optical laser light acquisition times of less than four seconds. NASA plans to complete the full experiment demonstration in FY 2014.

## SPACE COMMUNICATIONS SUPPORT

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Formulation	Development	Operations
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The SCaN architecture planning and systems engineering group is developing the first set of systems requirements for a future Unified SCaN Network. This capability will provide customers an internationally interoperable unified interface, and a more integrated internal approach for SCaN networks.

The Spectrum Management group continued working with the White House, Congress, national regulators, and spectrum users within NASA, to implement the President's Broadband Initiative. NASA led the Executive Branch's efforts in several technical compatibility studies, the most critical of which focused on introducing new commercial broadband and other federal systems – primarily the Department of Defense – into spectrum occupied by TDRS. These studies are an essential element of the President's Initiative, and key to finalizing conditions for spectrum planned for auction in fall of 2014, which will not adversely affect NASA's current and planned operations. The Spectrum Management group also led technical evaluations to protect GPS frequencies from potential interference from commercial mobile systems being proposed in adjacent frequencies.

### WORK IN PROGRESS IN FY 2014

SCaN's technology development group will test the full range of LLCD optical data rates to and from the spacecraft. The experiment will demonstrate initial international interoperability communications with three ground terminals, including one developed by the European Space Agency. The LLCD is the first step in NASA's roadmap to maturing and demonstrating space optical communications. The next step will build on the LLCD space and ground terminal architectures, expanding the technology demonstration to a Laser Communication Relay. This activity will use two optical modules with a new modem designed for use in geosynchronous Earth orbit relay environments. In addition, the demonstration will utilize a new optical switch capability, which will connect space terminals onboard satellites, and implement an adaptive optics capability in the ground systems. The program completed a Preliminary Design Review in early FY 2014.

The Spectrum Management group continues to support the President's Broadband Initiative and spectrum auctions planned for this year. Efforts continue to protect GPS frequencies from introducing incompatible commercial mobile services into adjacent frequencies; NASA analyses will be submitted to the national regulators – National Telecommunications and Information Administration and Federal Communications Commission – to support a US decision on this issue. In addition, the Agency is continuing its preparatory work for the FY 2015 World Radiocommunication Conference.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

NASA will utilize the SCaN testbed onboard the ISS to perform experiments with an operational software-defined radio. Engineers will evaluate LLCD results and incorporate them into the planning for an on-orbit optical communications relay demonstration. Development will continue on the deep space atomic clock, which will improve navigation for deep space missions and use fewer resources on spacecraft to lessen the burden for the Deep Space Network.

## SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations
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The Spectrum Management group will be intimately engaged in the 2015 World Radiocommunication Conference, as NASA has several key initiatives for adoption, including an agenda item seeking additional spectrum for uplinks in the 7190-7235 MHz band for earth exploration satellite service and an agenda item to remove regulatory restrictions (eliminating the five km distance limitation) to support extravehicular activities (EVA) in the 410-420 MHz band. The group will also continue working with the commercial space industry to identify appropriate spectrum to support launch and on-orbit operations.

Systems engineering, standards, and spectrum management efforts will continue to respond to new issues and meet the needs of evolving domestic and international NASA missions.

### Project Schedule

Date	Significant Event
Q1 FY 2014	Begin LLCD evaluation
NET FY 2018	Launch Laser Communication Relay Demonstration

### Project Management & Commitments

Space Communications Support functions are managed by the SCaN Program Office at NASA HQ.

Element	Description	Provider Details	Change from Formulation Agreement
Space Communications Support	Space Communications support provides critical communication and navigation architecture planning, systems engineering, standards definition and management, spectrum management, and technology development for NASA.	Provider: NASA Responsible Center: HQ	

### Acquisition Strategy

Space Communications Support functions use multiple, small contracted efforts, most of which are support services functions.

## SPACE COMMUNICATIONS SUPPORT

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Formulation	Development	Operations
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### MAJOR CONTRACTS/AWARDS

There are no major contracts or awards.

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Integrated Review	Standing Review Board	Sep 2012	Assess the goals, approach, and performance of the SCaN program, including Space Communications Support functions.	Passed	None

## HUMAN SPACE FLIGHT OPERATIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	Notional			
				FY 2016	FY 2017	FY 2018	FY 2019
Total Budget	102.6	--	108.1	112.0	112.0	112.0	112.0



On April 8, 2013 on the International Space Station, astronaut Chris Cassidy, Expedition 35 flight engineer, weighs in using the Space Linear Acceleration Mass Measurement Device in the Columbus European Laboratory. Since crewmembers cannot weigh themselves in zero gravity, they use this method as the next best thing. Skylab astronauts, the first crewmembers to fly in space for over a month at a time some 40 years ago, used a body mass measurement device that was somewhat different from this. Prolonged spaceflight has a variety of effects on the human body and monitoring weight and especially weight loss is an important measurement that needs to be accomplished and documented.

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

Through more than fifty-two years of human space exploration, NASA has faced challenges that led to advances in technology, produced new industries, and nurtured our relationships with other nations. As in the earliest days of Mercury, the very core of human space exploration is the crew. Today, from the comfort of our homes, people on Earth can watch NASA's highly trained astronauts in high definition, engaged in daily life on the International Space Station. The Human Space Flight Operations (HSFO) program supports the training, readiness, and health of the crewmembers prior to, during, and after a spaceflight mission. All crews on board the Space Station have undergone the rigorous and challenging process of spaceflight preparation, critical to mission success.

As the US embarks on the next phase of human space exploration, NASA is developing the transportation system that will travel to destinations beyond Earth's orbit. But the Agency must also prepare the human system for living and working in the hostile space environment extended periods. As astronauts travel towards deep space, several questions come to mind. What health risks will astronauts face and how can they be resolved? What kind of training will crews need to prepare for months of travel in the harsh environment of space? How will they deal with medical emergencies or technical anomalies when Earth is no longer within reach? The HSFO program is charged with answering these questions – and others – to assure crew safety and mission success.



## **HUMAN SPACE FLIGHT OPERATIONS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

At the Johnson Space Center (JSC) in Houston, Texas, HSFO supported pre-flight training and medical services for all ISS crewmembers to ensure their health prior to, during, and after each mission. During FY 2013, NASA completed four successful Expedition missions, which included five launches from Baikonur Cosmodrome in Kazakhstan aboard the Soyuz.

In support of on-orbit operations, HSFO sought to lower the amount of allowable CO<sub>2</sub> on board the Station, recommended medical radiation exposure limits for 12-month ISS missions, and provided recommendations on documented cases of US and Russian space adaption sickness. The program also provided evaluation, testing, and development support for hardware and operations designs of NASA's future launch capabilities, including Orion, the Space Launch System, and US commercial partners.

During the summer, HSFO participated in selecting NASA's 2013 astronaut candidate class, which began training in August and will continue training throughout FY 2014. With successful completion of their training, candidates will be eligible for flight assignments in early 2015. HSFO provided comprehensive medical and psychological support for the incoming class, with emphasis on the Agency's future long-duration space exploration goals. In addition, the program's Behavioral Health and Performance team developed a testing protocol to baseline cognitive functions for the astronauts. Having an accepted protocol will lower human health risks associated with behavioral and psychiatric conditions by mitigating errors due to poor team cohesion, inferior performance, and loss of sleep.

The program also met its goal of improving clinical and research data sharing between ISS partners, in order to better understand the effects of exposure to the space environment on humans. After medical evaluations demonstrated vision changes in some crewmembers, HSFO incorporated visual impairment/intra-cranial pressure (VIIP) in-flight examinations as part of the regular monitoring requirements for spaceflight. HSFO also convened the VIIP syndrome panel, consisting of domestic and international experts, including some from NASA's ISS and Human Research programs, to address this syndrome. Internal and external collaboration has improved NASA's understanding of the effects and possible causes of VIIP in the astronaut population.

### **WORK IN PROGRESS IN FY 2014**

HSFO is implementing new targeted solutions and monitoring strategies recommended by the VIIP Panel Report to screen long-duration crewmembers for ocular problems, support real time medical operations aboard the ISS, and monitor and rehabilitate returning crews. Personnel are also developing modified medical standards for a 12-month mission scheduled for 2015 based on NASA's improved understanding of VIIP syndrome.

HSFO's Flight Medicine Clinic, VIIP, and Lifetime Surveillance of Astronaut Health team members will support a VIIP Research and Clinical Advisory Panel, and an Imaging Working Group review. These meetings will facilitate discussions regarding VIIP project priorities and presentation of updated clinical

## **HUMAN SPACE FLIGHT OPERATIONS**

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data to specialists in neuro-ophthalmology, neurosurgery, and neuroimaging. Additionally, external specialists will provide input to update NASA's current clinical practices and decision-making processes.

In addition, HSFO will support a second Bone Health Summit with the Research and Clinical Advisory Panel, to provide clinical and epidemiological expertise to participants. Potential areas of improvement in HSFO bone health program have been identified, and expert-developed recommendations addressed by the Astronaut Occupational Health Program. HSFO will provide crew surveillance during training and on-orbit activities associated with ISS rodent research, in order to identify and help mitigate allergic responses that may arise after animal exposure.

Currently, on behalf of the HSFO and the Office of the Chief Health and Medical Officer (OCHMO), the Institute of Medicine's Committee on Aerospace Medicine and the Medicine of Extreme Environments (CAMMEE) is reviewing what ethical and policy considerations are involved when space related exposures and risks are uncertain and exposures may exceed current standards. A report of their findings will be presented to HSFO and OCHMO in the second quarter of 2014.

Experts will review new methods of monitoring and mitigating long-term bone and muscle loss for effectiveness as applied to longer missions.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The new astronaut class selected in FY 2013 will be eligible for flight assignments beginning in FY 2015. Starting in FY 2017, flights to the ISS are planned on commercial vehicles, making it possible that the class of FY 2013 will receive assignments on commercial crew missions.

HSFO will work closely with the Office of the Chief Health and Medical Officer and international counterparts to develop medical standards and criteria for long-duration missions, including prolonged radiation exposure. To accomplish this goal, HSFO will standardize medical and exposure data into a single integrated system for participating international astronauts. This evolved information system will provide private, secure access for all international partners, which is needed to support crew clinical care and vital data management for the human research communities.

HSFO and the Human Health and Performance Directorate at JSC are working to produce clinical practice guidelines for assessing and managing astronauts with VIIP syndrome. In addition, both organizations will continue to conduct studies on the risks and implications of long-term exposure to space radiation, and review new methods of monitoring and mitigating long-term bone and muscle loss.

## **Program Elements**

### **SPACE FLIGHT CREW OPERATIONS (SFCO)**

SFCO provides trained astronauts for all NASA human space flight efforts. Project responsibilities include directing and managing flight crew activities, selecting astronaut candidates, recommending flight crew assignments, and operating program support aircraft – most notably a fleet of T-38 aircraft for high performance astronaut space flight readiness training. In addition SFCO ensures space flight readiness

## HUMAN SPACE FLIGHT OPERATIONS

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training requirements continue to be driven by ongoing ISS operations, planned exploration and commercial development.

### CREW HEALTH AND SAFETY (CHS)

CHS enables healthy and productive crew during all phases of space flight missions, implements a comprehensive astronaut health care program, and works to prevent and mitigate negative long-term health consequences of space flight. The project works with the Human Research Program (HRP) to transition research products assuring crew health and safety to operations, and medically assesses astronaut candidates as part of the selection process. In this collaboration, HRP concentrates on the research aspects of crew health, while CHS focuses on the research results, converting them into operational protocols. As research continues on ISS through 2024, CHS actively seeks new ways of doing business, including collaborative opportunities with other Federal agencies and academia.

### Program Schedule

Date	Significant Event
Mar 2014	Institute of Medicine Study
Mar 2014	Collaborate with the National Council of Radiation Protection and Measurement
Apr 2014	VIIP Analysis and Evaluation
July 2014	Astronaut Class of 2013 Group A training for long duration flight
Jan 2015	Astronaut Class of 2013 Group B training for long duration flight
Oct 2015	Complete all T-38 longeron replacement

### Program Management & Commitments

Program Element	Provider
SFCO will provide trained astronauts for all US human space flight endeavors and bring experienced astronauts expertise to help resolve operations or development issues.	Provider: SFCO Lead Center: JSC Performing Center(s): JSC Cost Share Partner(s): None
CHS will assess and maintain the health of astronauts prior to, during, and post flight.	Provider: CHS Lead Center: JSC Performing Center(s): JSC Cost Share Partner(s): None

## HUMAN SPACE FLIGHT OPERATIONS

### Acquisition Strategy

The section below identifies the current contract(s) that support SFCO and CHS.

### MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Aircraft Maintenance and Modification Program	DynCorp International LLC	Ellington Field, Houston, TX, El Paso, TX
Bioastronautics Contract	Wyle Integrated Science and Engineering Group	Houston, TX

### INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Independent Assessment	National Academies	Sep 2011	Evaluate plans relative to the role and size of SFCO activities following the Space Shuttle retirement and completion of the assembly of the ISS including the astronaut corps' fleet of training aircraft.	The NRC conclusions largely reinforced NASA decision making and approach to crew training.	N/A
Performance	Institute of Medicine	Jul 2012	At the request of NASA, an IOM committee reviewed NASA HRP's Scientific Merit Assessment Processes for directed research.	The IOM committee found that the scientific merit assessment process used by the HRP for directed research is scientifically rigorous and is similar to the processes and merit criteria used by many other Federal agencies and organizations.	N/A

## HUMAN SPACE FLIGHT OPERATIONS

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Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Performance	Institute of Medicine	Jul 2012	The Institute of Medicine's Committee on Aerospace Medicine and the Medicine of Extreme Environments (CAMMEE) reviewed What ethical and policy considerations are involved when exposures/risks are uncertain and exposures may exceed current standards?	The CAMMEE will to provide a report to NASA March 2014.	N/A

## LAUNCH SERVICES

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>81.2</b>	<b>--</b>	<b>83.0</b>	<b>86.7</b>	<b>89.1</b>	<b>89.1</b>	<b>89.1</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Enclosed in its payload fairing, NASA's Tracking and Data Relay Satellite K, passes through the Launch Complex 39 area at Kennedy Space Center to its launch site. The spacecraft is part of the next-generation series in NASA's constellation of space-based communication satellites that provide tracking, telemetry, command, and high-bandwidth data return services.

Utilizing commercially available domestic launch services, NASA's Launch Services Program (LSP) has provided affordable and reliable space access for science, exploration, communication, weather, and technology development satellites for the last 15 years. Without these launch services, NASA's science spacecraft would have a difficult time reaching orbit, and missions like NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft would not be able to acquire data on the structure and composition of the Mars atmosphere.

LSP acts as a broker, matching spacecraft with launch vehicles through competitive processes with commercial providers. Once the right vehicle is selected, the program buys the spacecraft a ride to space, and works with the customer to ensure mission success, starting

with pre-mission planning and continuing through the spacecraft's post-launch phase. LSP's state-of-the-art technology management, business, procurement, and engineering best-practices, strategic planning, studies, and techniques are instrumental in providing NASA missions with access to a dependable and secure Earth-to-space bridge, launching spacecraft to orbit our planet, or further into deep space.

LSP acquires and manages launch services, and ensures that pricing is consistent and fair. In addition, the program certifies the readiness of new commercial launch vehicles for NASA and other civil sector agencies' high value spacecraft. The program also conducts engineering analyses and other technical tasks that maximize launch success for every NASA robotic payload. LSP supports the entire civil sector community, including agencies such as the National Oceanic and Atmospheric Administration (NOAA) and United States Geological Survey (USGS).

## LAUNCH SERVICES

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### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

During FY 2013, three major payloads successfully launched utilizing LSP-acquired services: TDRS-K, LDCM, and IRIS. The TDRS-K and LDCM missions presented a particular challenge for LSP, as they were launched just 12 days apart, from opposite US coasts. TDRS-K launched aboard the heavy-lift Atlas V from Cape Canaveral Air Force Station in Florida on January 31, 2013; eleven days later, LDCM lifted off from Vandenberg Air Force Base in California – also aboard an Atlas V. Supporting both launches tested LSP’s scheduling and resource management capabilities, and the program responded with two resounding successes that served to further vital science and technology. A third major payload – IRIS – was delivered to orbit four months later from Vandenberg, this time aboard an Orbital Sciences Corporation Pegasus XL. IRIS is the eleventh of NASA’s Small Explorer missions, and its compact size made it a good match for the Pegasus rocket, which was lifted to launch altitude over the Pacific Ocean, strapped to the belly of a Lockheed L1011 aircraft.

#### Tracking and Data Relay Satellite (TDRS-K)

Mission Operator: NASA Human Exploration & Operations (SCaN)

Provide NASA with crucial crosslink communications capability between control and data processing facilities on the ground, and Earth-orbiting spacecraft such as Hubble Space Telescope, International Space Station, and dozens of unmanned scientific satellites.

#### Landsat Data Continuity Mission (LDCM)

Mission Operator: US Geological Survey/NASA Science Mission Directorate

Provide repetitive acquisition of high resolution multispectral data of the Earth’s surface, collecting valuable data and imagery to be used in agriculture, education, business, science, and government.

#### Interface Region Imaging Spectrogram (IRIS)

Mission Operator: NASA Science Mission Directorate

Observe how solar material moves, gathers energy, and heats up as it travels through a little-understood region in the sun's lower atmosphere; provide insight into solar storms that disrupt power supplies, transportation systems and communication networks on Earth.

Date	Mission	Launch Vehicle Configuration	Launch Site
Jan 2013	TDRS-K	Atlas V	Cape Canaveral Air Force Station (CCAFS), Florida
Feb 2013	LDCM	Atlas V	Vandenberg Air Force Base (VAFB), California
Jun 2013	IRIS	Pegasus XL	VAFB, California

## LAUNCH SERVICES

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In addition, LSP acquired launch services for two future science missions in FY 2013: OSIRIS-REx and ICESat-2. United Launch Services will launch both missions. Osiris-REx launches aboard an Atlas V from Cape Canaveral, Florida, and ICESat-2 aboard a Delta II from Vandenberg Air Force Base.

### **Origins-Spectral Interpretation Resources Identification-Security-Regolith Explorer (OSIRIS-Rex)**

Mission Operator: NASA Science Mission Directorate

Visit an asteroid in 2016, perform 6 months of surface mapping, and use a robotic arm to collect samples to return to Earth; data will help explain our solar system's formation and how life began, as well as improve our understanding of asteroids that could impact our planet.

### **Ice Clouds and land Evaluation Satellite (ICESat-2)**

Mission Operator: NASA Science Mission Directorate

Collect altimetry data of the Earth's surface optimized to measure ice sheet elevation change and sea ice thickness, while also generating an estimate of global vegetation biomass.

Mission	Launch Vehicle Configuration	Launch Provider	Planned Launch
OSIRIS-Rex	Atlas V	ULS	Sep 2016
ICESat-2	Delta II	United Launch Services (ULS)	Dec 2016 (UR)

NASA and LSP are also partnering with several universities to launch small research satellites through the Educational Launch of Nanosatellites project and the CubeSat Launch Initiative, which provides opportunities for small satellite payloads to fly as secondary payloads on upcoming launches. These payloads provide educational opportunities for students in science, technology, engineering, and mathematics disciplines. CubeSats have been selected from 25 states across the US, with 29 launched and 11 manifested on NASA, National Reconnaissance Office, and United States Air Force missions. To provide additional launch options for small civil sector payloads and promote continued evolution of the US commercial space launch market, LSP released a solicitation for a CubeSat-class, firm fixed-price launch service. NASA awarded a contract to Generation Orbit Launch Services Inc., for three CubeSats in 2016. This contract is a pathfinder for acquiring future launch services for low-cost and/or high-risk-tolerant payloads.

## **WORK IN PROGRESS IN FY 2014**

On an ongoing basis, LSP provides expertise and active launch mission management for 35 to 40 NASA scientific spacecraft missions in various stages of development. Three of these have launched, or are planned to launch in FY 2014: MAVEN, TDRS-L, and OCO-2. Both MAVEN and TDRS-L launched from Cape Canaveral in Florida, while OCO-2 will lift off from Vandenberg Air Force Base in California.



## LAUNCH SERVICES

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### **Mars Atmosphere and Volatile Evolution (MAVEN)**

Mission Operator: NASA Science Mission Directorate

Explore Mars' upper atmosphere, ionosphere and interactions with the sun and solar wind; loss of compounds such as carbon dioxide, nitrogen dioxide, and water from the atmosphere over time will provide insight into current atmosphere and climate, liquid water, and planetary habitability.

### **Tracking and Data Relay Satellite (TDRS-L)**

Mission Operator: NASA Human Exploration & Operations (SCaN)

Provide NASA with crucial crosslink communications capability between control and data processing facilities on the ground, and Earth-orbiting spacecraft such as Hubble Space Telescope, International Space Station, and dozens of unmanned scientific satellites.

### **Orbiting Carbon Observatory 2 (OCO-2)**

Mission Operator: NASA Science Mission Directorate

Study atmospheric carbon dioxide by collecting space-based global measurements of atmospheric CO<sub>2</sub> with the precision, resolution, and coverage needed to characterize regional sources and sinks; also quantify CO<sub>2</sub> variability over seasonal cycles year after year.

In advance of launching NASA's Jason-3 sea surface measurement mission in FY 2015, LSP will be extensively involved in certifying the Space Exploration Technologies (SpaceX) Falcon 9 1.1 launch vehicle. The Falcon 9 made history in 2012 when it delivered the first commercial cargo vehicle into orbit for rendezvous with the International Space Station. Falcon 9 certification is vital to the nation's space program, as it adds to existing intermediate class capabilities, which enhances competition. Multiple providers not only enable launch cost reductions, but also increase probability of a sustained manifest schedule. The program continues to acquire launch services for numerous NASA science missions over the course of the year.

In addition to the full launch service management the program provides for most missions, the program also offers advisory support, expertise, and knowledge to NASA programs and projects utilizing launch services not procured and managed by LSP. The program is currently providing these advisory services to several missions, including:

- ISS Commercial Resupply Services missions, which are launching on the SpaceX Falcon 9 and the Orbital Sciences Antares launch vehicles
- Orion Multi-Purpose Crew Vehicle Exploration Flight Test 1, which is using the Delta IV heavy launch vehicle Commercial Crew Program
- NASA's Commercial Crew Program
- The joint US/Japan Global Precipitation Measurement "Core" rain and snow observation mission, which will launch on a Japanese H-IIA vehicle

## LAUNCH SERVICES

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### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Three civil sector missions are planned for launch in FY 2015: MMS, SMAP, and Jason-3. Currently, both MMS and SMAP are scheduled for launch in November 2014 – the former from Cape Canaveral in Florida, and the latter from Vandenberg in California. Jason-3 will also launch from Vandenberg, in March 2015.

#### **Magnetospheric MultiScale (MMS)**

Mission Operator: NASA Science Mission Directorate

Utilize four spacecraft flying in formation to investigate how the Sun's and Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other in a process that is important everywhere in the universe, known as magnetic reconnection.

#### **Soil Moisture Active Passive (SMAP)**

Mission Operator: NASA Science Mission Directorate

Provide global measurements of soil moisture and its freeze/thaw state to enhance understanding of processes that link the water, energy and carbon cycles, and extend the capabilities of weather and climate prediction models.

#### **Jason-3**

Mission Operator: NASA, CNES, NOAA, EUMETSAT

Monitor global ocean circulation, study ties between the ocean and the atmosphere, improve global climate forecasts and predictions, and monitor events such as El Niño and ocean eddies.

NOAA's Jason-3 mission is an international cooperative mission with NASA's Jet Propulsion Laboratory, the National Oceanic and Atmospheric Administration (NOAA), France's Centre National d'Etudes Spatiales (CNES) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). As part of the Jason-3 launch activity, LSP will continue to support certification of the SpaceX Falcon 9 launch vehicle. If SpaceX does not meet certification, then LSP would be required to terminate the contract and re-compete for another launch vehicle for Jason-3.

In addition, LSP will continue launch service acquisition activities necessary to support NASA and other approved government missions, as well as providing launch related mission support to approximately 35 to 40 NASA scientific spacecraft missions in various development phases. The program will also provide launch system advisory support to ISS Commercial Resupply Services missions, the NOAA Deep Space Climate Observatory (DSCOVR) mission, and Commercial Crew program activities.

## LAUNCH SERVICES

### Program Schedule

Date	Significant Event
Nov 2013	MAVEN launch aboard Atlas V
Jan 2014	TDRS-L launch aboard Atlas V
Feb 2014	GPM Core launch aboard H-IIA*
Jul 2014	OCO-2 launch aboard Delta II
Sep 2014	EFT-1 aboard Delta IV Heavy*
Oct 2014	MMS launch aboard Atlas V
Nov 2014	SMAP launch aboard Delta II
Nov 2014	DSCOVR aboard Falcon 9(v1.1)*
Mar 2015	Jason-3 launch aboard Falcon 9 (v1.1)

*\*LSP in advisory role only*

### Program Management & Commitments

Program Element	Provider
Expendable Launch Vehicle (ELV) Launch Services	Provider: ULS, OSC, SpaceX, Lockheed Martin Space Systems Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A

### Acquisition Strategy

In 2000, LSP put a unique acquisition strategy in place for procuring ELV launch services from domestic commercial launch service suppliers. To meet the needs of science customers who typically spend three to seven years developing a spacecraft mission, NASA created a novel contractual approach that provided multiple competitive launch service options to cover small, medium, and intermediate-sized missions under the original NASA Launch Services (NLS) contracts. The follow-on contract mechanism, known as NLS II, has similar contract features, such as not-to-exceed prices; indefinite delivery/indefinite quantity contract terms; and firm-fixed price, competitive, launch service task-order-based acquisitions. The NLS II ordering period will expire in June 2020. To keep competition fresh and encourage new launch capability development on these 10-year contracts, NASA provides opportunities to US industry on a regular basis to add new commercial launch service providers and/or launch vehicles to the active contract.

NASA has also made efforts to provide a more complete launch service that includes payload processing at the launch site. LSP has put in place firm-fixed price indefinite delivery/indefinite quantity contracts for commercial payload processing capabilities on both the east and west coasts. In November 2012, NASA awarded West Coast Commercial Payload Processing Facility contracts to Astrotech Space

## LAUNCH SERVICES

Operations (ASO) and Spaceport Systems International at Vandenberg Air Force Base in California. In January 2013, NASA awarded the East Coast Commercial Payload Processing Facility contract to ASO in Titusville, Florida. The contractors, ASO and Spaceport Systems International, will provide all resources necessary to deliver and perform payload processing such as standard and non-standard services, mission unique services, special task assignments, and facility modification required for each specific mission awarded. The Payload Processing Facility contracts ordering period expires in December 2018.

## MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
NLS-I-L*	ULS, LLC	Centennial, CO
NLS-II-A	Lockheed Martin Space Systems	Denver, CO
NLS-II-U	ULS, LLC	Centennial, CO
NLS-II-S	SpaceX	Hawthorne, CA
NLS-II-O	OSC	Dulles, VA
Payload Processing Facility	Astrotech Corporation	Titusville, FL
Payload Processing Facility	Astrotech Corporation	VAFB, CA
Integrated Processing Facility	Spaceport Systems International	VAFB, CA
ELVIS 2	a.i. Solutions, Inc.	Lanham, MD

*\*ULS is the only remaining NLS Contractor with active awarded missions*

## INDEPENDENT REVIEWS

The LSP Program Implementation Review (PIR) is scheduled for May 2014.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
PIR	Standing Review Board	May 2014	Life Cycle Review	TBD	N/A

## LAUNCH SERVICES

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### HISTORICAL PERFORMANCE

LSP Managed ELV Missions from Inception through FY 2013

Launch Vehicle Configuration	Provider	Number of Launches	Successful Launches	Unsuccessful Launches
Athena	Lockheed Martin/Alliant Techsystems	1	1	0
Atlas IIA	Lockheed Martin	5	5	0
Atlas IIAS	Lockheed Martin	1	1	0
Atlas V	Lockheed Martin	2	2	0
	ULS	7	7	0
Delta II	Boeing Launch Services	26	26	0
	ULS	13	13	0
Pegasus Hybrid	OSC	1	1	0
Pegasus XL	OSC	13	13	0
Taurus XL	OSC	2	0	2
Titan II	Lockheed Martin	3	3	0

## ROCKET PROPULSION TEST

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>45.9</b>	<b>47.8</b>	<b>45.8</b>	<b>47.2</b>	<b>47.6</b>	<b>47.6</b>	<b>47.6</b>
Change from FY 2014			-2.0				
Percentage change from FY 2014			-4.2%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Engineers conduct a test of the Orbital Sciences Corporation Aerojet-Rocketdyne AJ-26 engine at Stennis Space Center in Mississippi. The AJ-26 is a modified version of the Russian NK-33 engine, which has been out of production since the end of the Soviet manned lunar program. Orbital refurbished the NK33 engines, and in September, the AJ-26 powered their Antares rocket from Wallops Flight Facility in Virginia. The launch marked Orbital's final demonstration flight, and the maiden voyage of its Cygnus cargo vehicle. Developed as a part of NASA's Commercial Orbital Transportation Services program, Cygnus delivered student experiments, food and supplies to the International Space Station, paving the way for future commercial resupply missions.

Development and test of rocket propulsion systems is foundational to spaceflight. Whether the payload is a robotic science experiment or a human-crewed mission, the propulsion system must be safe, reliable, and accurate. A rigorous engine test program is a critical component of any rocket propulsion development activity.

NASA's Rocket Propulsion Test (RPT) program maintains and manages a wide range of facilities capable of ground testing rocket engines and components under controlled conditions. This world-class test infrastructure includes facilities located across the United States, and provides a single entry point for any user of the rocket test stands. The program retains a skilled workforce, capable of performing tests on all modern day rockets including supporting complex rocket engine developments. RPT program evaluates customer test requirements and desired outcomes, minimizing test time and costs. The program efficiently manages facility usage and eliminates redundant capability by closing, consolidating, modernizing, and streamlining NASA's rocket test facilities.

RPT is NASA's implementing authority for rocket propulsion testing. The program approves

and provides direction on test assignments, capital improvements, and facility modernization and refurbishment. RPT integrates multi-site test activities, identifies and protects core capabilities, and develops advanced testing technologies.

## ROCKET PROPULSION TEST

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The Agency has designated RPT as the NASA representative for the National Rocket Propulsion Test Alliance (NRPTA) – an inter-agency alliance with the Department of Defense (DoD) to facilitate efficient and effective use of the federal government’s rocket propulsion test capabilities. The RPT Program Manager serves as a member of the NRPTA Senior Steering Group, and appoints NASA’s alliance co-chair. This position is a rotational appointment chosen from primary center representatives of RPT’s Management Board.

For additional programmatic information, go to: <http://rockettest.nasa.gov/>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

By the end of FY 2013, the RPT program had safely performed over 349 tests – a 300 percent increase over FY 2012. Test time totaled over 270,000 seconds, with more than 13,000 seconds of hot fire at various levels of thrust.

In early September, the J-2X engine – a new version of a liquid fuel upper stage rocket engine – completed its testing series on the A-1 test stand at Stennis Space Center (SSC), culminating with a 330-second test. The first human-rated liquid oxygen and liquid hydrogen rocket engine to be developed in 40 years, the J-2X upper stage engine is a candidate for the heavy-lift Space Launch System (SLS), which is a critical component of NASA's deep space exploration program development.

Also at SSC, the Orbital Sciences Corporation and Aerojet Rocketdyne conducted test firings of the AJ-26 engine. The AJ-26 engine powered the Orbital Antares rocket that successfully launched in September from NASA’s Wallops Flight Facility in support of the Commercial Orbital Transportation Services project.

Marshall Space Flight Center tested the F-1 gas generator for the SLS advanced booster engineering demonstration risk reduction effort, designed to lead to an affordable booster that meets the evolved capabilities of the heavy lift SLS.

The Boeing Corporation conducted testing of their orbital maneuvering and reaction control system thruster at the White Sands Test Facility (WSTF) as part of NASA’s Commercial Crew program. Also at WSTF, engineers conducted tests to support DoD’s Missile Defense Agency engine and thruster program, the Peacekeeper safing project, and hot fire test and decontamination efforts for the Minuteman life extension program.

NASA completed limited facility repairs and modifications to the Plum Brook Station B-2 facility at Glenn Research Center (GRC), to enhance NASA’s only thermal vacuum facility capable of testing articles containing cryogenic oxygen and hydrogen. In addition, SSC continued major refurbishment activities for the B-2 test stand, critical to SLS core stage testing. SSC also began the first phase refurbishment of the high pressure industrial water system, which provides cooling, deluge, and acoustic dampening for test articles. The system is designed to provide 300,000 gallons per minute at nearly 300 psi.

## **ROCKET PROPULSION TEST**

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### **WORK IN PROGRESS IN FY 2014**

In FY 2014, SSC has several continuing test programs underway, including the J-2X and RS-25 in support of the SLS program, and flight certification testing for the AJ-26 engine. Development testing will also continue for NASA's Morpheus lander, and for commercial companies that seek to test their engine systems on a reimbursable basis. Refurbishment and repair activities for critical enabling infrastructure include replacing the B-leg of the high pressure industrial water system, repairing SSC's liquid oxygen and liquid hydrogen barge and high pressure gas facility, and replacing the E-Complex data acquisition system. In addition, to prepare for SLS core stage testing, RPT will continue B-2 test stand refurbishment.

WSTF will perform testing for the DoD Missile Defense Agency, Boeing commercial crew development, US Air Force Peacekeeper, US Air Force Minuteman, SLS, Orion service module, and Boeing commercial crew service module. To support Boeing commercial crew testing in 2016, modifications to test stand 301 will continue with construction activities scheduled to begin in late 2014. In addition to test and construction activities, WSTF will complete redesign of the large altitude simulation system.

GRC's Plum Brook Station will integrate a 30,000 gallon liquid hydrogen tank into the system to support testing, and also complete facility repairs for the 11 foot vacuum isolation valve to enable lower vacuum pressures, electric propulsion testing, and engine hot fire testing.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

Building on test results from previous years, RPT will continue to provide valuable propulsion data to the SLS and Orion programs as they prepare for Exploration Missions 1 and 2. These tests will continue to provide feedback on their baseline designs, increasing confidence in technical performance, as well as the ability to achieve launch readiness in FY 2018. This ongoing testing also allows the programs to assess changes that could increase performance and/or improve safety. Specifically, RPT will hot fire the SLS RS-25 engine on the A-1 test stand at Stennis. Eventually, four RS-25 engines will propel the SLS core stage upon launch.

To prepare for future SLS integrated engine testing at Stennis, RPT will continue refurbishment and construction activities, and initiate activation of the B-2 test stand, scheduled for completion in FY 2016. In anticipation of Orion service module testing, RPT will begin preparation of required test facilities to assess baseline designs and technical performance. Also in FY 2015, RPT will start refurbishing the large altitude simulation system, which supports future space environment testing for Orion service module, Boeing commercial crew vehicle, Missile Defense Agency, and US Air Force test articles.

RPT will also perform engine testing for other programs including the US Air Force Aerojet Rocketdyne RS-68 engine, the Orbital Antares rocket AJ-26 engine, and SpaceX and other commercial engine developers. RPT will continue testing of hazardous hypergolic fuels at WSTF. These unique facilities are critical for testing future space vehicles in a simulated space environment and ambient conditions.



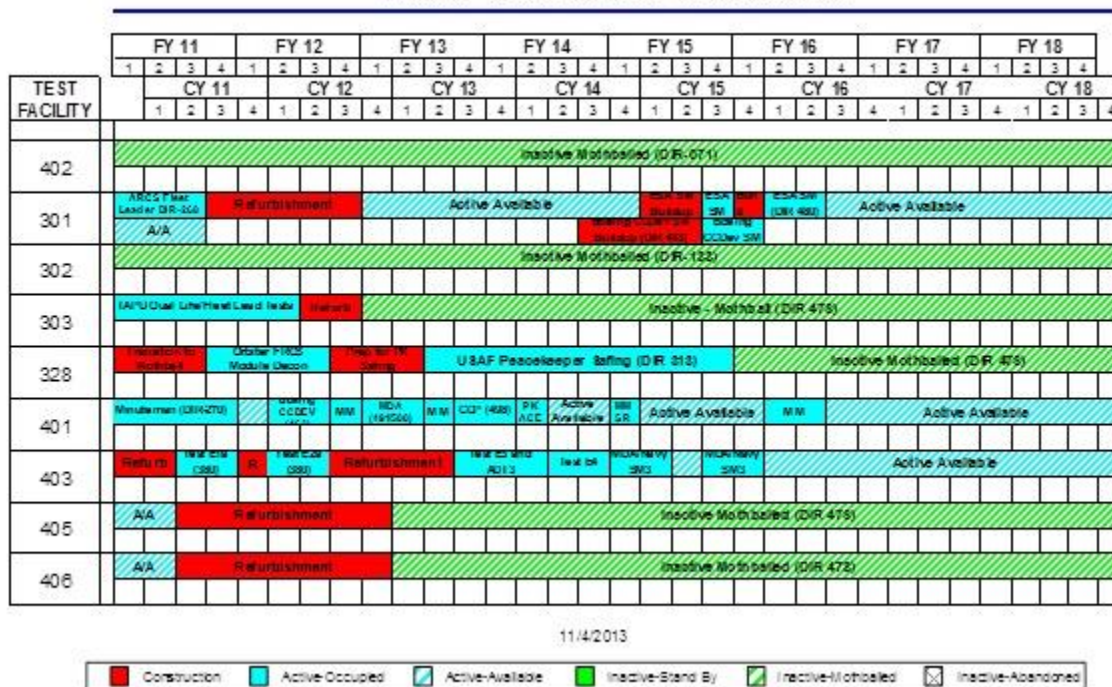
The following charts show past, current, and planned test campaigns at the various rocket propulsion test facilities listed at the left side of the table. The size designations at the far left of the SSC chart refers to the thrust class of engines the facility can test. The top of each chart shows time by quarter of fiscal year and calendar year, and the key to the status of each facility is at the bottom.

Test stands and facilities are solidly scheduled 18 months in advance. Defining scope of work, selecting test stands and fuel, and estimating labor and total cost to customers is a complex process that can take 18 to 36 months. RPT is working now with internal and external customer to design testing programs that will be conducted in FY 2015 and beyond.

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## ROCKET PROPULSION TEST

### WSTF Test Stand Utilization



## Program Management & Commitments

Program Element	Provider
RPT	Provider: RPT Lead Center: N/A Performing Center(s): SSC, JSC/WSTF, GRC Plum Brook Station, MSFC, KSC, WFF Cost Share Partner(s): Various other NASA programs, DoD, and commercial partners

## **ROCKET PROPULSION TEST**

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### **Acquisition Strategy**

No major acquisitions are identified for FY 2015.

### **MAJOR CONTRACTS/AWARDS**

No major contracts or awards are planned for FY 2015.

### **INDEPENDENT REVIEWS**

No reviews planned.

## EDUCATION

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Aerospace Research and Career Development Program	54.0	58.0	33.0	33.0	33.0	33.0	33.0
STEM Education and Accountability Program	62.3	58.6	55.9	56.8	57.7	58.6	59.6
<b>Total Budget</b>	<b>116.3</b>	<b>116.6</b>	<b>88.9</b>	<b>89.8</b>	<b>90.7</b>	<b>91.6</b>	<b>92.6</b>

## Education ..... EDUC-2

AEROSPACE RESEARCH AND CAREER DEVELOPMENT PROGRAM ..... EDUC-8

National Space Grant College and Fellowship Project ..... EDUC-10

Experimental Project To Stimulate Competitive Research (EPSCoR)..... EDUC-16

STEM EDUCATION AND ACCOUNTABILITY PROGRAM..... EDUC-20

Minority University Research Education Project ..... EDUC-22

STEM Education and Accountability Projects ..... EDUC-29

# EDUCATION

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Aerospace Research and Career Development Program	54.0	58.0	33.0	33.0	33.0	33.0	33.0
STEM Education and Accountability Program	62.3	58.6	55.9	56.8	57.7	58.6	59.6
<b>Total Budget</b>	<b>116.3</b>	<b>116.6</b>	<b>88.9</b>	<b>89.8</b>	<b>90.7</b>	<b>91.6</b>	<b>92.6</b>
Change from FY 2014			-27.7				
Percentage change from FY 2014			-23.8%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA Education ignites interest in Science, Technology, Engineering and Mathematics (STEM) and provides unique opportunities for learners of all ages to explore and develop their full learning potential. This NASA education downlink enabled students and educators around the world to connect virtually with astronauts Kevin Ford and Sunita Williams onboard the International Space Station. The event took place in the Moving Beyond Earth Gallery at the Smithsonian National Air and Space Museum in Washington, D.C. in honor of International Education Week, a joint initiative between the Department of State and the Department of Education that celebrates the benefits of international education and exchange.

In 2014, the President's Budget proposed a government-wide STEM reorganization to create a coherent framework for delivering STEM education to more students and more teachers more effectively while reducing fragmentation, and the Administration published a Five-Year Federal Strategic Plan on STEM Education to help align the reorganization with key goals and strategies. This plan reflects a more cohesive delivery of STEM education and coordination of all participating Federal agencies' resources. In FY 2015, NASA Office of Education (OE) will continue to support learners and institutions while reducing fragmentation consistent with the goals, objectives, and strategies of the Administration's Five-Year Strategic Plan.

The Agency proposes to restructure its education investments into a coordinated education program funded primarily through OE. OE will work closely with the other Federal agencies and focus funding on the Administration's five STEM education priorities. This approach will use NASA's expertise and resources to diversify the Nation's STEM education portfolio. The FY 2015

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request for OE is \$88.9 million. Additionally, the Budget provides \$15 million to NASA's Science Mission Directorate to fund the best application of NASA Science assets to meet the Nation's STEM education goals through a competitive process.

OE's vision to advance high quality STEM education using NASA's unique capabilities aligns to the Agency's strategic plan. OE will continue to be deliberate in developing and executing strategic partnerships with intergovernmental, academic, industrial, entrepreneurial, and international communities to achieve NASA's values, mission, and vision. OE's activities will define specific benefits and outcomes from each partnership, develop methods to more systematically manage partnerships, and leverage each organization's resources.

In addition to the National Space Grant College and Fellowship Program (Space Grant), Experimental Program to Stimulate Competitive Research (EPSCoR), and Minority University Research and Education Project (MUREP), NASA will consolidate the education functions, assets, and efforts of the mission directorates, offices, and Centers into the coordinated STEM Education and Accountability Projects. These assets are critical and unique components that NASA can integrate into STEM coordination efforts with other agencies.

NASA STEM education will remain in alignment with the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Reauthorization Act of 2010. NASA's investments will also provide unique support for minority serving institutions and community colleges, which generally serve a high proportion of minority students and prepare them for study at four-year institutions.

The Science Mission Directorate (SMD) will continue to fund the Global Learning and Observations to Benefit the Environment (GLOBE), a worldwide hands-on, primary, and secondary school-based activity. GLOBE's vision promotes and supports students, teachers, and scientists to collaborate on inquiry-based investigations of the environment and the Earth system working in close partnership with NASA, National Oceanic and Atmospheric Administration, and National Science Foundation Earth System Science Projects in study and research about the dynamics of Earth's environment. SMD will also fund the most meritorious education activities through a competitive process.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

The Agency will fundamentally restructure its STEM education investments into a coordinated education effort reporting to the NASA OE. NASA will continue to work closely with other Federal agencies in executing the Administration's STEM education objectives. The Agency aims to increase both the use of NASA resources and the availability of opportunities to a diverse audience of educators and students, including women, minorities, and persons with disabilities.

NASA will continue to support and collaborate with other agencies in the key areas identified by the Federal STEM Education Five-Year Strategic Plan: 1) improve STEM instruction and learning, 2) increase and sustain youth and public engagement in STEM, 3) enhance the STEM experience of undergraduate students, 4) provide STEM learning opportunities to groups historically underrepresented in STEM fields and 5) design graduate education for tomorrow's STEM workforce.

OE will continue its internal assets inventory and evidence-based assessment of Agency-conducted STEM education activities. OE will utilize a competitive process for allocating resources, to ensure that

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the most effective internal STEM education activities are supported. NASA will allocate funds to allow the Agency to support a data management system for performance measurement, analysis, evaluation, and reporting of NASA's STEM Education activities.

Offices such as the International Space Station (ISS) Program Office will continue to provide access to launch facilities related to STEM engagement efforts. Those resources will support NASA's ability to make its people, facilities, and flight platforms available for educational purposes. In FY 2015, NASA's STEM education expertise and assets will continue to play a unique role in the Nation's STEM education portfolio.

### ACHIEVEMENTS IN FY 2013

In FY 2013, NASA OE and the mission directorates and Centers reclassified their activities' portfolio, into four streamlined lines of business: STEM Engagement; Educator Professional Development; Institutional Engagement; and NASA Internships, Fellowships, and Scholarships (NIFS).

In 2013, OE awarded a cooperative agreement to the Universities Space Research Association (USRA) as a mechanism to improve integration of internships at NASA Centers.

MUREP funded 148 internships, including 52 interns from Minority Serving Institutions (MSI). Ten undergraduate students received NASA MUREP scholarships for the 2013-2014 academic year, and thirty graduate students received NASA Harriett G. Jenkins Graduate Fellowships, which provide doctoral funding to underserved, underrepresented, or to persons with disabilities.

The OE Summer of Innovation (SoI) pilot project reached over 39,000 students and 4,000 educators using NASA's unique STEM education activities during the summer and through other out-of-school learning opportunities. Through the Science, Engineering, Math, and Aerospace Academy (SEMAA), 15 project sites in 14 states inspired, engaged, and educated 55,573 students, families, caregivers, and instructors using NASA's STEM educational activities.

The Museum Alliance hosted at Jet Propulsion Laboratory (JPL) has grown to include more than 580 U.S. museums, science centers, planetariums, NASA Visitor Centers, and Challenger Learning Centers. NASA's FY 2013 Competitive Program for Science Museums, Planetariums, and NASA Visitor Centers Plus Other Opportunities received nearly 70 proposals from informal education institutions and NASA visitor centers. Six museums and four NASA visitor centers received new grants or cooperative agreements. These grants and cooperative agreements will create interactive exhibits, virtual worlds, professional development activities, and community-based programs to engage students, teachers and the public in STEM. Additional selections will depend on finalization of the FY 2014 budget. Thirty-six institutions continue work with funds from prior fiscal years.

OE signed a Space Act Agreement (SAA) with the Boys and Girls Clubs of America supporting space exploration and innovation to raise students' expectations for success and to pursue STEM careers. NASA OE also signed an SAA with Lockheed Martin to formulate and conduct the Exploration Design Challenge for students in grades 5-12. Over 150,000 students participated in activities tied to Exploration Flight Test (EFT-1) of the Orion spacecraft. NASA and the Department of Education (ED) entered into a reimbursable SAA to develop multiple STEM challenges in support of the ED's 21st Century Community Learning Center (21 CCLC) program for Colorado, Michigan, and Virginia.

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## WORK IN PROGRESS IN FY 2014

NASA will continue to align its STEM education activities with the priorities identified in the Federal STEM Education Five-Year Strategic Plan. For example, NASA and the U.S. Department of Education (ED) entered into a pilot reimbursable Space Act Agreement that ran from the Fall 2013 through Winter 2014. The pilot aligned to the near term actions under the CoSTEM priority to increase and sustain youth and public engagement in STEM. The partnership supported STEM objectives within ED's 21st Century Community Learning Center (CCLC) program. NASA customized online STEM challenges and associated curriculum materials aligned to 21CCLC objectives. NASA worked with three 21CCLC states Colorado, Michigan, and Virginia. NASA and ED are using the results from the pilot to draft a framework for other federal collaborations with the 21CCLC.

The Museum Alliance will extend an existing, free-of-charge NASA STEM content facilitation membership service to long-time partners in NASA education such as the Science Engineering Mathematics and Aerospace Academy (SEMAA). SEMAA sites at community colleges; minority-serving higher education institutions; and high schools, middle schools and elementary schools provide science centers and museums in urban and rural cities throughout the United States the opportunity to receive improved access to the most recent NASA content available across all NASA mission directorates. Representatives from Smithsonian-Affiliate Museums, for example the Museum of Flight in Seattle, Washington and the US Space and Rocket Center in Alabama, are already alliance members and take the NASA STEM content and adapt for locally conducted STEM engagement activities.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

The Federal STEM Education 5-year Strategic Plan highlights two STEM education coordination approaches and five priority STEM education investment areas where a coordinated Federal strategy will lead to major improvements in key areas. This increased coordination will maximize impact and produce strategies for closer and more effective collaboration among the agencies with STEM education investments. The Agency aims to increase both the effectiveness and utilization of NASA resources to reach the Administration's STEM education goals through interagency efforts.

STEM education resources within NASA will continue to use competitive processes to identify NASA's internal STEM education activities and assets across the Agency. NASA will make available its unique assets, such as the International Space Station, to STEM education programs Government-wide on a reimbursable basis in order to enhance their effective reach to students and educators., OE will continue evidence-collection activities for performance measurement, analysis, evaluation, and reporting of NASA's activities.

In FY 2014 NASA hosted for each of the lead agencies NSF, SI and ED interagency working groups (IWGs) sessions by the five priority STEM education investments. In FY 2015 NASA OE will continue its dedication to the IWG-created infrastructure, policies and practice led by the three convening agencies.

NASA will contribute toward the Administration's goals for STEM education through an education portfolio focused on the following:

- STEM Engagement: Provide opportunities for participatory and experiential learning activities that connect learners to NASA-unique resources;



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- NASA Internships, Fellowships, and Scholarships: Utilize NASA facilities and assets to provide work experiences and research and educational opportunities to improve retention in STEM and prepare students for employment in STEM jobs;
- Educator Professional Development: Prepare STEM educators and leaders to deliver quality STEM instruction utilizing unique NASA assets; and
- Institutional Engagement: Improve the capacity of U.S. institutions to deliver effective STEM education.

An overarching operating principle consistent throughout the portfolio remains the continued focus on making opportunities available to a diverse audience of educators and learners, including women, minorities, and persons with disabilities.

The Education program would use \$10.0 million from the Opportunity, Growth, and Security Initiative to support a diverse set of activities that complement the Agency's FY 2015 coordinated Education portfolio. The Opportunity, Growth and Security Initiative would enhance the reach and impact of NASA education activities. Specifically, it would provide an additional \$10 million for competitive funding within the OE's STEM Education and Accountability Projects to support the most effective NASA STEM activities. It is possible that some prior-year STEM projects that are not explicitly funded in the FY 2015 Budget could compete for this funding. The focus of the initiative will be on competitively selected activities 1) with a required NASA mission component and/or 2) that advance learning and engagement in STEM via partnerships or forms of direct financial assistance for youth, including undergraduates, and for youth-serving informal education institutions and other eligible institutions.

While the base Budget request for Education is \$88.9 million, enactment of the Opportunity, Growth, and Security Initiative would bring that level to \$98.9 million.

Further details on Education program activities are provided in the Opportunity, Growth, and Security Initiative section of this document.

## **Programs**

### **AEROSPACE RESEARCH & CAREER DEVELOPMENT (ARCD)**

The ARCD program strengthens the research capabilities of the Nation's colleges and universities and provides opportunities that attract and prepare an increasing number of students for NASA-related careers. These institutions conduct research that contributes to NASA mission directorates' research needs and furthers the Nation's scientific and technology innovation agendas. The student programs serve as a major link in the pipeline for addressing NASA's human capital strategies. The programs build, sustain, and effectively deploy the skilled, knowledgeable, diverse, and high-performing workforce needed to meet the current and emerging needs of NASA and the Nation.

The projects in the Aerospace Research and Career Development program are Space Grant and EPSCoR.

# EDUCATION

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## **STEM EDUCATION AND ACCOUNTABILITY (SEA)**

The STEM Education and Accountability (SEA) program provides unique NASA assets, including its people, resources and facilities available in support of the Nation's STEM education priorities. The projects within the SEA program are MUREP and the STEM Education and Accountability Projects (SEAP).

Following on progress toward NASA's internal consolidation of STEM programs, projects and activities that began in FY 2012, the SEA program currently funds competitive grants, cooperative agreements, and professional development at NASA Centers for high school and college students, K-12 educators, and higher education faculty. The program enhances education and research, academic, and technology capabilities of Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges and Universities, other Minority Serving Institutions (MSIs), and the Nation's non-profit informal education institutions. It also provides opportunities for underrepresented and underserved learners to participate in research and education opportunities through internships, scholarships, and fellowships including opportunities for minority institutions to improve the quality of their faculty preparation programs, thereby improving the quality and diversity of future STEM leaders.

NASA invests in a shared program evaluation and accountability effort across both the ARCD and SEA programs. Managed from NASA Headquarters, it ensures project alignment and helps identify and eliminate potential duplication of effort across NASA's education portfolio. NASA also actively participates in the National Science and Technology Council Committee on STEM and co-chairs the Federal Committee on STEM (FC-STEM). These two efforts ensure NASA's investments are non-duplicative of other Federal agencies, and are internally coordinated among OE, mission directorates, and Centers. CoSTEM coordinates Federal programs and activities in support of STEM education, pursuant to the requirements of Section 101 of the America COMPETES Reauthorization Act of 2010.

For more information on CoSTEM reports, go to:

<http://www.whitehouse.gov/administration/eop/ostp/nstc/committees/costem>.

## AEROSPACE RESEARCH AND CAREER DEVELOPMENT PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
National Space Grant College and Fellowship Project	37.2	40.0	24.0	24.0	24.0	24.0	24.0
Experimental Project To Stimulate Competitive Research (EPSCoR)	16.7	18.0	9.0	9.0	9.0	9.0	9.0
<b>Total Budget</b>	<b>54.0</b>	<b>58.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>	<b>33.0</b>
Change from FY 2014			-25.0				
Percentage change from FY 2014			-43.1%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Students in the NASA EPSCoR project at Utah State University tested the Ionic liquid (IL) thruster. Project participants investigated the IL propellants as environmentally sustainable alternatives to hydrazine, a commonly used but environmentally unsustainable space propellant. Existing catalytic ignition methods require significant energy input to initiate combustion and are disadvantageous for small spacecraft with limited power budgets. The thermoelectric USU ignition system offers greatly reduced power consumption.

Aerospace Research and Career Development (ARCD) supports national STEM efforts through the National Space Grant College and Fellowship Program (Space Grant) and the Experimental Program to Stimulate Competitive Research (EPSCoR).

The NASA Authorization Act of 1988 (P.L. 100-147) established Space Grant with a goal of enhancing the Nation's science enterprise by funding education, research, and public service projects through a national network of university-based Space Grant consortia. The NASA Authorization Act, FY 1992 (P.L. 102-588) established EPSCoR to strengthen the research capability of jurisdictions that have not in the past participated equitably in competitive aerospace research activities. The goal of the NASA EPSCoR is to provide seed funding that will enable jurisdictions to develop an academic research enterprise directed toward long-term, self-sustaining, nationally competitive capabilities in aerospace and aerospace-related research. This capability will, in turn, contribute to the jurisdiction's economic viability and

expand the Nation's base for aerospace research and development.

## **AEROSPACE RESEARCH AND CAREER DEVELOPMENT PROGRAM**

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These national projects enable NASA to advance more strategically STEM literacy by enhancing science and engineering education and research efforts in higher education, K-12, and informal education. In addition to education, ARCD promotes research and technology development opportunities for faculty and research teams that advance the Agency's scientific and technical priorities.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

See Explanation of Major Changes section of Education Account Overview. Funding will focus on the most effective and highest priority activities.

# NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations
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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>37.2</b>	<b>40.0</b>	<b>24.0</b>	<b>24.0</b>	<b>24.0</b>	<b>24.0</b>	<b>24.0</b>
Change from FY 2014			<b>-16.0</b>				
Percentage change from FY 2014			<b>-40.0%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Alaska Space Grant student Carlton Hautala scans underwater recordings from the central Aleutian Islands. As part of an introductory bioacoustics class at the University of Alaska, Fairbanks, Hautala learned to use search algorithms to detect and classify acoustic signals of whales.**

The Space Grant is a competitive grant opportunity project, enabling the active involvement of the entire country in NASA activities through its national network of 52 consortia in 50 states, the District of Columbia, and the Commonwealth of Puerto Rico. Space Grant supports and enhances science and engineering education and research efforts for educators and learners by leveraging the resource capabilities and technologies of over 1,000 affiliates from universities, colleges, industry, museums, science centers, and state and local agencies. Training grants with each consortium align their work with the Nation's STEM education priorities and the annual performance goals of the Agency.

Space Grant enables NASA to provide opportunities for students to gain research and hands-on engineering experiences on a variety of

authentic flight platforms, including high-altitude balloons, sounding rockets, aircraft, and space satellites. Space Grant leverages Agency investments in STEM education through collaborations with other national NASA education projects, including those conducted by NASA Mission Directorates and Centers. Space Grant also supports student participants in internship experiences at NASA Centers.

## **NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT**

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Formulation	Development	Operations
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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

See Explanation of Major Changes section of Education Account Overview. Funding will focus on the most effective and highest priority activities.

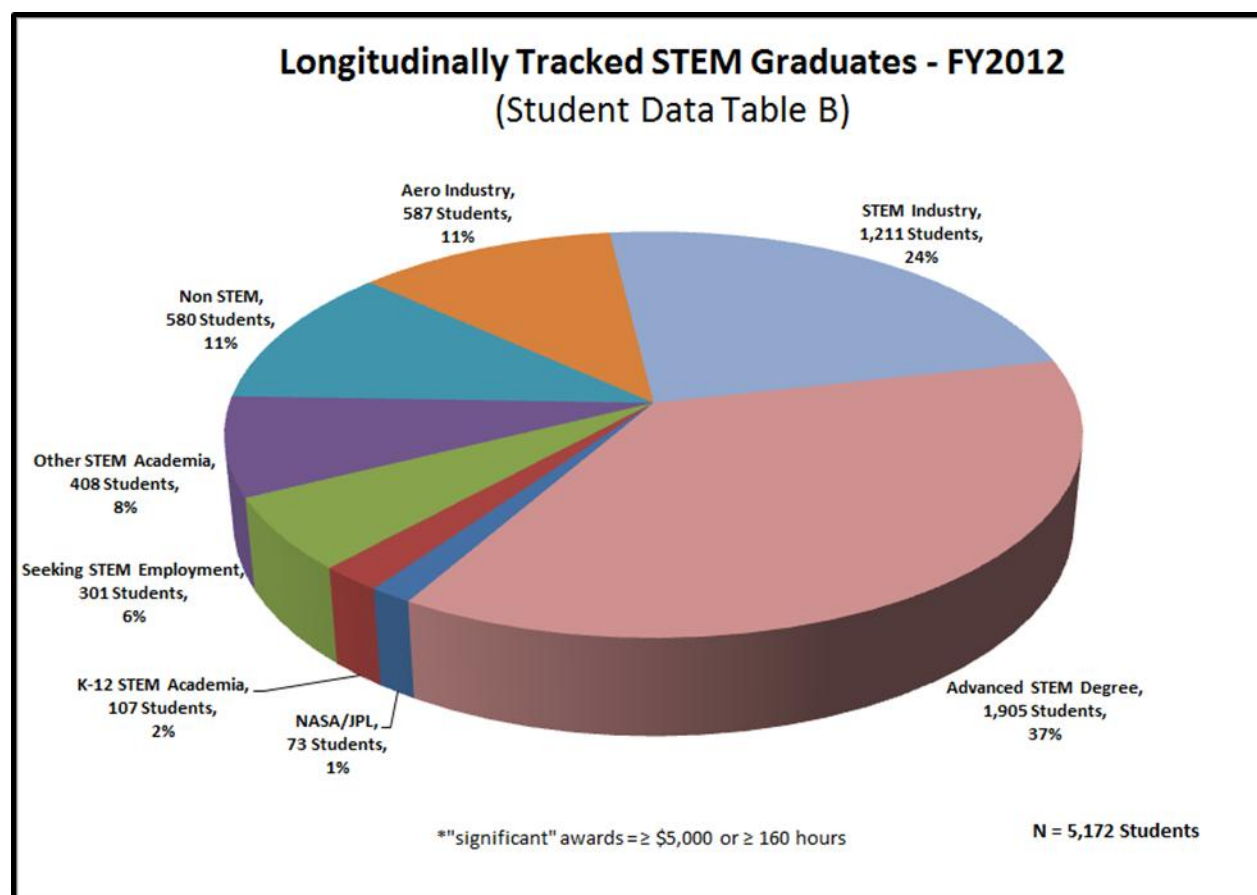
### **ACHIEVEMENTS IN FY 2013**

Space Grant provided direct support for 11,722 undergraduate and graduate students in scholarships, fellowships, internships and authentic hands-on research and engineering challenges. Diversity is a key component within the Space Grant project, achieving a 26 percent participation of underrepresented students, and 40 percent participation of female students in Space Grant activities. Educators are an important target audience of Space Grant. This year over 32,883 educators participated in NASA education activities. Space Grant also targets elementary and secondary students through NASA informal education activities, web-based activities, and other instructional and enrichment activities, reaching over 321,000 precollege students. The Agency conducts longitudinal tracking of Higher Education students receiving significant investments.

The figure below shows the status of 5,172 students who were longitudinally tracked in 2012 after taking their next step from Space Grant. As noted below, of the 5,172 STEM graduates, 1,905 or 37 percent of the graduates who participated in NASA Higher education programs are currently pursuing advanced STEM degrees.”

## NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations
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*Note: FY 2012 data is the most current data. FY 2013 Data is not available until June 2014.*

Space Grant consortia received another year of base funding to continue efforts outlined in their five-year strategic plan. All activities conducted by the 52 consortia are in alignment with Agency goals, the OE lines of business, as well as the National Science Technology Council (NSTC) CoSTEM priority areas. Space Grant base awards have components in scholarships/fellowship/internships, Higher Education, Research Infrastructure, Precollege, and Informal Education. Nine consortia received funding in the highly competitive Space Grant Innovative Pilot in STEM Education opportunity. These awarded consortia are conducting activities centered on undergraduate STEM retention rates or increasing the number of qualified K-12 STEM educators, per the President's Council of Advisors on Science and Technology (PCAST) goals to strive for one million STEM graduates and 100,000 new STEM middle and high school teachers over the course of the next ten years. Space Grant consortia also supported flight project activities led by student teams. Some of those flight activities include, but are not limited to:

## **NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT**

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Formulation	Development	Operations
<ul style="list-style-type: none"><li>• CubeSat Launch Initiative</li><li>• Rock-on Workshop</li><li>• Rock-Sat-C</li><li>• Rock-Sat-X</li><li>• DemoSat</li><li>• High Altitude Student Platform (HASP).</li></ul>		

### **WORK IN PROGRESS IN FY 2014**

Space Grant consortia are currently carrying out fourth year activities outlined in their five-year strategic plans. In addition to those activities, the Space Grant Program Office at NASA Headquarters is planning to release a one-year competitive supplementary-targeted opportunity focused on key CoSTEM priorities and enhancing community college STEM endeavors. NASA will implement activities identified in the Innovative Pilot proposals in FY 2014 as well. These student retention and STEM education activities under the pilot projects are in the first year of a two-year grant cycle. Lastly, the Space Grant Program Office at NASA Headquarters is preparing for an independent external evaluation of the national program. OE will incorporate results of the external evaluation into strategic planning for the Space Grant Program and for future solicitations.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In 2015, the program budget will support base awards for the 52 consortia, which includes the following elements that:

- Provide hands-on experiences for U.S. graduate and undergraduate students to prepare them for the future workforce and/or academic careers;
- Conduct programs and projects that align with the NASA Education priorities, CoSTEM, missions and state-specific needs to build upon the education pipeline in higher education, research infrastructure, precollege and informal education;
- Promote a strong STEM education base from elementary through secondary levels while preparing teachers in these grade levels to become more effective at improving student academic outcomes;
- Continue to build upon and maintain the existing national network of universities with interests and capabilities in aeronautics, space and related fields; and
- Leverage the opportunities emerging from the NASA Education strategy to develop high-impact, nationwide partnerships.



## **NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT**

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Formulation	Development	Operations
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### **Project Schedule**

Date	Significant Event
Quarter 1 of FY 2015	Release of Solicitations for Space Grant
Quarter 2 of FY 2015	Proposal Due and Review Process (Space Grant)
Quarter 3 of FY 2015	Selection and Awards (Space Grant)
Quarter 4 of FY 2015	Evaluation and Performance Data Due

### **Project Management & Commitments**

The Space Grant Project Manager at NASA Headquarters provides management responsibility for day-to-day Space Grant operations. Award selections by the 52 lead institutions are based on peer reviews by external panels that evaluate performance, and internal/external panels that assess performance, merit, and alignment to Agency education, research, and technology goals. Each consortium program or project must demonstrate alignment with NASA education objectives that align with NASA strategic goals. Civil servants at NASA centers actively engage with regional space grant consortia, providing direction, oversight, and integration with center and mission directorate activities.

### **Acquisition Strategy**

NASA solicits Space Grants through full and open competition for proposals accepted from Space Grant consortia in each state, Washington D.C., and the Commonwealth of Puerto Rico. Each consortium program or project must demonstrate alignment with NASA education objectives that align with NASA strategic goals. Awards are based on peer reviews by external panels that evaluate performance, and internal/external panels that assess performance, merit, and alignment to Agency education, research, and technology goals. Awards are typically for five years.

Consortia must submit annual performance data, student profile and award information (for students who meet the longitudinal tracking threshold), project information, and other performance data. The Space Grant Program Office also performs comprehensive program reviews every five years).

### **MAJOR CONTRACTS/AWARDS**

None.

## **NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT**

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Formulation	Development	Operations
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### **INDEPENDENT REVIEWS**

The Space Grant Program evaluation, which concluded in 2009, covered the five-year period from 2003 to 2007. It focused on a merit review of the performance by each consortia in three primary areas: overall performance and results (Program Performance and Results), effectiveness in terms of key elements of grant management practices (Network Participation and Responsiveness), and feedback from the consortium members (Affiliate Opinion Survey). Individual consortium results fell into four categories: Pass, Pass with Weaknesses, Pass with Deficiencies, and Serious Deficiencies. Depending on the category, consortia with results other than "Pass" were required to address the areas cited.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Independent/ External	TBD	N/A	An independent review by an external organization to assess the accomplishments and strategy of the Space Grant program	TBD	2014

## EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>16.7</b>	<b>18.0</b>	<b>9.0</b>	<b>9.0</b>	<b>9.0</b>	<b>9.0</b>	<b>9.0</b>
Change from FY 2014			<b>-9.0</b>				
Percentage change from FY 2014			<b>-50.0%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**Researchers and students from University of Montana prepare to hot-water drill to the bottom of the Greenland ice sheet. They use measurements made in the boreholes to constrain numerical simulations of the ice motion. Airborne radar measurements provide critical additional constraints of ice sheet geometry and internal layering from the NASA IceBridge mission.**

The Experimental Program to Stimulate Competitive Research (EPSCoR) is a competitive grant opportunity project that establishes partnerships between government, higher education, and industry and promotes lasting improvements in the research and development (R&D) capacity of that state or region. By improving research infrastructure, a region will improve its national R&D competitiveness and economy. EPSCoR develops academic research projects to establish long-term, self-sustaining, and nationally competitive activities in jurisdictions with modest research infrastructure so that they become more competitive in attracting non-EPSCoR funding.

EPSCoR funds states and regions that have not historically participated equitably in Federal competitive aerospace and aerospace-related research activities. EPSCoR supports

competitively funded awards in eligible states (as identified by the National Science Foundation) and provides research and technology development opportunities for faculty and research teams. NASA actively seeks to integrate the research conducted by EPSCoR jurisdictions with the scientific and technical priorities pursued by the Agency.

## **EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)**

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Formulation	Development	Operations
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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

See Explanation of Major Changes section of Education Account Overview. Funding is focused on the most effective and highest priority activities.

### **ACHIEVEMENTS IN FY 2013**

NASA funded Year 2 (of 3) of the multi-year Research Infrastructure Development (RID) awards, representing all 29 eligible jurisdictions, with a net value of \$3.6 million. These RID awards will continue through FY 2015 with a total funding value of \$10.9 million

NASA also received 30 proposals in response to its annual competitive call for research. NASA funded 14 proposals from 14 jurisdictions with a net value of \$10.4 million over the 3-year term of the grants. The selected proposals represent research or technology development in NASA's mission directorates. These awards expire at the end of FY 2016 with annual reports that identify scientific and technical achievements.

In addition, three states (Utah, Iowa, and Tennessee) graduated from the NASA EPSCoR program because they demonstrated the ability to secure non- EPSCOR funding for sustainability. In 2013, EPSCoR added Guam as a new eligible jurisdiction.

### **WORK IN PROGRESS IN FY 2014**

EPSCoR will make new research awards in FY 2014 based on availability of funding. Each funded proposal will establish research activities that will make significant contributions to NASA's strategic research and technology development priorities and contribute to the overall research infrastructure, science and technology capabilities, higher education, and economic development within the jurisdiction.

EPSCoR, in cooperation with the International Space Station (ISS) Program Office, is providing an opportunity titled "EPSCoR International Space Station (ISS) Flight Opportunity." EPSCoR will collaborate with the Space Technology Mission Directorate (STMD) to initiate a series of workshops aimed at increasing the states knowledge of NASA's unique and innovate capabilities, resources and facilities.

In support of the Federal EPSCoR Interagency Coordinating Committee (EICC), NASA EPSCoR is working to identify and provide subject matter experts to evaluate other agency EPSCoR proposals. To date, NASA EPSCoR has identified and provided three scientists to support the Department of Energy (DOE) review panels.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015, NASA EPSCoR will issue a competitive call for extramural research proposals, RID proposals, ISS Flight Opportunity proposals, and support STMD/EPSCoR workshops. NASA EPSCoR

## **EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)**

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Formulation	Development	Operations
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will continue to be a very active member of the EPSCoR Interagency Coordinating Committee (EICC) and attempt to increase collaboration. The new research solicitation will focus on priority research and the technology development needs of NASA's mission directorates. The RID solicitation will focus on building the jurisdictions' research infrastructure. The ISS Flight Opportunity solicitation will focus on increasing the awarded states' awareness of the NASA spaceflight processes. The STMD/EPSCoR workshops will communicate new research and enhance collaboration between NASA and jurisdictions. EPSCoR will work with the EICC members to participate in NASA spaceflight research efforts to improve the leveraging of Federal EPSCoR investments per H.R. 5116 America Competes Reauthorization Act of 2010.

### **Project Schedule**

Date	Significant Event
Quarter 1 of FY 2015	Release of Solicitations for Research, RID and ISS Opportunity
Quarter 2 of FY 2015	Proposal due and Review Process (Research, RID and ISS Opportunity)
Quarters 3 & 4 of FY 2015	Selection and Awards (Research, RID and ISS Opportunity)

### **Project Management & Commitments**

The program manager for NASA EPSCoR is located at NASA Headquarters, and is responsible for overall administrative duties of this national project. The project manager is located at Kennedy Space Center (KSC) and provides management responsibility for day-to-day operations. Representatives from each NASA mission directorate work closely with EPSCoR project management to ensure that current and future research requirements are in EPSCoR solicitations. The mission directorate representatives serve as the proposal selection committee, further ensuring that the selected work contributes to NASA priorities. Technical monitors at the NASA Centers and Headquarters monitor and assess the progress of each award. They provide scientific guidance and technical advice throughout the year as required regarding the overall progress of the proposed effort, and review all progress reports. Additional involvement may occur, depending upon the nature of the collaboration already established or desired. This includes integrating the EPSCoR research into ongoing activities or research efforts, and increasing the principal investigator and his or her team's awareness of other related or relevant research in NASA.

NASA is a member of the Federal EPSCoR Interagency Coordinating Committee (EICC), chaired by the National Science Foundation (NSF). The committee works to improve the leveraging of Federal EPSCoR investments. NASA EPSCoR will continue to develop strategies to adhere to the guidance within the America COMPETES Act.

## EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

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Formulation	Development	Operations
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### Acquisition Strategy

NASA solicits and awards EPSCoR grants through a competition among institutions from designated EPSCoR states. Each jurisdiction's proposal must demonstrate alignment with the Administration and NASA Strategic Plan for education. All research selections undergo rigorous peer reviews by external panels that evaluate technical merit and internal and external panels that assess content, merit, feasibility, and alignment to Agency education, research, and technology goals.

### MAJOR CONTRACTS/AWARDS

None.

### INDEPENDENT REVIEWS

The America COMPETES Reauthorization Act of 2010 required that: "The [NSF] Director shall contract with the National Academy of Sciences to conduct a study on all Federal agencies that administer an Experimental Program to Stimulate Competitive Research or a program similar to the Experimental Program to Stimulate Competitive Research." Completion of this report occurred in FY 2013 with a final report released on November 14, 2013.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Independent	National Academies	Nov-2013	Cross-agency evaluation of EPSCoR and other Federal EPSCoR-like programs and accomplishments per H.R. 5116 America Competes Reauthorization of 2010	NASA shall consider and incorporate the findings of the November, 2013 report of the National Academy of Sciences on the EPSCoR program into its fiscal year 2015 budget request.	N/A

## STEM EDUCATION AND ACCOUNTABILITY PROGRAM

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Minority University Research Education Project	27.9	30.0	<b>30.0</b>	30.0	30.0	30.0	30.0
STEM Education and Accountability Projects	34.4	28.6	<b>25.9</b>	26.8	27.7	28.6	29.6
<b>Total Budget</b>	<b>62.3</b>	<b>58.6</b>	<b>55.9</b>	<b>56.8</b>	<b>57.7</b>	<b>58.6</b>	<b>59.6</b>
Change from FY 2014			<b>-2.7</b>				
Percentage change from FY 2014			<b>-4.6%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Students participated in a stargazing event at Hoffman-Boston Elementary School in Arlington, Va. NASA Administrator Charles Bolden (not pictured) spoke with students and participated in hands-on activities, including examining moon rocks and using a variety of telescopes.

The SEA program makes unique NASA assets, including people, resources, and facilities available in support of the Nation's STEM education priorities, including programs designed by the Department of Education, National Science Foundation, and the Smithsonian Institution. Through the competitive award of federal domestic assistance funds and collaboration with other federal agencies, the program provides interns, fellows, and educators access to NASA assets and content. It connects NASA's partners, including higher education institutions, minority-serving institutions, community colleges, NASA visitor centers, museums, and planetariums to the broad scientific discoveries, aeronautics research, and exploration missions of the Agency.

NASA provides multi-year grants and cooperative agreements to the Nation's Historically Black Colleges and Universities, Hispanic Serving Institutions, Tribal Colleges, and other Minority Serving Institutions through the Minority University Research and Education Project (MUREP). MUREP awardees provide internships, scholarships, fellowships, mentoring, and tutoring for underserved and underrepresented learners in K-12, informal, and higher education settings, (including community colleges), particularly those serving a high proportion

of minority and underserved students, persons with disabilities, and women.

## **STEM EDUCATION AND ACCOUNTABILITY PROGRAM**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

See Explanation of Major Changes section of Education Account Overview. Funding is focused on the most effective and highest priority activities.



## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>27.9</b>	<b>30.0</b>	<b>30.0</b>	<b>30.0</b>	<b>30.0</b>	<b>30.0</b>	<b>30.0</b>
Change from FY 2014			<b>0.0</b>				
Percentage change from FY 2014			<b>0.0%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L.113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**The NASA University Research Centers (URCs) project achieves a broad-based, competitive aerospace research capability among the nation's minority institutions. URCs are multidisciplinary research units established at minority institutions to focus on a specific area of NASA interest.**

NASA provides financial assistance (grants and cooperative agreements) to the Nation's Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs), Asian American and Native American Pacific Islander-Serving Institutions (AANAPISIs), Tribal Colleges and Universities (TCUs) and eligible community colleges as required by the four Minority Serving Institutions (MSIs) Executive Orders through MUREP. These types of institutions target recruitment and retention of underrepresented and underserved students, including women and girls, and persons with disabilities into the STEM fields. Participation in NASA projects and research has the potential to stimulate increasing numbers of learners to continue and complete their studies at all education levels and encourages students to earn advanced degrees in STEM fields critical to NASA and the Nation.

NASA's MUREP investments help to ensure that NASA can meet future workforce needs in STEM fields. MUREP enhances the research, academic, and technology capabilities of HBCUs, HSIs, TCUs, AANAPISIs, and other Minority Serving Institutions (MSIs). Multi-year grants awarded to all types of MSIs assist faculty and students in research and authentic STEM engagement pertinent to NASA missions. These competitive awards provide general STEM knowledge, skills, and abilities to underrepresented and underserved learners through research, internships, scholarships, and fellowships at NASA Centers; and to provide opportunities for minority institutions to improve the quality of their faculty preparation programs and thereby improve the quality and diversity of future STEM leaders.

## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

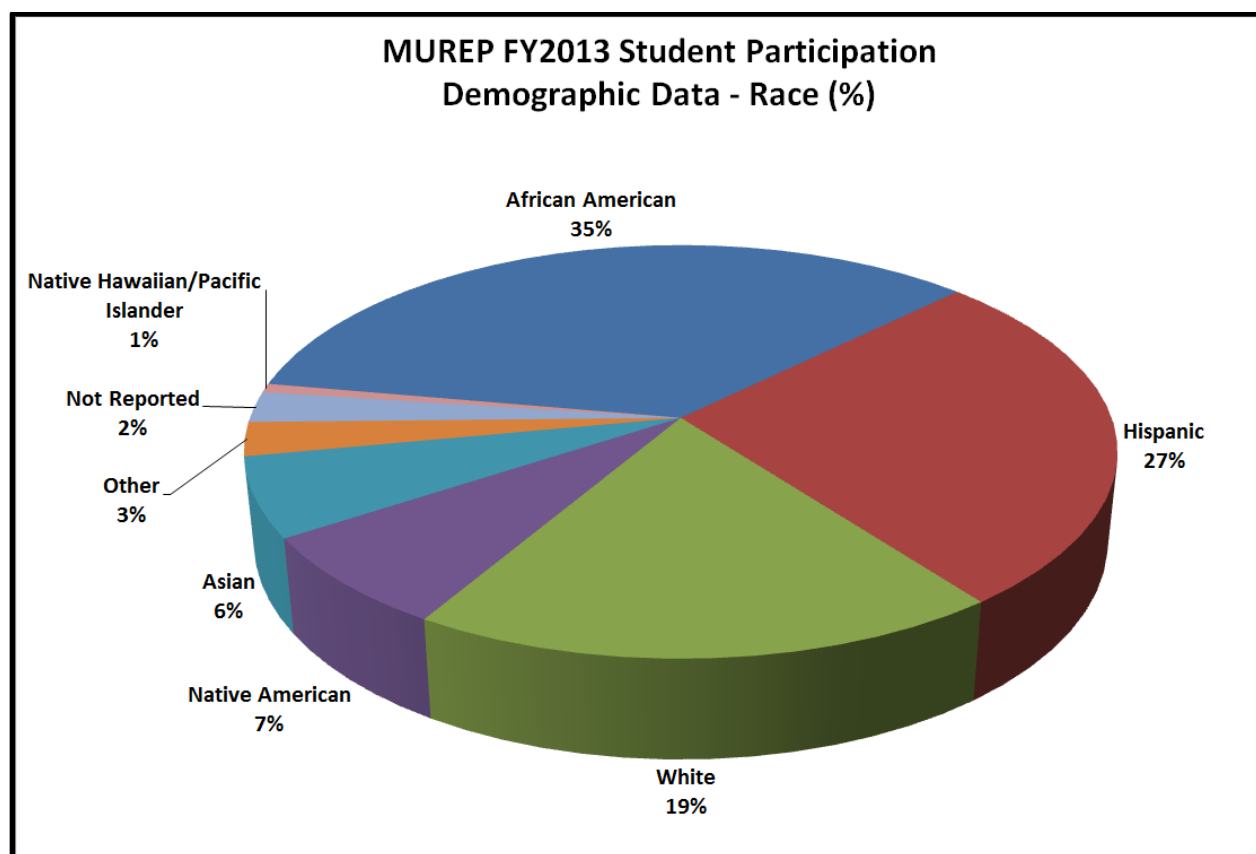
Formulation	Development	Operations
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### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

Financial support for minority students affects retention and completion rates of STEM degrees. The National Academy of Sciences, National Academy of Engineering, and Institute of Medicine (2011) highlighted that “compelling factors affecting the supply of minority STEM graduates has involved financial incentives.” Research experiences also contribute to increasing retention rates among all students. In FY 2013, MUREP directly supported over 800 postsecondary students with a significant investment of 160 or more contact hours or \$3,000 or more student stipend of which 37 percent were females, three percent were persons with disability, and over 90 percent were students from underrepresented and underserved groups.



MUREP funded graduate fellowships and undergraduate scholarships to increase the number of minority, disadvantaged, or underrepresented groups in the future STEM workforce. Graduate fellowships focus on increasing the number of Master's and Doctoral degrees awarded to underrepresented and underserved persons (women, ethnic minorities, and persons with disabilities) in the STEM disciplines. Likewise, the

## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

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Formulation	Development	Operations
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Undergraduate Scholarship focuses on underserved and underrepresented students in the STEM disciplines, thereby addressing the critical shortage of qualified STEM professionals across the nation. The goal of these competitive fellowships and scholarships is to address the Agency's mission-specific workforce needs and target areas of national need in minority STEM representation. In FY 2013, MUREP supported 63 graduate fellows where 62 percent were female, three percent were persons with disabilities, and three percent had former military service. In FY 2013, MUREP supported 81 undergraduate scholars. Forty-nine percent of those scholars were females.

MUREP's Innovations in Climate Education (NICE) is a competitive activity to promote climate and Earth System Science literacy. Approximately 7,700 higher education students participated in 70 new or revised NICE courses offered at four-year institutions and community colleges. In addition, 3,800 elementary and secondary educators and 11,275 elementary and secondary students participated in NASA climate-related educational activities. Over 3,100 administrators, parents, civic groups, and other professionals participated in NICE activities as well. The NICE activity reach extended to 32 different states, as well as the District of Columbia.

University Research Centers (URCs) provide a broad-based competitive NASA-related research capability among Minority Serving Institutions (MSIs) that foster new aerospace science and technology concepts. In 2013, the awardees authored 655 NASA-related research papers, publications, and presentations under the URCs activity. Research projects included Control Systems, Uninhabited Air Vehicles, Advanced Computation and Communications, Biofuel Combustion, Jet Propulsion, and many other fields. There have also been three patents granted and 45 students successfully earned advanced degrees in NASA-related fields.

Achieving Competence in Computing, Engineering, and Space Science (ACCESS) provides summer internships to highly qualified students with disabilities. Since its inception, 297 students have participated in ACCESS internships with 17 students hired at NASA. In FY 2013, ACCESS hosted 34 students with disabilities. Twenty-three percent of the students were females, 29 students were undergraduate students, and five were graduate students.

NASA recognizes that achievements in the minority community are the result of consistent investments. Initial investments may occur several years in advance of having a significant impact. The University Research (UR) 1- Investigation of Countermeasures to Modulate and Augment the Immune System on the ISS research project is comprised of the first selected team of HBCUs to send research to the ISS. Jarvis Christian College, Prairie View A&M University, Savannah State College, Texas Southern University, and Tougaloo College are all recipients of MUREP competitive multiyear grants. The research experience gained through MUREP grants allowed the institutions to participate in the UR-1 activity sponsored by the ISS University Research Activity, which provided undergraduates, graduate students, and faculty researchers from Tier 2 and Tier 3 universities experience in planning and implementing ground-based and ISS-based experiments and professional development through established collaborations, partnerships, and experiences with NASA researchers. In FY 2013, UR-1 supported three graduate and seven undergraduate students. Fifty percent of the students were females.

## **MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT**

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Formulation	Development	Operations
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### **WORK IN PROGRESS IN FY 2014**

MUREP funds pre-K-12 educator professional development, internships, fellowships, and scholarships for underrepresented and underserved students and supports the development of STEM curricula at minority institutions and community colleges to help prepare underrepresented and underserved students in STEM disciplines and careers. A small amount of funds will support the multi-year cross-center internship cooperative agreement to the Universities Space Research Association (USRA) to ensure participation by students from eligible MSI. The majority of MUREP funding will be used to maintain active agreements with 17 HBCUs, 16 HSIs, four TCUs, four AANAPISIs, two Other Minority Serving Universities, and eight non-profit organizations that contribute to MUREP's goals. Some institutions and organizations received multiple awards.

For NASA's full report of accomplishments in MUREP, go to:  
<http://www.nasa.gov/offices/education/performance/index.html>.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

MUREP will continue to provide competitive funding opportunities to MSIs through an omnibus solicitation called Educational Opportunities in NASA STEM (EONS).

### **Project Schedule**

TBD

## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation	Development	Operations
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### Project Management & Commitments

The MUREP project manager is located at NASA Headquarters and provides management and oversight for overall activity operations. NASA Centers manage significant investments in project activity elements. In FY 2013, the current MUREP elements are as follows:

Element	Description	Provider Details	Change from Formulation Agreement
University Research Centers (URCs)	URCs are multi-disciplinary research centers at Minority Serving Institutions (MSI) that are supported to expand the Nation's base for aerospace research and development, and increase the production of underrepresented/underserved students who obtain degrees undergraduate and graduate degrees in NASA-related fields.	Provider: All NASA Centers Lead Center: AFRC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
Curriculum Improvements Partnership Award for the Integration of Research (CIPAIR)	CIPAIR was designed to strengthen the curricula of MSIs and community colleges in order to attract more students into STEM-based academic programs, retain them, and prepare them for success when they take the next steps in their education or in their careers	Provider: All NASA Centers Lead Center: HQ Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
Motivating Undergraduates in Science and Technology (MUST)	MUST increases the number of underrepresented/underserved students in STEM disciplines. Each MUST participant receives three-years of support in the form of a scholarship, internships at a NASA Center, mentoring, and professional development.	Provider: All NASA Centers Lead Center: GRC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	

## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Tribal Colleges and Universities Project (TCUP)	TCU activity supports the Nation's Tribal Colleges through grants that provide funding for academic and research infrastructure development and support of STEM students at tribal colleges and universities.	Provider: All NASA Centers Lead Center: GSFC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
MUREP Small Projects (MSP)	MSA advances MUREP priorities by identifying gaps or areas where new projects will enhance NASA higher education portfolio and better meet Agency objectives. Achieving Competence in Computing, Engineering, and Space Service is an example of an MSA activity that now fills an identified programming gap (i.e., internships for students with disabilities).	Provider: All NASA Centers Lead Center: KSC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
Jenkins Pre-Doctoral Fellowship Project (JFPF)	JPF increases the number of underrepresented/ underserved STEM students at the graduate level. JPF provides three-years of support for each participant with a stipend, tuition off-set, a NASA internship, mentoring, and professional development.	Provider: All NASA Centers Lead Center: ARC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
NASA Science and Technology Institute for Minority Institutions (NSTI-MI)	NSTI-MSI increases the research capacity of MSIs, increases the number of undergraduate STEM students, and supports Agency research objectives.	Provider: All NASA Centers Lead Center: ARC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	

## MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
NASA Innovations in Climate Education (NICE) (Note: renamed from Innovations in Global Climate Change Education)	NICE provides grants to MSIs to: enhance climate change education; improve the teaching and learning about climate change and Earth system science; increase the number of underrepresented and underserved K-12 teachers of math and science; and increase the number of students prepared for graduate study in climate- related subjects.	Provider: All NASA Centers Lead Center: LaRC Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	

### Acquisition Strategy

MUREP solicits new and innovative education products, tools, and services from qualified MSIs and nonprofit organizations. This occurs in response to changes in STEM education trends, identified gaps or opportunities in the education portfolio of investments, a response to demonstrated customer need or demand, or when the Administration or Congress identifies new priorities. NASA awards education cooperative agreements, grants and contracts through full and open competition. Selections are based on peer reviews by external panels that evaluate educational merit and internal/external panels for content, merit, feasibility, and alignment to education goals.

### MAJOR CONTRACTS/AWARDS

None

### INDEPENDENT REVIEWS

All MUREP activities document performance through either external evaluations or internal reviews conducted by NASA staff. For example, a Technical Review Committee, made up of NASA and industry engineers and scientists, reviews each University Research Centers grantee annually during the five-year performance period. All review reports are used as a part of the renewal package for individual grantees.

## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations
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### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>34.4</b>	<b>28.6</b>	<b>25.9</b>	<b>26.8</b>	<b>27.7</b>	<b>28.6</b>	<b>29.6</b>
Change from FY 2014			-2.7				
Percentage change from FY 2014			-9.4%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**NASA Explorer Schools (NES) connects schools, educators, and learners with NASA resources and personnel in a refreshing new way, giving teachers and students access to unique NASA missions. The project gives teachers help and guidance in using NASA education resources in their classroom. In 2013, NES celebrated its 10-year anniversary of educating hundreds of schools and teachers, along with hundreds of thousands of students.**

NASA will continue to integrate and consolidate its STEM Education projects and activities into a more focused portfolio, consistent with Congressional direction to streamline and consolidate STEM education programs within NASA. Specifically, NASA will continue internal consolidation of education functions, assets, and efforts of the mission directorates into the coordinated STEM Education and Accountability Projects (SEAP). SEAP assets are critical and unique components that NASA can make available to the National Science Foundation, Smithsonian Institution, and Department of Education, on a reimbursable basis, as they facilitate federal STEM education activities through the Administration's Committee on STEM process for agency coordination.

Additionally, the expiration of some prior-year cooperative agreements enables NASA to reinvent its formal and informal education portfolio to better address the Administration's STEM goals. Working in collaboration with

other federal agencies, NASA will continue to support STEM activities across four lines of business: 1) educator professional development, 2) STEM engagement, 3) institutional engagement, and 4) internships, fellowships and scholarships.

NASA will continue to provide opportunities to a diverse audience of students, educators and learners, including women, minorities, and persons with disabilities. NASA will continue to review and consider



## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

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Formulation	Development	Operations
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appropriate ways to incorporate the most meritorious education functions, assets, and efforts of the Aeronautics Research Mission Directorate (ARMD) and Human Exploration and Operations Mission Directorate (HEOMD) into the SEAP. SEAP will continue to enhance coordination with other agencies and focus on those areas of STEM education where the Federal government can have maximum impact, including innovations in performance monitoring, evaluation and formal and informal education. Through grants, cooperative agreements and other mechanisms NASA will make its people, resources, facilities, and discoveries available to key stakeholders and strategic partners, such as educational organizations and science museums.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

See Explanation of Major Changes section of Education Account Overview. In FY 2015 NASA will conduct a competition across the mission directorates and NASA Centers to identify the most meritorious education activities that should be funded with SEAP funds. Potential applicants and recipients for this funding could include the following.

- Projects and activities (e.g., scholarship, fellowship and institutional grants programs) previously funded by ARMD, HEOMD, or NASA Centers;
- Projects and activities not previously funded and would be new in FY 2015; and
- Projects and activities that awarded multi-year grants, cooperative agreements, or contracts in a prior year seeking to continue another year of funding for previously competitively selected grantees or contract awardees.

The goal of this competition would be to ensure that SEAP funding is made available to the most effective and highest priority education activities across the agency. Additionally, NASA will continue to implement a STEM intra- and inter-agency coordination effort that will serve as the focal point for NASA to ensure that the Agency's assets support STEM activities directed by the National Science Foundation (NSF), Smithsonian Institution (SI), and Department of Education (ED) and are consistent with the Five-Year Federal Strategic Plan on STEM Education and the Administration's STEM reorganization

### ACHIEVEMENTS IN FY 2013

The number of elementary and secondary students participating in NASA instructional and enrichment activities was approximately over 2 million. The percentage of elementary and secondary students expressing interest in STEM careers following their involvement in NASA education programs was 86 percent, a positive indicator for NASA's success in STEM engagement. In addition, the Summer of Innovation (SOI) pilot project, launched in 2010 in support of the President's Educate to Innovate campaign, engaged approximately 58,289 students in grades four to eight. The majority of the students served by SOI were from underserved/underrepresented populations, including:

- 58 percent minority;
- 50 percent female; and
- 79 percent received free/reduced lunch.

## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

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Formulation	Development	Operations
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NASA's FY 2013 Competitive Program for Science Museums, Planetariums, and NASA Visitor Plus Other Opportunities (NASA Research Announcement NNH13ZHA001N) received nearly 70 proposals from informal education institutions and NASA visitor centers requesting support for teacher professional development, exhibits, planetariums shows, and STEM engagement programming. The final selection process is nearing completion, with final selections depending on finalization of the FY 2014 budget. Thirty-six institutions from prior awards had active projects during FY 2013. At the same time, the Museum Alliance grew to include more than 580 U.S. museums, science centers, planetariums, NASA visitor centers, and Challenger Learning Centers.

Through the One-Stop Shopping Initiative, more than 15,000 undergraduate, graduate and high school students applied for NASA-unique formal education opportunities including internships, fellowship, and scholarships. NASA selected nearly 1,200 students.

### WORK IN PROGRESS IN FY 2014

SEAP will fund a mix of new and old grants, contracts, and cooperative agreements highlighted in Project Management and Commitments below. In FY 2013, NASA issued a consolidated NASA Research Announcement (NRA): Competitive Program for Science Museums, Planetariums, and NASA Visitor Centers Plus Other Opportunities that will operate through FY 2014. This competitive NRA investment combined three, distinct prior year's NASA OE activities. Prior to the FY 2013 NRA, there had been an internal-only competition for NASA visitor centers, and external-only competition for museums and planetariums (including the Smithsonian museums and their affiliates), and no public calls for unsolicited proposals from other types of institutions, such as youth serving organizations. The Summer of Innovation (SoI) pilot project will complete implementation, and lessons learned will be available for implementation by federal and non-federal STEM education stakeholders.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

As noted in the Explanation of Major Changes section, SEAP will support the most effective and highest priority STEM projects and activities across the agency. SEAP will establish the structure to provide efficient coordination of education efforts throughout NASA, and with external partners. In particular, the Education Coordinating Council (ECC), established in FY 2012 to ensure that the most effective NASA assets are made available to support the Nation's STEM education priorities, will conduct a self-assessment of Council operations. Additionally, potentially in collaboration with federal partners, the ECC will review NASA activities that support data collection, rigorous evaluation, and dissemination of evidence of NASA's contributions toward the achievement of the Nation's wider STEM goals.

### Project Schedule

Consistent with the National Science and Technology Council five-year Federal STEM education Strategic Plan, the STEM Education and Accountability projects will align its portfolio of activities over the next five years. In the first year, NASA will work with the CoSTEM to finalize criteria for success,

## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations
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develop common evidence standards, evaluation and research toolkits, and identify efficiencies and collaborative opportunities.

In years two through five, the Agency will establish baselines and increase alignment with the adopted criteria. NASA will align its future evaluation strategy with the status report on the National Science and Technology Council five-year Federal STEM Education Strategic Plan. Successful STEM education practices and strategies identified through STEM education research studies and evaluations will guide NASA investments in STEM education.

Date	Significant Event
On-going throughout FY 2015	NSTC Committee on STEM Meetings

### Project Management & Commitments

The STEM Education and Accountability project and lines of business managers for educator professional development, internships, fellowships and scholarships, STEM engagement and institutional engagement are located at NASA Headquarters and provide oversight for strategic activities and operations. In 2015, NASA will make new commitments based on the competitive acquisition strategy described below. NASA Centers, including JPL, or other previously selected awardees may be eligible to compete for SEAP funding (see Explanation of Major Changes section for more detail). The table below illustrates some cooperative agreements or contracts awarded in prior years.

Element	Description	Provider Details	Change from Formulation Agreement
Cooperative Agreement Number: NNX13AJ37A	Cooperative Agreement Selection Under the Cooperative Agreement Notice issued by OE NASA Internships Solicitation number: NNJ13ZBR001C	Provider: USRA Lead Center: Headquarters Performing Center(s): All Cost Share Partner(s): Not Applicable	No change Cooperative Agreement expires May 2018 Performance start date May 2013
Contract Number: C13-012	The NASA Glenn Education Support Services contract will help advance high-quality science, technology, engineering, and mathematics (STEM) education in Cleveland, NASA Headquarters in Washington, and other NASA centers, as necessary.	Provider: Paragon Tec Inc. of Cleveland Lead Center: Glenn Performing Center(s): All Cost Share Partner(s): Not Applicable	No Change Contract expires March 2018 Performance start date April 2013

## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation		Development	Operations
Element	Description	Provider Details	Change from Formulation Agreement
Cooperative Agreement Number: NNX10AJ63A	The NASA DIGITAL LEARNING NETWORK provides NASA STEM education content, missions, and research to those who register free, interactive events listed in our catalog, or watch the DLiNfo Webcast Channel.	Provider: OSU CENTER FOR INNOVATION AND ECONOMIC DEVELOPMENT, INC. Lead Center: Headquarters Performing Center(s): All Cost Share Partner(s): Not Applicable	No Change Cooperative Agreement expires July 2015. Performance Start Date August 2010.

### Acquisition Strategy

As noted in the Explanation of Major Changes section, NASA will conduct a competition across mission directorates and NASA centers to identify the highest priority STEM projects and activities. Potential applicants and recipients include projects and activities previously funded by ARMD, HEOMD, and NASA Centers. Once projects and activities have been selected, consistent with existing NASA practices, NASA will award any education cooperative agreements, grants, and contracts through full and open competitions. External and internal experts base selections in part on peer reviews. The Education Coordinating Council (ECC) also makes recommendations to the Associate Administrator for Education on any funding allocated to activities implemented directly by NASA Centers, including JPL.

### MAJOR CONTRACTS/AWARDS

None.

### INDEPENDENT REVIEWS

Independent review is responsive to both a Government Accountability Office report (GAO-12-342SP) and reports from the National Science and Technology Council Committee on STEM. NASA embeds evaluation and accountability requirements within SEA activities as appropriate for performance monitoring.

## STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations
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External experts reviewed the Summer of Innovation Pilot as explained in the table below.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program design review	External experts	May-Jun 2012	Identify preferred program models; Identify new project requirements based on research evidence	New project requirements identified and implemented in 2013 and 2014.	Nov-Dec 2014
Evaluation design review	External experts	Aug 2012	Identify new evaluation design and develop high-level evaluation plan to assess preferred program model	New evaluation plan developed and implemented by Abt Associates in 2013 and 2014	Jan 2013 Mar-Apr 2014

## CROSS AGENCY SUPPORT

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		FY 2019
Center Management and Operations	1991.6	--	2038.8	2059.2	2079.7	2100.5	2121.6
Agency Management and Operations	719.4	--	739.8	747.2	754.7	762.3	769.8
<b>Total Budget</b>	<b>2711.0</b>	<b>2793.0</b>	<b>2778.6</b>	<b>2806.4</b>	<b>2834.4</b>	<b>2862.8</b>	<b>2891.4</b>

### Cross Agency Support ..... CAS-2

#### Center Management and Operations .....CAS-5

#### Agency Management and Operations.....CAS-9

AGENCY MANAGEMENT ..... CAS-13

SAFETY AND MISSION SUCCESS ..... CAS-16

AGENCY IT SERVICES (AITS) ..... CAS-23

STRATEGIC CAPABILITIES ASSETS PROGRAM..... CAS-27

HEADQUARTERS BUDGET BY OFFICE..... CAS-30

HEADQUARTERS TRAVEL BUDGET BY OFFICE ..... CAS-31

HEADQUARTERS WORKFORCE BY OFFICE ..... CAS-32

# CROSS AGENCY SUPPORT

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Center Management and Operations	1991.6	--	<b>2038.8</b>	2059.2	2079.7	2100.5	2121.6
Agency Management and Operations	719.4	--	<b>739.8</b>	747.2	754.7	762.3	769.8
<b>Total Budget</b>	<b>2711.0</b>	<b>2793.0</b>	<b>2778.6</b>	<b>2806.4</b>	<b>2834.4</b>	<b>2862.8</b>	<b>2891.4</b>
Change from FY 2014			<b>-14.4</b>				
Percentage change from FY 2014			<b>-0.5%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA's human capital program supports and enables NASA's mission by identifying, acquiring, and sustaining a workforce of the nations' top scientists, engineers, and other technical staff, supported by a capable group of professional and administrative personnel. NASA uses an innovation index based on selected Employee Viewpoint Survey items as an indicator of the overall health and progress of its human capital management. In 2012, NASA scored the highest across the Government on this Index, and during 2013, the Agency remained steady in most of the working conditions that drive innovation, especially by giving employees a feeling of personal empowerment with their work processes.

Cross Agency Support (CAS) activities manage the administration of the Agency, operate and maintain NASA Centers and facilities, including Headquarters, and provide oversight to reduce risk to life and mission for all NASA programs.

CAS provides both institutional and program capabilities for the Agency. Institutional capabilities ensure that Agency operations are effective, efficient, and meet statutory, regulatory, and fiduciary responsibilities. Program capabilities ensure that technical skills and assets are ready and available to meet program and project milestones; that missions and research are technically and scientifically sound; and that Agency practices are safe and reliable. Together these capabilities sustain 4,800 buildings and structures on 330,000 acres across the Agency's Centers and facilities.

Missions rely on CAS program and institutional capabilities to accomplish their objectives. Engineering, systems engineering, and safety and mission assurance capabilities support technical activities. Information technology (IT), infrastructure, and security capabilities support the productivity of NASA scientists and

engineers. Human capital management, finance, procurement, occupational health and safety, equal employment opportunity and diversity, and small business programs contribute to the strategic and operational planning and management that ensure resources are available when needed. International and

# CROSS AGENCY SUPPORT

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interagency relations, legislative and intergovernmental affairs, and strategic communications facilitate communications with a broad range of external communities. These program and institutional capabilities and related processes speak to the complexity of the support necessary for successful NASA missions and safe Agency and Center operations.

NASA's CAS account includes two themes: Center Management and Operations; and Agency Management and Operations.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA continues to invest in facilities maintenance and IT investments to reduce risk and future liabilities and to provide for more sustainable and cost efficient operations. Improving the Agency's information security posture will enhance the ability to make risk-based decisions regarding IT infrastructure, and help assure the Agency IT systems and networks securely support NASA's critical mission and business functions.

## ACHIEVEMENTS IN FY 2013

CAS activities provide the workforce and facilities required to conduct NASA's missions. NASA is working to create an innovative workplace where Agency work can be conducted anywhere and anytime by putting information, data, and tools at the fingertips of those individuals who need it. In FY 2013, NASA:

- Conducted the Virtual Executive Summit, which demonstrated that relevant Agency communications, collaboration, and learning could be effectively delivered in a distributed environment that engages employees both virtually and onsite.
- Assessed the Agency's aircraft and flight simulator capabilities against mission requirements to identify changes required to the NASA portfolio;
- Continued consolidation of arc jet test capabilities at Ames Research Center (ARC). Work included verification and activation of the test equipment already transferred from Johnson Space Center and final transfer of the remaining major test equipment to ARC; and
- Achieved at least \$10 million in cost savings/cost avoidance through strategic sourcing and contracting efficiencies. This was achieved through a number of activities including the Enterprise License Management Team, the Stennis Space Center (SSC) Multiple Award Construction Contract.

## WORK IN PROGRESS IN FY 2014

CAS continues its crosscutting support of the Agency's aeronautics and space activities, using innovative approaches to provide the required programmatic, business, and administrative capabilities. Key activities underway include:

- Full deployment of an enhanced agency-wide recruiting and hiring program targeting recent graduates with the intention of ensuring a robust, diverse pipeline of the next generation of scientists, engineers, and mission support professionals;



## CROSS AGENCY SUPPORT

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- Modernization of the IT security assessment and authorization process, including definition of risk reducing metrics, creation of dashboards for visualizing and communicating the Agency's cyber security posture, and expansion of security operations efforts to provide early warning of cyber vulnerabilities; and
- Increases to reliability-centered maintenance and conditioned-based monitoring activities at the Centers to provide early detection and correction of facility maintenance issues.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

In FY 2015, CAS programs will continue to enable program and institutional capabilities to conduct NASA's aeronautics and space activities. In addition, CAS programs will:

- Initiate a pilot Presidential Management Fellow – Science, Technology, Engineering, and Mathematics (STEM) track program to help meet the challenge of attracting and hiring early career STEM employees;
- Conduct safety reviews and independent technical assessments of NASA's missions; and
- Continue to improve its Information Technology network security with an enterprise approach to perimeter control and maintenance, including implementation of an Enterprise Firewall and Web Content Filter, deployment of a Network Access Control (NAC) system inside NASA's networks, and replacement of Center Virtual Private Networks (VPNs) with an enterprise enabled solution.

## Themes

### CENTER MANAGEMENT AND OPERATIONS

Center Management and Operations (CMO) provides the ongoing management, operations, and maintenance of NASA Centers and component facilities in nine states. Missions rely on the Centers to provide the skilled staff and specialized infrastructure required to accomplish their objectives.

### AGENCY MANAGEMENT AND OPERATIONS

Agency Management and Operations (AMO) provides management and oversight of Agency missions and performance of NASA-wide mission support activities. AMO activities at NASA Headquarters ensure that core services are ready and available across the Agency for performing mission roles and responsibilities.

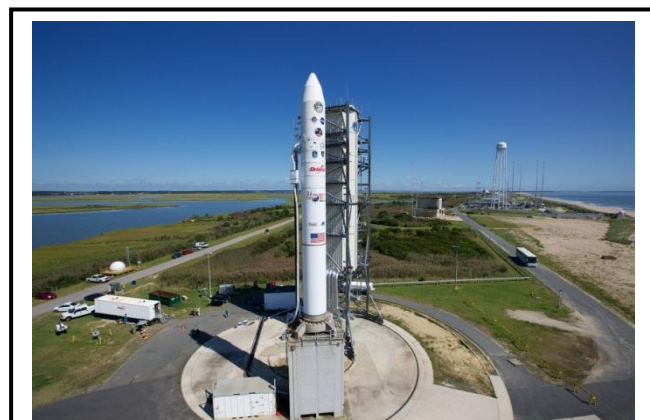
## CENTER MANAGEMENT AND OPERATIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Center Institutional Capabilities	1539.7	--	<b>1584.3</b>	1600.1	1615.9	1632.0	1648.4
Center Programmatic Capabilities	451.8	--	<b>454.5</b>	459.1	463.8	468.5	473.2
<b>Total Budget</b>	<b>1991.6</b>	<b>--</b>	<b>2038.8</b>	<b>2059.2</b>	<b>2079.7</b>	<b>2100.5</b>	<b>2121.6</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA Centers across the country provide the institutional and programmatic capabilities required to support the mission. Here, workers at Wallops Flight Facility on Wallops Island, VA make final preparations for launch of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission.

NASA's CMO budget funds the ongoing management, operations, and maintenance of nine Centers and three major component facilities in nine states. CMO includes two major activities: Center Institutional Capabilities and Center Programmatic Capabilities.

Institutional capabilities provide the facilities, staff, and administrative support to ensure that Center operations are effective and efficient and that activities meet statutory, regulatory, and fiduciary responsibilities. Program capabilities support scientific and engineering activities at the Centers. These program capabilities ensure that technical skills and assets are ready and available to meet program and project milestones; that missions and research are technically and scientifically sound; and that center practices are safe and reliable. Missions rely on these program and institutional

capabilities to provide the skilled staff and specialized infrastructure required to accomplish their objectives.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None

### ACHIEVEMENTS IN FY 2013

Centers provided the services, tools, and equipment to support mission activities, protect and maintain the security and integrity of information and assets, and ensure that personnel work under safe and healthy conditions.

## CENTER MANAGEMENT AND OPERATIONS

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To reduce infrastructure burden, Centers consolidated facilities and disposed of infrastructure no longer required by the mission. Key disposal activities included the auction and sale of two Glenn Research Center (GRC) buildings and transfer of two Marshall Space Flight Center (MSFC) buildings located in Utah from government to private ownership.

To reduce energy consumption, the Agency awarded five Energy Savings Performance/Utility Energy Service Contracts (ESPC/ UESC) projects totaling nearly \$44.6 million, exceeding NASA's original pledge of \$19.6 million toward the President's initiative to increase ESPC/UESC contracting.

To improve efficiency and reduce travel costs, Centers improved their videoconferencing capabilities, allowing employees to more easily collaborate with co-workers across the Agency.

### WORK IN PROGRESS IN FY 2014

NASA continues to seek and implement operational efficiencies that enable the Agency to conduct its day-to-day technical and business operations. For example, GRC is reducing the number of printers and copiers by consolidating the delivery of printer services. Similar activities agency-wide, along with a reduction in some center services partially offset continuing growth in operations costs.

To provide for early detection and correction of facility maintenance issues, Centers are increasing reliability-centered maintenance and condition-based monitoring activities. These activities reduce facility repair costs by correcting problems before costly failures occur.

### KEY ACHIEVEMENTS PLANNED FOR FY 2015

Centers will provide the services, tools, and equipment to complete essential tasks, protect and maintain the security and integrity of information and assets, and ensure that personnel work under safe and healthy conditions. In FY 2015, Center Management and Operations will support:

- Facility maintenance and operations, including utility and custodial support of approximately 4,800 buildings and structures (80 percent of NASA's assets by value are over 40 years old with a current total replacement value of \$33 billion);
- IT activities for video, voice, network, IT security, and desktop support at centers;
- Institutional operational safety support to protect personnel and assets, aviation safety, emergency preparedness, nuclear safety, construction safety, and other safety services;
- Physical security, fire protection and response, emergency management, export control, and other basic and specialized protective services;
- Compliance with environmental regulations, executive orders, and related requirements to protect human health and the environment;
- Human resource management including recruitment, hiring, workforce planning, training, and performance management supporting approximately 16,900 civil servants at the Centers;
- Occupational and environmental health and medical support such as industrial hygiene, health physics, hearing conservation, and licensed and credentialed medical personnel and facilities to meet specialized mission requirements;
- Personal property management, transportation management, mail management, and other logistical support;

## **CENTER MANAGEMENT AND OPERATIONS**

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- Duplicating and printing support, video production, audio/visual services, and publications and graphics (includes specialized support for the production and archiving of Scientific and Technical Information);
- Senior leadership and management of the Center, executive staff and administrative support, student programs, and developmental assignments;
- Routine public affairs activities, dissemination of information about NASA programs and projects to the general public, and responses to public inquiries;
- Administration and management of Center financial operations;
- Acquisition and contract management capabilities and practices supporting more than 51,000 procurement actions each year;
- Engineering assessment and safety oversight pertaining to the technical readiness and execution of NASA programs and projects; and
- Analysis, design, research, test services, and fabrication capabilities to enable efficient implementation of the programs and projects.

### **Program Elements**

#### **CENTER INSTITUTIONAL CAPABILITIES**

Center Institutional Capabilities encompasses a diverse set of activities essential for safe and effective operations. These activities provide the ongoing operations of NASA Centers and major component facilities and ensure a safe, healthy, and environmentally responsible workplace. Included are essential operations such as Center security, environmental management and safety services, and facility maintenance and operations. To support the Agency's Center-based workforce, Center Institutional Capabilities provide utilities, IT, legal, occupational health, equal employment opportunity, and human resources services. This capability manages and sustains Center staff, facilities, and operations. This coordinated Center approach to institutional management is an essential element in preserving specialized national capabilities that NASA, industry, academia, and other government agencies rely on.

#### **CENTER PROGRAMMATIC CAPABILITIES**

NASA's Center Programmatic Capabilities supports the Agency's scientific and engineering activities by providing engineering assessment and safety oversight pertaining to the technical readiness and execution of NASA programs and projects. It also sustains NASA's analysis, design, research, test services, and fabrication capabilities to enable efficient implementation of the programs and projects conducted at the Centers.

A key component of NASA's overall system of checks and balances is provided within Center Programmatic Capabilities. The engineering, safety and mission assurance, and health and medical organizations at the Centers: (1) provide, support, and oversee the technical work, and (2) provide formally delegated Engineering (Figure 1) and Safety and Mission Assurance Technical Authorities (Figure 2) at NASA Centers. These technical authorities provide independent oversight and review of programs and projects in support of safety and mission success. Cognizant technical authorities formally review and concur on technical and operational matters involving safety and mission success risk. Concurrence is based on the technical merits of each case and includes agreement that the risks are

## CENTER MANAGEMENT AND OPERATIONS

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acceptable. This assures that NASA's activities are implemented safely in accordance with accepted standards of professional practice and applicable NASA requirements.

### Engineering Technical Authorities

\$ (in Millions)	FY 2015
Ames Research Center (ARC)	8.0
Armstrong Flight Research Center (AFRC)	7.1
Glenn Research Center (GRC)	12.5
Goddard Space Flight Center (GSFC)	13.0
Johnson Space Center (JSC)	22.2
Kennedy Space Center (KSC)	14.9
Langley Research Center (LaRC)	17.4
Marshall Space Flight Center (MSFC)	36.3
Stennis Space Center (SSC)	3.4
<b>Grand Total</b>	<b>134.8</b>

Figure 1: Engineering Technical Authorities provide for independently funded engineering assessment of programs.

### Safety and Mission Assurance Technical Authorities

\$ (in Millions)	FY 2015
ARC	3.6
AFRC	4.0
GRC	2.5
GSFC	14.1
JSC	6.7
KSC	8.5
LaRC	3.2
MSFC	8.3
SSC	1.8
<b>Grand Total</b>	<b>52.7</b>

Figure 2: Safety and Mission Assurance Technical Authorities provide for independently funded safety assessment of programs.

## AGENCY MANAGEMENT AND OPERATIONS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Agency Management	372.3	--	<b>365.6</b>	369.3	373.0	376.7	380.3
Safety and Mission Success	172.5	--	<b>163.7</b>	165.4	167.0	168.8	170.5
Agency IT Services (AITS)	148.0	--	<b>183.6</b>	185.3	187.2	189.0	190.9
Strategic Capabilities Assets Program	26.6	--	<b>26.9</b>	27.2	27.5	27.8	28.1
<b>Total Budget</b>	<b>719.4</b>	<b>--</b>	<b>739.8</b>	<b>747.2</b>	<b>754.7</b>	<b>762.3</b>	<b>769.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**At Cape Canaveral Air Force Station's Space Launch Complex-41, NASA Administrator Charles Bolden, along with other agency and contractor officials spoke to members of the news media about preparations for the Mars Atmosphere and Volatile Evolution (MAVEN) mission.**

AMO provides management and oversight of Agency missions and performance of NASA-wide mission support activities. AMO activities at NASA Headquarters ensure that core services are ready and available Agency-wide for performing mission roles and responsibilities; Agency operations are effective and efficient, and activities are conducted in accordance with all statutory, regulatory, and fiduciary requirements.

NASA Headquarters develops policy and guidance for the Centers and provides strategic planning and leadership. Headquarters establishes Agency-wide requirements and capabilities that improve collaboration, efficiency, and effectiveness. Agency management leverages resources and capabilities to meet mission needs, eliminate excess capacity, and scale assets accordingly.

AMO provides for policy-setting, executive management, and direction for all corporate functions. AMO supports the operational costs of the Headquarters installation. The AMO theme is divided into four programs: Agency Management, Safety and Mission Success (SMS), Agency Information Technology Services (AITS), and Strategic Capabilities Asset Program (SCAP).

## **AGENCY MANAGEMENT AND OPERATIONS**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

NASA further reduced administrative costs and implemented operational efficiencies of Headquarters services. This enables the Agency to maximize its investments in the mission and reallocate resources to increase Agency IT security and business management applications activities.

### **ACHIEVEMENTS IN FY 2013**

NASA was recognized as the Best Place to Work in the Federal Government among large agencies including being ranked first in leadership, support for diversity, and teamwork.

For the third consecutive year, the Agency received a clean (unmodified) audit opinion of its accounting and financial systems.

To standardize and economize the delivery of a consolidated set of end-to-end network services, NASA implemented Agency systems for: 1) ordering and implementing network and telecommunications service requests; 2) initiating and tracking incidents and problems; 3) managing and controlling configuration information including an auto-discovery for network assets; and 4) managing and monitoring of network services via enterprise tools.

NASA added a new capability to the NASA Engineering Network that increased the ability of engineering tool users to track local and Agency-wide usage of high value engineering software tools.

SCAP's specialized workforce at the Ames Arc Jet checked and activated the major test equipment received from the JSC Arc Jet Facility and placed into operations as part of the arc jet capability consolidation effort. NASA anticipates annual operational cost savings of over \$5 million per year to the missions through this consolidation effort.

### **WORK IN PROGRESS IN FY 2014**

As part of a renewed lease and associated building renovation, NASA's Headquarters office building will achieve Leadership in Energy and Environmental Design (LEED) Silver certification by the end of FY 2014.

The Safety and Mission Assurance program will include safety reviews and independent technical assessments of NASA missions. The Office of the Chief Engineer (OCE) will expand program planning and control activities, extending and increasing the use, and enhance the quality of Earned Value Management on NASA's projects.

The Office of Chief Health Medical Officer (OCHMO) is continuing its implementation of the Health and Medical Technical Authority (HMTA) to establish health, medical, human performance policies, and requirements and standards for all human space flight programs and projects.

The Independent Verification and Validation (IV&V) Program is currently providing software expertise to 18 projects including 14 NASA missions, three multi-agency missions (NOAA/NASA), and one Space Act Agreement with the City of New York.

## **AGENCY MANAGEMENT AND OPERATIONS**

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NASA will implement a Continuous Diagnostic Mitigation (CDM) and Information Security Continuous Monitoring (ISCM) strategy to improve real-time or near-real-time situational awareness of its IT Security state. These activities will improve NASA's IT security and address concerns from NASA's Inspector General, as well as aid NASA in meeting its Cross-Agency Priority (CAP) goals as defined by the Department of Homeland Security (DHS).

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

In FY 2015, NASA will initiate a pilot for the Presidential Management Fellow –STEM track program that will provide for approximately ten participants across the Agency.

The Agency will continue to improve its network security with an enterprise approach to perimeter control and maintenance, including implementation of an Enterprise Firewall and Web Content Filter, deployment of NAC systems inside NASA's networks, and replacement of Center VPNs with an enterprise PIV-enabled solution.

Technical Authority will continue to be strengthened through the collaborative efforts between Office of Safety and Mission Assurance (OSMA), OCE, and the OCHMO. The offices will continue to work together conducting safety reviews and independent technical assessments of NASA's missions.

## **Program Elements**

### **AGENCY MANAGEMENT**

Agency Management provides functional and administrative management oversight for the Agency and operational support for NASA Headquarters. Agency Management governance and oversight activities include finance, protective services, general counsel, public affairs, external relations, legislative affairs, training, human capital management, procurement, real property and infrastructure, budget management, systems support, internal controls, diversity, equal opportunity, independent program and cost evaluation, and small business programs.

### **SAFETY AND MISSION SUCCESS**

SMS programs protect the health and safety of the NASA workforce and improve the likelihood for safety and mission success for NASA's programs, projects, and operations. SMS includes NASA Headquarters programs providing technical excellence, mission assurance, and technical authority. This includes the work managed by the OSMA, IV&V, OCE, and OCHMO.

### **AGENCY INFORMATION TECHNOLOGY SERVICES**

AITs program is a critical enabling capability dedicated to IT excellence to ensure every mission can achieve success within NASA's complex environment. The AITs mission improves management and security of IT systems while systematically improving the efficiency, collaboration capabilities, and streamlined service delivery and visibility for the entire Agency.



## **AGENCY MANAGEMENT AND OPERATIONS**

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### **STRATEGIC CAPABILITIES ASSETS PROGRAM**

SCAP ensures the essential Agency test facilities are maintained in a state of readiness. SCAP maintains the skilled workforce and performs essential preventative maintenance to keep these facilities available to meet program requirements. Core capabilities supported within SCAP are thermal vacuum chambers, simulators, and the Arc Jet Facility.

## AGENCY MANAGEMENT

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>372.3</b>	<b>--</b>	<b>365.6</b>	<b>369.3</b>	<b>373.0</b>	<b>376.7</b>	<b>380.3</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



**NASA Headquarters in Washington D.C. provides overall planning and policy direction for Headquarters and the corporate management for all its field centers, which includes at least 55,000 civil servant employees and on and near site contractors NASA-wide.**

Agency Management provides functional and administrative management oversight for the Agency and operational support for NASA Headquarters. This program primarily supports ongoing operations. Agency Management supports the activities necessary to conduct business in the Federal sector and provides the capability to respond to legislation and other mandates. The Agency Management program supports over 35 discrete operations and mission support activities.

Agency Management provides policies, controls, and oversight across a range of functional and administrative management service areas. Agency Management governance and oversight activities include finance, protective services, general counsel,

public affairs, international and interagency relations, legislative affairs, training, human capital management, procurement, real property and infrastructure, budget management, systems support, internal controls, diversity, equal opportunity, evaluation, and small business programs. The Agency Management program supports operational activities of Headquarters as an installation. These activities include building lease costs, facility operations costs (such as physical security, maintenance, logistics, information technology hardware, and software costs), automated business systems implementation, and operations costs (such as internal control initiatives related to transparency and accountability in government).

### EXPLANATION OF MAJOR CHANGES IN FY 2015

NASA reduced administrative costs and implemented operational efficiencies of Headquarters services. This enables the Agency to maximize its investments in the Agency's Missions.

## **AGENCY MANAGEMENT**

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### **ACHIEVEMENTS IN FY 2013**

In FY 2013, the Agency received a clean (unmodified) audit opinion of its accounting and financial systems for the third consecutive year. The auditor's opinion of an unmodified financial statement asserts the Agency's financial statements accurately represent its financial position and operations. This year NASA received a "cleanest of the clean" audit with no significant deficiencies.

The Partnership for Public Service recognized NASA as the Best Place to Work in the Federal Government among large agencies based on the 2013 Employee Viewpoint Survey Results. This includes ranking first in leadership, support for diversity, teamwork and first among women, African Americans, people with disabilities, and veterans. Additionally, NASA was named the Biggest Mover among large agencies, indicating that NASA had the most significant increase in the Best Place to Work indices. The Office of Personnel Management conducted this survey.

### **WORK IN PROGRESS IN FY 2014**

As part of a renewed lease, the Headquarters office building is being renovated to be Leadership in Energy and Environmental Design (LEED) Silver certified. This renovation will increase energy and workplace efficiency and create a more collaborative work environment. Energy efficiency will be achieved by the replacement of the HVAC system, transitioning to LEED lighting systems, and revamping floor plans that relocate offices away from the exterior walls allowing the heat pumps installed in the exterior walls to be integrated into an overall environmental management system. NASA's Headquarters office building will achieve LEED Silver certification by the end of FY 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

Attracting and hiring the highest quality early career STEM employees has been an ongoing challenge. To help address this challenge, NASA partnered with the Office of Personnel Management to develop a Presidential Management Fellow – STEM Track program. In FY 2015, NASA will initiate a pilot for this program that will provide for approximately ten participants across the Agency.

## **Program Elements**

### **HEADQUARTERS OPERATIONS**

Headquarters Operations manage and sustain the Headquarters employees and contractors, facilities, and operations required for program and institutional execution. Areas include:

- Information Technology and communications infrastructure hardware and software acquisitions and maintenance, and contracted services for IT support of the Headquarters staff;
- Facility operations support, including physical security, custodial, and maintenance services; equipment; expendable supplies; mail services; printing and graphics; motor pool operations; logistics services; emergency preparedness;
- Human resources staffing; employee payroll and benefits processing; retirement services; employee training; employee occupational health, fitness, and medical services; and grants awards processing; and

## **AGENCY MANAGEMENT**

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- Headquarters operations, including support provided by GSFC for accounting and procurement operations; configuration maintenance; automated business and administrative systems; contract close-out services; and payments to the Office of Naval Research for grants management.

## **MISSION SUPPORT**

The Agency Management budget also provides functional leadership of administrative and mission support activities. This diverse set of activities is performed at Headquarters and Centers on behalf of the Agency.

Mission Support activities include:

- Execution and management of the Agency's financial and budget processes and systems. This includes strategic planning, budget and financial management and accountability practices, while providing timely, accurate, and reliable information, and enhancing internal controls;
- Leadership and management of NASA protective services operations. This includes policy formulation; oversight, coordination and management of protective services operations, including security, fire, emergency management, and emergency preparedness; support for Agency counterintelligence and counter-terrorism activities; implementation of the identity, credentials and access management systems and other security systems, including communications; continuity of operations; and national intelligence community services;
- Technical expertise and oversight of the Agency infrastructure and management systems for: aircraft, environmental, real property, logistics, and strategic capabilities programs; and
- Leadership and management of the Agency's human capital resources, and Equal Employment Offices. These offices engage the Agency in proactive equal opportunity and diversity-inclusion initiatives workforce development and alternate dispute resolution services and complaint investigations.

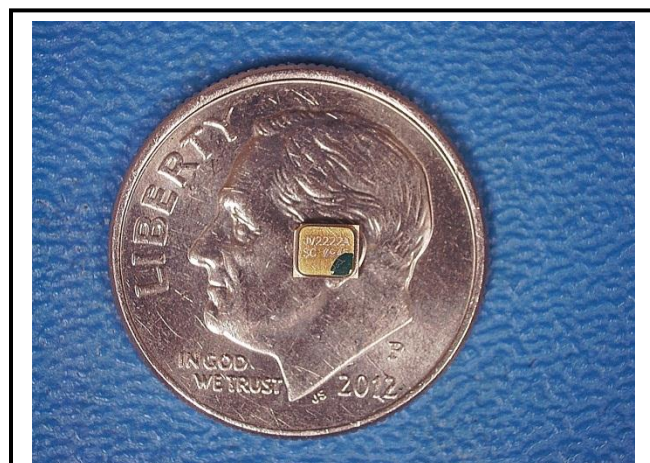
## SAFETY AND MISSION SUCCESS

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Safety and Mission Assurance	46.3	--	<b>46.4</b>	46.9	47.4	47.9	48.4
Chief Engineer	84.5	--	<b>83.7</b>	84.5	85.3	86.2	87.1
Chief Health and Medical Officer	4.2	--	<b>4.2</b>	4.3	4.3	4.4	4.4
Independent Verification and Validation	37.5	39.1	<b>29.4</b>	29.7	30.0	30.3	30.6
<b>Total Budget</b>	<b>172.5</b>	<b>--</b>	<b>163.7</b>	<b>165.4</b>	<b>167.0</b>	<b>168.8</b>	<b>170.5</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



Miniaturized electronic parts provide technology opportunities for space applications, yet difficult challenges. This JANS2222A transistor failed during board level testing due to an error in the laser marking process that created a ~5 micrometer-hole through which foreign materials entered and short-circuited the transistor.

SMS programs protect the health and safety of the NASA workforce and improve the likelihood that NASA's programs, projects, and operations will be completed safely and successfully. SMS includes programs that provide technical excellence, mission assurance, and technical authority. It also includes work managed by the OSMA, including the NASA Safety Center and IV&V; OCE including the NASA Engineering and Safety Center; and OCHMO. The elements of SMS reflect the recommendations outlined in many studies and by advisory boards and panels. These programs directly support NASA's core values and serve to improve the likelihood for safety and mission success for NASA's programs, projects, and operations while protecting the health and safety of NASA's workforce.

SMS develops policy and procedural requirements. This program results in recommendations to the Administrator, mission

directorates, Center Directors, and program managers who ultimately are responsible for the safety and mission success of all NASA activities and the safety and health of the workforce. SMS resources provide the foundation for NASA's system of checks and balances, enabling the effective application of the strategic management framework and the technical authorities defined in NASA's Strategic Management and Governance Handbook. SMS funds provide training and maintain a competent technical workforce within the disciplines of system engineering (including system safety, reliability, and quality) and space medicine.

## **SAFETY AND MISSION SUCCESS**

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SMS resources are essential for evaluating the implications on safety and mission success, including the health and medical aspects of new requirements and departures from existing requirements. With this funding, discipline experts analyze the criticality of the associated risks and evaluate the risks acceptability through an established process of independent reviews and assessments. The information and advice from these experts provide critical data that is used by the technical authorities to develop authoritative decisions related to application of requirements on programs and projects.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The number of projects that IV&V will provide software assurance and expertise on is reduced from 14 projects to five projects.

### **ACHIEVEMENTS IN FY 2013**

In FY 2013, SMS conducted 19 formal, stringent Safety and Mission Success Reviews. These reviews are the culmination of the identification and mitigation of all potential SMA problems for launches and high criticality events. Substantive participation in Directorate Program Management Council (DPMC), Flight Planning Boards, Key Decision Points (KDP) reviews, and scores of lower level reviews and assessments collectively enable effective governance and successful mission implementation.

The OSMA updated eight Agency-level directives/standards in the areas of quality, reliability/maintainability, risk classification, mishap investigation, software safety, and underwater operations safety; each document updated this year was thoroughly vetted to ensure requirements were clear, necessary, and supported NASA's mission.

NASA's IV&V provided software expertise to 20 projects and seven NASA Centers. IV&V also provided eight favorable launch/operational readiness votes: one for MAVEN and seven for International Space Station (ISS): five launches taking crew to the ISS, one return of crew leaving the ISS, and one ISS software stage transition. A favorable readiness vote is provided when all IV&V-identified issues and risks have been satisfactorily resolved by the customer. The resolution of these issues is an indicator that the system software will operate as designed.

The NASA OCHMO sought new ways to utilize the data contained within the Electronic Health Records System (EHRS) at all NASA Centers. The EHRS allows NASA to efficiently access and analyze medical records for employees across the Agency, thereby enhancing the effectiveness of preventive health assessments and OSHA-required surveillance exams. Other long-standing benefits of the EHRS include increased chart accuracy, reductions in potential medical errors due to direct import of laboratory data via direct interface capability and the ability to analyze trends in employee health information across the Agency that can be utilized for focused health promotion efforts.

NASA added a new capability to the NASA Engineering Network. This increased the ability of engineering tool users to track local and Agency-wide usage of high value engineering software tools for further implementation of cost savings that result from using Enterprise License Agreements for software procurement. Using these Enterprise License Agreements increased efficiency and demonstrated reduced cost for engineering tools.

## **SAFETY AND MISSION SUCCESS**

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In the area of human space flight, the OCHMO supported all ISS flight readiness reviews and review activities relevant to Commercial Cargo, Commercial Crew, and Exploration System Integration programs. Additionally, in partnership with the subject matter experts in veterinary and human medicine, the OCHMO provided ongoing oversight of the Institutional Review Board (IRB) and Animal Care and Use Committee activities, including specific crew training for on-orbit animal research subject support.

### **WORK IN PROGRESS IN FY 2014**

The SMA program continues to conduct safety reviews and independent technical assessments for NASA missions, including any newly selected projects. The SMA program will also continue to enhance its portfolio of requirements and technical guidance documents and its suite of SMA training; advance NASA's capabilities to mitigate and remove on-orbit debris, reduce hazards, and increase the understanding of the current and future orbital debris environment; and advance its program to detect, track, catalog, and reduce the number of counterfeit electronic parts in the NASA supply chain. The OCHMO is continuing its implementation of the Health and Medical Technical Authority (HMTA) to establish health, medical, human performance policies, requirements and standards for all human space flight programs and projects; technical standards levied on or supported by R&T programs and projects; and NASA-unique occupational and environmental health requirements that are not mandated by OSHA or the EPA. In cases where there is no NASA-unique or federally-mandated health/medical requirement or standard, the OCHMO is also responsible for establishing policies, procedures and standards. In addition to providing direction and oversight for a rapid review of crew health and safety in support of the one year on-orbit ISS mission, the OCHMO will lead the Multilateral Medical Policy Board (MMPB) in addressing and resolving several critical issues dealing with crew health and medical operations support to Soyuz landings.

The IV&V Program is currently providing software expertise to 18 projects including 14 NASA missions, three multi-agency missions (NOAA/NASA), and one Space Act Agreement with the City of New York.

The OCE including the NASA Engineering and Safety Center (NESC) will continue to remain vigilant in supporting the achievement of the Agency's major priorities. OCE will continue to provide a strong check and balance in technical reviews including maintaining Technical Authority caucuses to ensure full integrity, common understanding and that all dissenting and divergent opinions had been fully heard and appropriately considered. The NESC will strive to maintain the ability to conduct over 50 independent assessments for NASA's highest risk challenges maintaining prioritization on the ISS, Commercial Crew, Orion/Space Launch System (SLS), James Webb Space Telescope (JWST) and Space Technology. The OCE will capture and share knowledge using methods conducive to the workforce demand and demographic. The OCE will continue to increase the ability of engineering tool users to track local and Agency-wide usage of high value engineering software tools for further implementation of cost savings that result from using Enterprise License Agreements for software procurement.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

At the core of the Agency's preventive approach to achieve safety, health, and mission success are: (1) active engagement with NASA programs and institutions to advise, advocate, and ensure safety and mission success; (2) routine on-site inspections and regular self-audits to ensure compliance with mandatory regulations, Agency policies, industry standards and best practices; (3) robust knowledge management and communities of practice that capture and inculcate lessons learned into future missions;

## **SAFETY AND MISSION SUCCESS**

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(4) multi-faceted training and development programs to ensure the SMS workforce has the necessary skills and capabilities; and (5) comprehensive review processes to identify and mitigate risks and analyze and understand failures when they occur. This strategy and practice will continue to provide a systematic approach to support mission success.

The OCHMO will continue to implement the HMTA as it pertains to all technical standards for R&T and human space flight programs and projects, as well as those that relate to occupational and/or environmental health requirements that are not established by OSHA or EPA. Additionally, the OCHMO will continue to support the only two non-military Aerospace Medicine residencies in the US - Wright State University and the University of Texas Medical Branch - to ensure the sustainability of the discipline, as well as to support the pipeline for future talent.

In the area of medical policy, the OCHMO will begin a multi-year project using the Spacecraft Maximum Allowable Concentrations and Spacecraft Water Exposure Guidelines; and in collaboration with the National Council of Radiation Protection & Measurements, the OCHMO is working to revise the space radiation standard to ensure the health and safety of those aboard the ISS.

In FY 2015, IV&V will continue to provide expert software analysis on NASA's safety and mission critical software to help assure safety and mission success by identifying software problems as early as possible, minimizing the cost of rework and supporting key milestone decisions. Additionally, the IV&V Program will continue to enhance its technical capabilities and focus on continuous improvement and value.

Technical Authority will continue to be strengthened through the collaborative efforts between OSMA, OCE, and the OCHMO. The offices will continue to work together conducting safety reviews and independent technical assessments of NASA's missions, including ISS, Commercial Crew, Orion/SLS, JWST, robotic missions and Space Technology investments.

## **Program Elements**

### **SAFETY AND MISSION ASSURANCE**

SMA establishes and maintains an acceptable level of technical excellence and competence in safety, reliability, maintainability, and quality engineering within the Agency. SMA assures that the risk presented by either the lack of safety requirements or from the lack of compliance with safety requirements is analyzed, assessed, communicated, and used for proper decision making and risk acceptance by the appropriate organizational leader.

Fundamental to these responsibilities are the definition and execution of a robust and well-understood methodology and process for the application of the safety, reliability and quality in defining the level of risk. SMA conducts a schedule of reviews and assessments that focus on the life cycle decision milestones for crucial NASA programs and projects and safety, reliability, and quality processes. Embodied in this program is a structured development of methodology and investigation into system attributes that improve the probability of mission success.



## **SAFETY AND MISSION SUCCESS**

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The NASA Safety Center is an important component of SMA and is responsible for consolidating Agency-wide SMA efforts in four key areas: SMA technical excellence, knowledge management, audits and assessments, and mishap investigation support.

### **OFFICE OF THE CHIEF ENGINEER**

OCE establishes and maintains program/project management and engineering policy and technical standards creating the foundation for excellence of the Agency's program and project management and engineering workforce, system-engineering methodology, and the Agency's system of engineering standards. The office manages the NASA Engineering and Safety Center which is responsible for enabling rapid, cross-Agency response to mission critical engineering, and safety issues at NASA and for improving the state of practice in critical engineering disciplines. Established in FY 2003 in response to the recommendations of the Space Shuttle Columbia Accident Investigation Board, NASA Engineering and Safety Center performs independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success. SMS funding provides for the core NASA Engineering and Safety Center organization of senior engineering experts from across the Agency, including the NASA Technical Fellows, and technical discipline teams comprised of experts from NASA, industry, and academia. As an Agency-wide resource with a reporting path that is independent of the Mission Directorates and independent funding from the OCE, the NASA Engineering and Safety Center helps ensure safety and objective technical results for NASA.

OCE sponsors the Academy of Program/Project and Engineering Leadership to develop program and project management and systems engineering skills. This academy provides a formal professional development curriculum designed to address four career levels from recent college graduate to executive. The OCE professional development programs directly support project teams in the field through workshops, coaching, interactions with technical experts, training, forums, and publications. The office enables technical collaboration and information sharing through the NASA Engineering Network, an Agency-wide capability providing single point access to technical standards, communities of practice, and lessons learned in a secure operating environment. The engineering standards program maintains compliance with Office of Management and Budget Advisory Circular 119 and offers a centralized source of required engineering standards for NASA programs and projects at one-fourth the cost of a decentralized approach. In addition, OCE manages the Space Act authorized Inventions and Contributions Board, which is chartered with recognizing and rewarding innovation within the Agency.

### **OFFICE OF THE CHIEF HEALTH AND MEDICAL OFFICER**

OCHMO promulgates Agency health and medical policy, standards, and requirements, assuring the medical technical excellence of the Agency. It assures the physical and mental health and well-being of the NASA workforce, and assures the safe and ethical conduct of NASA-sponsored human and animal research. The office monitors the implementation of health and medical related requirements and standards in all developmental human space flight programs through designated discipline experts at NASA Centers. The office provides oversight of medical and health related activities in operational human space flight through Center-based discipline experts and clinical boards. Ongoing medical and health discipline professionalism and licensure are supported through annual certified continuing medical education activities and flight surgeon education. Clinical currency is maintained through sponsored, university-based physician training programs that are sponsored by OCHMO. NASA's biomedical

## **SAFETY AND MISSION SUCCESS**

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research programs in support of human space flight are guided by NASA-developed health and medical standards.

### **INDEPENDENT VERIFICATION AND VALIDATION**

Software on NASA's missions is extremely critical. It saves the lives of astronauts and ensures that billion dollar investments provide the return that taxpayers deserve. IV&V is a proven means of making sure this critical software works properly and of reducing the cost to develop the software. IV&V identifies software problems as early as possible, minimizing the cost of rework and supporting key management decisions.

The NASA IV&V Program provides software expertise, services, and resources to improve the likelihood for safety and mission success for NASA's programs, projects, and operations while protecting the health and safety of NASA's workforce. The IV&V Program analyzes mission software, independently from the developing organization, on NASA's most critical software systems to assure safety and mission success of those systems.

IV&V applies state-of-the-art analytical methods and techniques, complemented with effective software engineering tools and best practices, to evaluate the correctness and quality of critical and complex software systems throughout the project's system development life cycle.

IV&V provides resources and software expertise to other SMA elements in support of independent evaluations of software related approaches and processes. The IV&V Program supports sustaining software technical excellence in the SMA community, sustaining software domain knowledge within the SMA organization, and in formulating software development improvement recommendations to the Agency.

IV&V performs independent testing of critical system software as a state-of-the-practice analytical technique that enhances the likelihood of discovering the most difficult kinds of problems in mission software early in the development lifecycle. Critical system software problems can surface because of multiple complex interactions, under specific environmental and operational conditions, and under unique software configurations. The IV&V program's independent test capability enables:

- Advanced testing and simulations of NASA's mission and safety critical software;
- Testing and evaluation of robotics and intelligent systems;
- Capability development within the systems engineering disciplines;
- Central computing platform for commonly used software assurance tools by engineers; and
- Training and education for workforce and students.

## **SAFETY AND MISSION SUCCESS**

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### **Acquisition Strategy**

#### **INDEPENDENT REVIEWS**

<b>Review Type</b>	<b>Performer</b>	<b>Date of Review</b>	<b>Purpose</b>	<b>Outcome</b>	<b>Next Review</b>
Safety	Aerospace Safety Advisory Panel	Jan 2014	Evaluate NASA's safety performance and advise the Agency on ways to improve that performance.	Recommendations to the NASA Administrator and to Congress. Annual reports located at: <a href="http://oiir.hq.nasa.gov/asap/">http://oiir.hq.nasa.gov/asap/</a>	Apr 2014

## AGENCY IT SERVICES (AITS)

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
IT Management	13.3	--	14.6	14.6	14.6	14.6	14.6
Applications	59.1	--	62.5	62.5	62.5	62.5	62.5
Infrastructure	75.5	--	106.5	108.2	110.1	111.9	113.8
<b>Total Budget</b>	<b>148.0</b>	<b>--</b>	<b>183.6</b>	<b>185.3</b>	<b>187.2</b>	<b>189.0</b>	<b>190.9</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The AITS program provides many of the Agency's information technology services, including IT security policy and incident monitoring, web services for the Agency's websites, network management, enterprise business applications and consolidated end user base services. The AITS program provides innovative IT solutions to assist NASA's scientists, engineers and analysts achieve mission success. The program also improves citizen access to NASA scientific data and increases citizen participation in NASA activities.

The AITS program transformed the IT service model from a decentralized Center-based model to an enterprise model for infrastructure and business applications. To achieve this transformation, the AITS program implemented the I3P to improve security, achieve cost efficiencies, and provide standardized services to all users across the Agency. AITS developed and maintains NASA's current and target architectures and service optimization objectives. This program supports federal green

IT and data center consolidation efforts. Core capabilities include the NASA Enterprise Application Competency Center, Agency Consolidated End-User Services, NASA Data Center, Security Operations Center, Scientific and Technical Information Program, NASA network management and operations centers (NOCs), and the IT Discovery and Application Management Services.

The AITS program manages NASA's websites and services, that facilitate the Agency's statutory requirement to disseminate information concerning its activities and missions results. The NASA Web

## **AGENCY IT SERVICES (AITS)**

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Enterprise Services and Technologies initiative consolidates NASA's web infrastructure, to the cloud (where appropriate), enhances business and technical agility, eliminates vendor specific dependencies, drives down operational overhead for web presence, drives down the cost of custom web/on-demand services for missions, programs, and projects, improves NASA IT security, explores shared services across NASA Centers, and improves online customer service delivery through innovative technology. The program also implements services to allow citizens, collaborators, and other partners to use existing social media and other applications to access NASA systems and information.

Under the AITS program, the Agency continues to improve its network security with an enterprise approach to perimeter control and maintenance, including the use of Personal Identification Verification (PIV) smartcards for both local and remote system access. In addition, AITS is consolidating several NASA Center-specific applications into enterprise-level services, leveraging cloud offerings where possible.

The program continued an initiative to enable NASA's mobile workforce to work anytime, anywhere using NASA devices or personal devices while ensuring adequate security of NASA's data and information. To ensure that NASA's information is secure while working away from the office, the Agency instituted the Data at Rest (DAR) initiative for NASA issued computers. This initiative provides whole disk encryption to help protect NASA data if a computer is lost or stolen. The current scope for DAR protection includes all laptops and any desktop containing Personally Identifiable Information or other sensitive data.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

NASA will increase its IT security activities to improve data protection and continuity of services, better protect the network, reduce loss of information, minimize impacts on business-critical functions, and provide more efficient processing and analysis of security information. NASA will also replace outdated business systems to improve performance, reduce costs, and retire risks associated with running obsolete systems.

### **ACHIEVEMENTS IN FY 2013**

To standardize and economize the delivery of a consolidated set of end-to-end network services NASA implemented Agency systems for: 1) ordering and implementing network and telecommunications service requests; 2) initiating and tracking incidents and problems; 3) managing and controlling configuration information including an auto-discovery for network assets; and 4) managing and monitoring of network services via enterprise tools. Standard approved reference architectures and product lists for Wide Area Networks (WANs) and Local Area Networks (LANs) were developed to ensure architecture consistency and efficiencies; enterprise maintenance agreements were established resulting in significant savings. NASA implemented multiple Information Technology Infrastructure Library processes to improve service delivery under the enterprise service model.

The Enterprise Service Desk (ESD) supported the I3P initiative and NASA customers 24 hours/day, 365 days/year. ESD provides a central service desk, service request system, a self-service, Tier 0 Web portal, knowledge sharing capability, ability to centrally capture and provide notifications, and system status capabilities. Since ESD began operating in November 2011, metrics show the progress and success of the project whereby customer satisfaction is at 95 percent; calls answered within 60 seconds is at 85 percent;

## **AGENCY IT SERVICES (AITS)**

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abandonment rate at 2.8 percent; and first call resolution on Tier 1 related items at 92 percent. Overall, 280,000 incidents and over 115,000 service requests were processed and represents an increase of approximately 12 percent and 15 percent respectively in volume year over year.

NASA reduced the total number of data centers from the original 79 reported to 35. Our revised commitment indicates that NASA will reduce to approximately 22 data centers by 2015.

The NASA email system and infrastructure transition from Exchange 2007 to Exchange 2010 was completed in March 2013. The modification includes providing end user customers with a one gigabyte mailbox size. This increase allows storage of more email on the servers, which can be accessed from other mobile devices and leveraging the work from anytime and anywhere.

### **WORK IN PROGRESS IN FY 2014**

NASA has taken on the challenge to meet the Cross-Agency Priority (CAP) goals defined by the DHS, and to achieve 95 percent use of the Administration's priority cyber security capabilities on NASA information systems by end of FY 2014, including strong authentication, Trusted Internet Connections (TIC) and Continuous Monitoring.

NASA will implement a Continuous Diagnostic Mitigation (CDM) and Information Security Continuous Monitoring (ISCM) strategy to improve real-time or near real-time situational awareness of its IT Security state. NASA continues to increase initiatives related to IT Security, some examples include: (1) transformation and expansion of continuous monitoring capabilities; governance, risk, and compliance; and penetration testing; (2) deploying intrusion detection systems across mission, corporate, and research networks; (3) increasing web application security scanning; (4) implementation of Personal Identity Verification (PIV) on internal and remote access to network and mobile systems; and (5) implementing intrusion prevention systems at trusted Internet connection locations. These activities will improve NASA's IT security and address concerns from NASA's Inspector General, as well as aid NASA in meeting its CAP goals as defined by the DHS.

NASA will capitalize on its cyber security transformation by modernizing the risk management framework (to include Security Assessment and Authorization and continuous monitoring processes), defining metrics for measuring risk reduction, creating dashboards for visualizing and communicating the Agency's cyber security posture, and expanding the security operations efforts to provide early warning of cyber vulnerabilities.

The Agency will complete steps needed for full TIC compliance and management of the Agency's perimeter as an enterprise. By focusing on transforming and modernizing its cyber security program through improved processes and capabilities focused on network defense, detection of abnormalities, configuration and asset management, and situational awareness, NASA will address Office of Inspector General (OIG) and Government Accountability Office (GAO) findings and recommendations for improving underlying and systemic IT security deficiencies and weaknesses. NASA has taken on the challenge to meet the CAP goals defined by DHS, and to achieve 95 percent use of the Administration's priority cyber security capabilities on NASA information systems by end of FY14, including strong authentication, TIC, and continuous monitoring. A plan of action to meet the target level for each CAP has been developed.

## **AGENCY IT SERVICES (AITS)**

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NASA is working closely with the General Services Administration (GSA) to ensure NASA data is accessible, machine-readable, and available on Data.gov. The Open Innovation Program is coordinating the third annual Internal Space Apps Challenge, which will feature challenges within six mission focus areas: robotics, human spaceflight, Earth watch, planet watch, space technology, and asteroids. To date, almost 100 locations are in the running to host the 2014 event in over 70 countries.

The Agency is working to re-architect NASA's WANs to establish a defensible Agency network perimeter. The Agency will continue to improve its network security with an enterprise approach to perimeter control and maintenance, including planning and development of an Enterprise Firewall and Web Content Filter, planning to deploy NAC systems inside NASA's networks, designing an enterprise PIV-enabled remote access system to replace Center VPNs. These activities will greatly enhance NASA's security posture. Efficiencies will be realized through additional standardization of voice and security architectures, additional improvements to service deployment and management processes, consolidated management and operations of Center LANs, and planning for centralized monitoring and management of Center networks from an enterprise NOC replacing Center-specific network operations centers and capabilities. NASA is augmenting the wide area backbone to maintain mission critical service levels, to accommodate growing requirements more efficiently and securely, to enable the consolidation of NASA's mission and corporate WANs backbones, and to reduce transport costs.

NASA is completing all phases of the Identity Management PIV Access Implementation Plan. The goal is to enforce PIV on all user and machine objects by the end of FY 2014.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The Agency will continue to improve its network security with an enterprise approach to perimeter control and maintenance, including implementation of an Enterprise Firewall and Web Content Filter, deployment of NAC systems inside NASA's networks, and replacement of Center VPNs with an enterprise PIV-enabled solution. Efficiencies will be realized through additional standardization of network and telecommunications architectures, additional improvements to service deployment and management processes, and transition to centralized monitoring and management of Center networks from an enterprise NOC. NASA's mission services will begin transitioning to the new CSO backbone, allowing for the decommission of legacy transport services which will result in cost avoidances. Capacity increases to the CSO backbone will be implemented to support additional Space Communications and Navigation requirements.

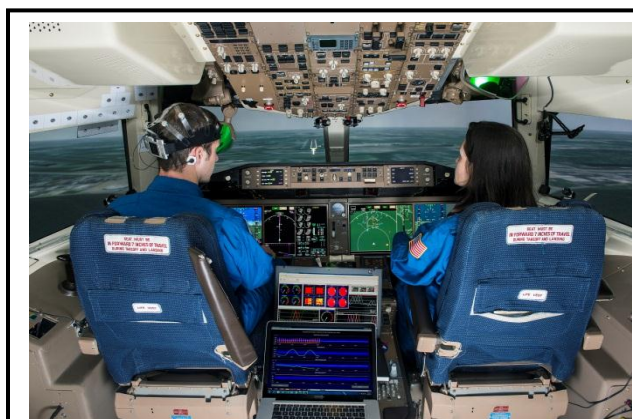
# STRATEGIC CAPABILITIES ASSETS PROGRAM

## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>26.6</b>	<b>--</b>	<b>26.9</b>	<b>27.2</b>	<b>27.5</b>	<b>27.8</b>	<b>28.1</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



The NextSafe 2.5 simulation experiment is being performed at the Research Flight Deck (RFD). The RFD is part of the Flight Simulation Facilities at NASA LaRC located in Hampton, VA. The RFD consists of all-glass reconfigurable cockpit with programmable side-stick control inceptors, oculometers, and electronics flight bags. NASA's unique Flight Simulation Capabilities has enabled and contributed to areas of aviation safety, air traffic management, supersonics aircraft design, space exploration, and scientific missions.

SCAP ensures that select critical test facilities are in a state of readiness. SCAP maintains the skilled workforce and performs essential preventative maintenance to keep these facilities available to meet program requirements. Core capabilities SCAP supports are thermal vacuum chambers, simulators, and the Arc Jet Facility.

SCAP establishes alliances between all Centers with like assets, makes recommendations on the disposition of capabilities no longer required, identifies re-investment/re-capitalization requirements within and among classes of assets, and implements changes. SCAP reviews the Agency's assets and capabilities each year to ensure that the requirements for the facilities continue to be valid.

SCAP ensures maximum benefit across the Government by broadening its alliances outside the Agency for capabilities (e.g., thermal vacuum chambers). A collaborative working group consisting of the Space Environment Test Alliance Group, including NASA, DoD, and

other partner entities facilitates this effort. The group members gain awareness of capabilities across agencies, academia, and industry; share best practices; provide technical support; and refer test programs to facilities best suited to meet test requirements.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

None.



## **STRATEGIC CAPABILITIES ASSETS PROGRAM**

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### **ACHIEVEMENTS IN FY 2013**

SCAP continued to sustain and ensure that the test facilities identified as essential by the Agency were maintained in a state of readiness. SCAP maintained the skilled workforce and performed preventative maintenance necessary to keep these facilities available to meet current and future program requirements.

SCAP's specialized workforce at the Ames Arc Jet checked and activated the major test equipment received from the JSC Arc Jet Facility and placed into operations as part of the arc jet capability consolidation effort. NASA anticipates annual operational cost savings of over \$5 million per year to the missions through this consolidation effort.

SCAP assets supported the development, testing, verification, and validation for NASA, DoD, NOAA, FAA, European Space Agency (ESA), and commercial test programs in the following areas:

- Simulators: air traffic management technology demonstration, Unmanned Aerial System airworthiness standards and guidelines, motion cueing, Loss of control and recovery, Sierra Nevada Dream Chaser simulation, and other ongoing development and testing;
- Thermal vacuum and acoustic chambers: JWST instrument and optical calibration, Global Precipitation Monitoring Observatory, Magnetospheric Multiscale Observatory, Space Exploration Technologies (SpaceX) payload fairing testing for the Falcon 9, Commercial Crew and Cargo launch program testing, and other space environmental testing; and
- Arc jet: thermal protection materials, system development and qualification testing.

### **WORK IN PROGRESS IN FY 2014**

- SCAP's specialized workforce at the Ames arc jet will continue to verify and validate that the transferred equipment meets future Orion requirements.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

SCAP will continue to sustain the strategic technical capabilities needed by NASA to achieve successful missions. In addition, SCAP will continue to develop and implement disposition plans for assets no longer needed. This improves long-term health and sustainment of the remaining NASA assets.

SCAP will support ARC to perform a feasibility study for the Ames Arc Jet recapitalization siting and sequencing plan.

SCAP plans to review and identify high-risk areas for the thermal vacuum capability at MSFC to assess the condition of the assets.

## **Program Elements**

SCAP maintains the skilled workforce and performs maintenance required to keep essential NASA assets available to meet program requirements.

## **STRATEGIC CAPABILITIES ASSETS PROGRAM**

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### **SIMULATORS**

Simulators are critical components of the success of NASA's aeronautics research in the areas of fundamental aeronautics and aviation safety. These capabilities provide scientists and engineers with tools to explore, define, and resolve issues in both vehicle design and missions operations.

This capability includes an array of research and development crewed flight simulator assets that are in the operations phase and includes:

- A Vertical Motion Simulator and its associated laboratories and equipment located at ARC; and
- A Cockpit Motion Facility and its supporting suite of simulators (the differential maneuvering simulator and the visual motion simulator) and central support facilities for aeronautics and spaceflight vehicle research located at LaRC.

### **THERMAL-VACUUM, VACUUM, AND ACOUSTIC CHAMBERS**

This capability includes several assets located at NASA facilities (GRC, GSFC, JPL, JSC, KSC, and MSFC) that simulate conditions during launch and in space environments. These assets have a minimum outline dimension of 10 feet by 10 feet and can accommodate a complete spacecraft. These chambers have the capability of producing pressures down to 0.01 torr or lower and thermal shrouds capable of liquid nitrogen temperatures (-321 degrees Fahrenheit) or lower. Acoustic chambers are capable of generating approximately 150 decibels at frequencies in the range of 25 to 1,000 Hertz.

These chambers are used to perform significant risk mitigation for most NASA payloads launched into space as well as many payloads in other government agencies, such as NOAA and DoD. Testing performed in these chambers ensures the assembled spacecraft will meet the strict requirements of harsh launch and space environments. Recent successful space vehicles tested in thermal vacuum and acoustic chambers include: Mars Science Laboratory, Geostationary Operational Environmental Satellites, Ariane and SpaceX payload fairing separations.

### **ARC JET**

This capability includes assets that provide simulated high-temperature, high-velocity environments and support the design, development, test, and evaluation activities of thermal protection materials, vehicle structures, aerothermodynamics, and hypersonic aerodynamics. A gas (typically air) is heated and accelerated to supersonic/hypersonic speeds using a continuous electrical arc. This high-temperature gas passes over a test sample and produces an approximation of the surface temperature and pressure environments experienced by a vehicle on atmospheric entry.

Arc jet testing was critical in ensuring the safe return from orbit of space shuttles with tile damage and providing essential validation of materials for Mars entry missions, including the Mars Science Laboratory. The Dragon spacecraft, made by the commercial company SpaceX, also completed its heat shield development testing at NASA's Arc Jet Facility.

## HEADQUARTERS BUDGET BY OFFICE

### AGENCY MANAGEMENT BUDGET BY HEADQUARTERS OFFICE

(\$ in millions in full cost)	Actual	Enacted	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Aeronautics Research	6.7	6.9	6.8	6.9	7.1	7.2	7.4
Human Exploration and Operations	25.1	25.5	25.1	25.6	26.2	26.7	27.1
Science	27.1	27.7	27.3	27.8	28.5	29.0	29.5
Space Technology	4.6	4.8	4.7	4.8	4.9	5.0	5.1
<b>Mission Directorates</b>	<b>63.4</b>	<b>64.8</b>	<b>64.0</b>	<b>65.2</b>	<b>66.7</b>	<b>67.9</b>	<b>69.0</b>
Office of the Administrator	24.5	24.7	23.2	23.4	23.6	23.8	24.0
Chief Engineer	4.6	4.7	4.7	4.8	4.9	5.0	5.1
Chief Financial Office	25.2	25.0	24.4	24.7	25.1	25.4	25.7
Chief Health and Medical Office	1.7	1.7	1.7	1.7	1.7	1.8	1.8
Chief Information Office	8.6	8.7	8.6	8.8	9.0	9.2	9.3
Chief Scientist	0.9	1.2	1.2	1.2	1.2	1.2	1.3
Chief Technologist	1.2	1.3	1.3	1.3	1.3	1.3	1.4
Communications	15.3	14.8	13.1	13.2	13.4	13.6	13.7
Diversity and Equal Opportunity	4.5	4.2	4.2	4.2	4.3	4.4	4.4
Education	3.1	3.2	3.2	3.2	3.3	3.4	3.4
General Counsel	8.1	8.2	8.2	8.3	8.5	8.6	8.7
International and Interagency Relations	12.3	12.0	11.6	11.8	12.0	12.1	12.3
Legislative and Intergovernmental Affairs	3.6	3.7	3.7	3.8	3.9	3.9	4.0
Safety and Mission Assurance	6.0	6.0	6.0	6.1	6.3	6.4	6.5
Small Business Programs	1.7	1.7	1.7	1.7	1.7	1.7	1.7
<b>Staff Offices</b>	<b>121.2</b>	<b>121.2</b>	<b>116.7</b>	<b>118.2</b>	<b>120.1</b>	<b>121.7</b>	<b>123.2</b>
NASA Management Office at JPL	8.0	8.6	8.1	8.1	8.2	8.3	8.4
Human Capital Management	15.3	16.0	16.7	16.8	15.9	16.0	16.1
Headquarters Operations	107.3	113.7	105.9	106.4	106.8	107.1	107.2
Strategic Infrastructure	14.9	15.3	15.0	15.2	15.4	15.6	15.8
Internal Controls and Management Systems	2.1	2.2	2.1	2.1	2.1	2.2	2.2
Procurement	7.1	11.2	11.1	11.2	11.3	11.5	11.6
Mission Support Directorate Front Office	2.3	1.9	1.9	1.9	2.0	2.0	2.1
NASA Shared Services Center	14.7	12.8	6.8	6.8	6.8	6.8	6.7
Protective Services	16.0	16.4	17.4	17.5	17.7	17.8	17.9
<b>Mission Support</b>	<b>187.6</b>	<b>198.0</b>	<b>184.9</b>	<b>186.0</b>	<b>186.2</b>	<b>187.1</b>	<b>188.0</b>
<b>Total, Agency Management</b>	<b>372.3</b>	<b>384.0</b>	<b>365.6</b>	<b>369.3</b>	<b>373.0</b>	<b>376.7</b>	<b>380.3</b>

## HEADQUARTERS TRAVEL BUDGET BY OFFICE

### HEADQUARTERS TRAVEL BUDGET BY OFFICE

	Actual	Enacted	Request
(\$ in millions in full cost)	FY 2013	FY 2014	FY 2015
Aeronautics Research*	0.3	0.5	0.5
Human Exploration and Operations*	2.8	2.9	3.2
Science*	1.9	2.1	2.1
Space Technology*	1.3	2.0	2.0
<b>Mission Directorates</b>	<b>6.4</b>	<b>7.5</b>	<b>7.8</b>
Office of the Administrator	1.1	1.1	1.1
Chief Engineer	0.8	0.7	0.7
Chief Financial Office	0.2	0.3	0.3
Chief Health and Medical Office	0.1	0.1	0.1
Chief Information Office	0.3	0.3	0.3
Chief Scientist	0.0	0.1	0.1
Chief Technologist**	0.0	0.2	0.2
Communications	0.2	0.2	0.2
Diversity and Equal Opportunity	0.1	0.1	0.1
Education*	0.2	0.5	0.5
General Counsel	0.1	0.1	0.1
International and Interagency Relations	0.5	0.5	0.5
Legislative and Intergovernmental Affairs	0.0	0.0	0.0
Safety and Mission Assurance	0.3	0.3	0.3
Small Business Programs	0.1	0.1	0.1
<b>Staff Offices</b>	<b>3.8</b>	<b>4.6</b>	<b>4.5</b>
NASA Management Office at JPL	0.0	0.1	0.1
Human Capital Management	0.6	0.6	0.6
Headquarters Operations	0.1	0.1	0.1
Strategic Infrastructure	0.4	0.4	0.4
Internal Controls and Management Systems	0.0	0.0	0.0
Procurement	0.1	0.3	0.3
Mission Support Directorate Front Office	0.0	0.0	0.0
Protective Services	0.2	0.2	0.2
<b>Mission Support</b>	<b>1.4</b>	<b>1.8</b>	<b>1.7</b>
<b>Total, Agency Management</b>	<b>11.5</b>	<b>13.8</b>	<b>14.0</b>

\* Travel for the Mission Directorates and Education are funded from their respective appropriation accounts. This chart represents the total travel funding at Headquarters (not just in the CAS Agency Management program account).

\*\* Chief Technologist travel for FY 2013 is embedded in the Space Technology travel budget.

## HEADQUARTERS WORKFORCE BY OFFICE

	Actual				Enacted				Request			
	FY 2013				FY 2014				FY 2015			
	FTE	SES	NC*	WYE	FTE	SES	NC*	WYE	FTE	SES	NC*	WYE
Aeronautics Research	38	8		10	38	8		10	8		10	10
Human Exploration and Operations	140	14		76	140	14		65	139	14		65
Science	148	19		112	148	19		112	147	19		111
Space Technology**	26	1		4	26	1		8	26	1		8
<b>Mission Directorates</b>	<b>352</b>	<b>41</b>	<b>0</b>	<b>202</b>	<b>352</b>	<b>41</b>	<b>0</b>	<b>195</b>	<b>350</b>	<b>41</b>	<b>0</b>	<b>194</b>
Office of the Administrator	54	7	5	12	54	7	6	10	54	7	6	9
Chief Engineer	24	7		15	24	7		16	24	7		16
Chief Financial Office	98	8	1	35	98	8	1	37	98	8	1	37
Chief Health and Medical Office	10	1		4	10	1		1	10	1		1
Chief Information Office	47	7		26	47	7		67	47	7		67
Chief Scientist	5	2			5	2			5	2		0
Chief Technologist**	7	2			7	2			7	2		
Communications	52	3	2	28	50	3	2	23	50	3	2	23
Diversity and Equal Opportunity	17	5		22	17	5		18	17	5		18
Education	17	2		3	17	2		3	17	2		3
General Counsel	39	5	1		39	5	1		39	5	1	
International and Interagency Relations	50	8		6	50	8		6	50	8		6
Legislative and Intergovernmental Affairs	26	3	4		26	3	4		26	3	4	
Safety and Mission Assurance	32	5		19	32	5		3	32	5		3
Small Business Programs	5	1		3	5	1		5	5	1		5
<b>Staff Offices</b>	<b>483</b>	<b>66</b>	<b>13</b>	<b>173</b>	<b>481</b>	<b>66</b>	<b>14</b>	<b>188</b>	<b>481</b>	<b>66</b>	<b>14</b>	<b>187</b>
NASA Management Office at JPL	24	0		2	24	1		1	24	1		2
Human Capital Management	33	5		7	33	5		15	33	5		11
Headquarters Operations	96	3		304	96	3		328	93	3		328
Strategic Infrastructure	56	4		16	56	4		2	56	4		2
Internal Controls and Management Systems	10	0		1	10	0		2	10	0		2
Procurement	32	4			32	4			32	4		
Mission Support Directorate Front Office	8	1			8	1			8	1		
Protective Services	41	1		8	41	1		6	41	1		6
<b>Mission Support</b>	<b>300</b>	<b>18</b>	<b>0</b>	<b>338</b>	<b>300</b>	<b>19</b>	<b>0</b>	<b>355</b>	<b>297</b>	<b>19</b>	<b>0</b>	<b>350</b>
<b>Total Agency Management</b>	<b>1,135</b>	<b>125</b>	<b>13</b>	<b>713</b>	<b>1,133</b>	<b>126</b>	<b>14</b>	<b>737</b>	<b>1,128</b>	<b>126</b>	<b>14</b>	<b>731</b>

Note: \*NC stands for Non-Career

\*\*FTEs were transferred from the Chief Technologist to the Space Technology Mission Directorate after it was established in FY 2013.

# CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

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Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional FY 2017	FY 2018	FY 2019
Construction of Facilities	589.5	--	370.6	302.7	305.7	308.8	311.8
Environmental Compliance and Restoration	57.0	--	75.5	76.3	77.0	77.8	78.6
<b>Total Budget</b>	<b>646.6</b>	<b>515.0</b>	<b>446.1</b>	<b>379.0</b>	<b>382.7</b>	<b>386.6</b>	<b>390.4</b>

<b>Construction and Environmental Compliance and Restoration .....</b>	<b>CECR-2</b>
<b>Construction of Facilities .....</b>	<b>CECR-6</b>
INSTITUTIONAL COF .....	CECR-8
EXPLORATION COF .....	CECR-18
SPACE OPERATIONS COF .....	CECR-22
<b>Environmental Compliance and Restoration.....</b>	<b>CECR-26</b>

# CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

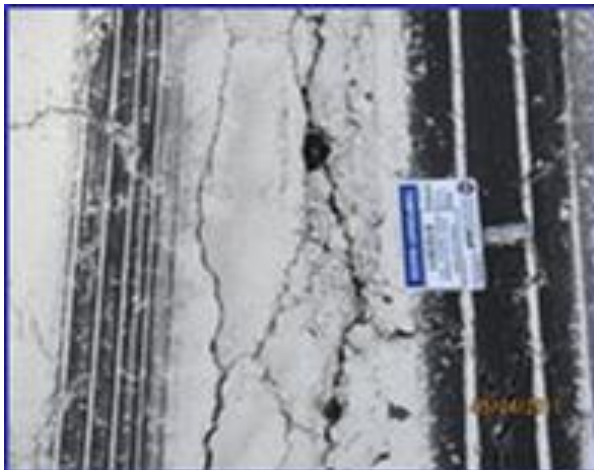
## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Construction of Facilities	589.5	--	370.6	302.7	305.7	308.8	311.8
Environmental Compliance and Restoration	57.0	--	75.5	76.3	77.0	77.8	78.6
<b>Total Budget</b>	<b>646.6</b>	<b>515.0</b>	<b>446.1</b>	<b>379.0</b>	<b>382.7</b>	<b>386.6</b>	<b>390.4</b>
Change from FY 2014			-68.9				
Percentage change from FY 2014			-13.4%				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.*



**Section of Runway at Wallops Flight Facility Deteriorated Pavement in Centerline.** This deteriorated pavement is typical of the condition at runways and taxiways throughout the airfield. NASA intends to correct the most severe pavement with an FY 15 Airfield Repair project. Additional work will be required in a second phase in the near future.

NASA designs and implements construction of facilities projects, facility demolition projects, and environmental compliance and restoration activities through its Construction and Environmental Compliance and Restoration (CECR) account.

Construction of Facilities (CoF) makes capital repairs and improvements to NASA's infrastructure and provides NASA projects and programs with the test, research, and operational facilities required to accomplish their missions. About 82 percent of NASA's infrastructure and facilities are beyond their constructed design life, thus posing elevated and rising risk to current and future missions. Aging, Apollo-era legacy infrastructure is inefficient and costly to maintain and operate, and assets over 40 years old pose a significant risk to NASA's unique research and development mission. To address these challenges, NASA's CoF program focuses on reducing and modernizing NASA's infrastructure into fewer, more efficient and sustainable facilities.

# CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

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Environmental Compliance and Restoration (ECR) projects clean up pollutants released into the environment during past activities. NASA prioritizes these cleanups to protect human health and the environment, and preserve natural resources for future missions.

Together, these construction and remediation activities help ensure that NASA's assets are ready, available, and appropriately sized to conduct NASA's missions.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

Refer to Construction of Facilities and Environmental Compliance and Restoration sections.

## ACHIEVEMENTS IN FY 2013

During FY 2013, NASA:

- Completed the demolition of 82 structures at various sites in FY 13. Demolition of inactive and obsolete facilities eliminates the cost of maintaining old, abandoned facilities in a safe and secure condition. Significant completed demolition projects include the demolition of Test Stand 4696 at the Marshall Space Flight Center, which was an Apollo era rocket engine test stand.
- Began construction of the following projects:
  - Launch Command Center, Wallops Flight Facility
  - High Pressure Industrial Water, Stennis Space Center
  - Arc Jet Boiler, Ames Research Center
  - West Arroyo Parking Structure, Jet Propulsion Laboratory
- Completed construction of the following projects:
  - Shipping and Receiving Facility, Glenn Research Center
  - Consolidated IT Center, Dryden Research Center
- At the Santa Susana Field Laboratory (SSFL), the ECR program issued a Draft Environmental Impact Statement for the Proposed Demolition and Environmental Cleanup Activities, completed the multi-year interim soil removal action (ISRA) program by removing approximately 15,000 cubic yards of contaminated soil, continued ongoing groundwater sampling to investigate seeps, faults, source zone areas, and to refine flow models, continued operation of the Groundwater Extraction and Treatment System (GETS), which removes contaminants from groundwater and helps prevent off-site migration and continued on-going long-term monitoring of groundwater wells and seeps for the purposes of verifying contaminant movement.

## WORK IN PROGRESS IN FY 2014

Exploration Construction of Facilities activities in FY 2014 focus on meeting the requirements of the Space Launch System program. Projects include restoration of the B-2 test stand at Stennis Space Center.

To support Space Operations activities, work continues on the 21st Century Launch Complex at Kennedy Space Center and the 34-meter antenna system at Canberra.



# CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

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Planned Institutional CoF projects will protect the Agency's critical assets, improve mission assurance, reduce mission risk, and maintain mission essential capabilities. These include utility system repairs and replacement of obsolete buildings, such as the administrative building at the Kennedy Space Center Central Campus and Marshall Space Flight Center Building 4220, which is currently 95% complete. Other work in progress includes installation of environmental compliance hardware, refurbishment/replacement of helium compressors, and continuation of the Replace High Pressure Industrial Water Systems projects at the Stennis Space Center.

Additionally, NASA is replacing the Electrical Distribution System at Wallops Island in support of launch and vehicle processing, and the Central Air Compressors at Glenn Research Center providing compressed air for research throughout the campus.

In FY 2014, NASA's ECR program plans cleanup activities at all NASA Centers, with priority given to protecting human health and the environment in balance with Environmental Protection Agency and state regulatory agreements and requirements. The investigation and cleanup of contaminated groundwater, soils, and demolition of facilities at Santa Susana Field Laboratory in accordance with the State of California consent order with along with the completion of the Environmental Impact Statement reflects this Agency priority.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

Construction activities planned include:

- Major repair by replacement projects at Johnson Space Center (JSC) and Langley Research Center (LaRC) that will correct deficiencies noted by the National Academies of Science and support core NASA research efforts.
- Repairs and upgrades at all Centers to mitigate near-term risk to missions by revitalizing electrical, mechanical, life safety, and utility systems;
- Investments to reduce energy cost and consumption;
- Demolition of obsolete facilities;
- Construction for Space Operations activities to support Space Communication and Navigation and the 21st Century Space Launch Center; and
- Construction for Exploration activities to support Space Launch System, Orion Multi-Purpose Crew Vehicle (MPCV), and Exploration Ground Systems
- NASA will begin discussing with GSA, and allocating resources toward an options analysis for, the plan requested by the US House Committee on Transportation and Infrastructure directing GSA to provide a final OMB approved housing plan that provides for Federal Government ownership of the NASA Headquarters.

Environmental Compliance and Restoration activities planned include:

- Continuing cleanup of ground water contamination and investigation of soil contamination at White Sands Test Facility, to include completion of closure activities, implementation of source area facility investigations, long-term monitoring of groundwater and continued operation of the plume front and mid-plume ground water treatment systems

# CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

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- Continuing investigation and cleanup of groundwater and soil contamination at Kennedy Space Center, planned activities include the installation of new groundwater treatment systems, extensive removal of contaminated soils, investigation of additional sites for potential contamination, continued sampling of over 400 monitoring wells, and continued operations of groundwater cleanup systems
- Operating and maintaining systems to clean up contaminated groundwater emanating from Jet Propulsion Laboratory and continued operations of the Lincoln Avenue and Monk Hill drinking water treatment systems
- Investigation and cleanup of contaminated groundwater and soils, operations of groundwater treatments systems and continued long-term monitoring of the groundwater at Santa Susana Field Laboratory
- Continuing operations of treatment systems and monitoring at AFRC, Goddard Space Flight Center (GSFC), SSC, and WFF.
- Completing active cleanup activities and continuing long-term monitoring at ARC, GRC, and Michoud Assembly Facility (MAF)

The CECR program would utilize \$93.7 Million from the Opportunity, Growth, and Security Initiative to construct the Measurement Sciences Laboratory (MSL) complex at the LaRC.

Construction of the MSL complex will consolidate and modernize existing aging technical facilities at LaRC. The new complex will provide state-of-the-art lab facilities supporting research and development initiatives unique to the Agency in support of all of NASA's mission areas.

Further details on the MSL project are provided in the Opportunity, Growth, and Security Initiative section of this document.

## CONSTRUCTION OF FACILITIES

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
Institutional CoF	313.1	--	299.7	302.7	305.7	308.8	311.8
Exploration CoF	252.6	--	52.3	0.0	0.0	0.0	0.0
Space Operations CoF	20.8	--	18.6	0.0	0.0	0.0	0.0
Science CoF	3.0	--	0.0	0.0	0.0	0.0	0.0
<b>Total Budget</b>	<b>589.5</b>	<b>--</b>	<b>370.6</b>	<b>302.7</b>	<b>305.7</b>	<b>308.8</b>	<b>311.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.*



**Artist Rendering of the Human Health and Performance Laboratory.** This facility will replace 7 deficient buildings and provide modern open concept labs which are flexible and improve collaboration. The facility will be vital to NASA's research in understanding human performance in space and mitigating space flight risks to crews.

NASA's CoF program includes programmatic and non-programmatic construction projects that reduce facility-related risk to mission success and increase sustainability.

The Institutional CoF program designs and constructs non-programmatic facilities projects. Utility system repairs and replacements improve the reliability of NASA's infrastructure and reduce operational consumption of energy (steam, electricity, and gas). Refurbishment and repair by replacement projects replace inefficient, deteriorated buildings with efficient high performance facilities. Demolition projects eliminate facilities that are no longer needed.

Together these activities help reduce operating costs and develop a sustainable and energy efficient infrastructure to enable NASA's missions.

Programmatic CoF provides critical capabilities in testing and development that directly support NASA's current missions. These projects modify NASA facilities to provide specific technical requirements to manufacture, test, process, or operate hardware for NASA programs. These projects are identified by NASA flight and research programs as specific changes to NASA technical capabilities essential to the success of NASA programs.

Projects with initial cost estimates between \$1 and \$10 million are included in the program as minor revitalization and construction projects. Projects with initial cost estimates of \$10 million or greater are

## **CONSTRUCTION OF FACILITIES**

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budgeted as discrete projects. Projects with initial cost estimates of \$1 million or less are accomplished by routine day-to-day facility maintenance and repair activities provided for in program and Center Management and Operations budgets.

### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

The FY 2015 request for Construction of Facilities includes funding to achieve Space Launch System, Orion MPCV, Exploration Ground Systems, 21st Century Launch Complex, and Space Communications and Navigation requirements. FY 2015 funds to support these programmatic construction requirements were transferred from Exploration and Space Operations accounts. Funding associated with all program designs and out-year programmatic construction activities remains in program accounts.

# Construction and Environmental Compliance and Restoration: Construction of Facilities

## INSTITUTIONAL CoF

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>313.1</b>	<b>--</b>	<b>299.7</b>	<b>302.7</b>	<b>305.7</b>	<b>308.8</b>	<b>311.8</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.*



**Artist Rendering of the repair by replacement office building 4221. This is the second major replacement building in MSFC's Main Administrative Complex. This facility will complete the northern end of the North Campus portion of the MSFC Master Plan. Building 4221 will replace the 50 year old Building 4201 with an energy and operationally efficient office structure. The building will provide state-of-the-art office space for approximately 450 people.**

NASA's Institutional CoF program includes programmatic and non-programmatic projects supporting two overarching Agency goals:

- Reduce facility-related risks to mission success, property, and personnel. CoF projects include repairs and/or improvements to NASA's existing facilities based on a prioritized system using a risk informed process; and
- Increase sustainability and environmental friendliness. These projects support NASA's core capabilities within a smaller, more efficient footprint. Projects include replacement of old, obsolete, costly facilities with new, high performance facilities that consolidate core functions and improve flexibility over the life of the facilities. These replacement facilities incorporate new technologies

and are designed with flexibility so they can address programmatic requirements, both known and still evolving over the next 40 years.

NASA's demolition program eliminates obsolete, un-needed infrastructure to improve efficiency and eliminate safety and environmental risks.

NASA's recent Institutional CoF program efforts are beginning to demonstrate the intended results. Since 1995, NASA has reduced energy usage by 17 percent. In FY 2013, NASA's deferred maintenance, which is an estimate of the essential but unfunded maintenance work necessary to bring all facilities up to standards, decreased 1.5 percent from FY 2012 levels.

## **INSTITUTIONAL CoF**

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### **EXPLANATION OF MAJOR CHANGES IN FY 2015**

None.

### **ACHIEVEMENTS IN FY 2013**

In FY 2013, NASA completed construction of the following projects:

- Installation of the JSC Arc Jet at ARC.
- Building 26 Renovation at GSFC

### **WORK IN PROGRESS IN FY 2014**

In FY 2014, construction continues on the Flight Project Center at GSFC and the Integrated Services Building at LaRC. We expect to complete shoreline restoration work at KSC following Hurricane Sandy and begin shoreline restoration at Wallops Island.

Utility system repairs and replacements will improve reliability throughout NASA's infrastructure and reduce the risk of utility caused failures.

Construction will begin on the replacement of the administrative buildings at KSC and MSFC. This project and other planned repair-by-replacement projects will replace old, inefficient buildings with smaller, more efficient buildings.

Demolition projects are underway to dispose of unneeded facilities.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

Planned CoF activities are detailed below.

We will begin repair of the WFF Airfield and the first phase of the compressors at LaRC. Additionally, we will begin a plan to replace access gates to improve security and safety at the JPL. We intend to begin installation of a renewable energy system (photovoltaics) at MSFC. Additionally, we intend to award seven electrical distribution systems projects to improve the reliability of critical infrastructure at NASA Centers.

NASA will continue to demolish unneeded facilities in support of NASA's goals to reduce the Agency footprint.

## **Institutional Discrete Construction of Facility Projects**

Discrete construction of facilities projects are those with initial cost estimates of \$10 million or greater.

### **CONSTRUCT HUMAN HEALTH AND PERFORMANCE LABORATORY**

Location: JSC, TX

FY 2015 Construction Estimate: \$52.0 million, Total Project FY 2015 to FY 2017 is \$57.0 million

#### **Scope/Description**

This project provides for repair by replacement of the 1960's era Building 37 Life Sciences Laboratory along with six outlying buildings located in the 200 area into a consolidated Human Health and Performance Laboratory with an approximate size of 117,878 square feet. The existing facilities (132,000 square feet) will be demolished. Increased density due to the efficient floor plan will allow for some research personnel and labs, not currently residing in the existing facilities due to space limitations, to be housed in the new facility.

The facilities provide critical ongoing program support including ground-based and in-flight medical operations. The applied research identifies, characterizes and mitigates the risks to human health and performance in space to enable successful space exploration. Spaceflight hazards that impact human health and performance include microgravity, radiation, isolation, closed environment, and distance from earth. Risks to human spaceflight include bone loss, sleep disorders, behavioral health issues, immune suppression, muscle atrophy, radiation exposure, environmental exposures, cardiovascular deconditioning, and autonomous medical care. Mitigations developed through research include technologies, countermeasures, preventions, treatments, requirements and standards. Science performed addressing the known risks include development of exercise countermeasures, physiological countermeasures, space radiation biology, behavioral health and performance, space human factors and habitability, exploration medical capability, and environmental monitoring.

The new facility will have a north wing and a south wing to contain the Human Performance and the Biomedical and Environmental wet labs (two floors), respectively; the top floor will accommodate the mechanical equipment and house the National Archive Sample Repository Freezer storage; and a two-story office block that will consist primarily of open workstation architecture. The new building will house approximately 290 people and will save approximately \$0.65 million in maintenance and utility costs annually. The facility will be designed to achieve a minimum LEED Silver rating, and will strive to meet LEED Gold.

#### **Basis of Need**

Building 37 Life Sciences Lab is in a deteriorated state and is substandard, inefficient, and inadequate to support the Human Health and Performance research and countermeasures development. Since construction in 1967 as the Lunar Receiving Laboratory Facility, the Life Sciences Lab function has changed significantly. The design of the highly specialized but inefficient HVAC system controlled potential contamination related to the lunar missions. The equipment has become unreliable and difficult to repair, as well as nearly impossible to modify to support mission changes. Failures of the HVAC system caused work stoppages and high lab temperatures delayed crew tests and damaged equipment. An obsolete underground shelter initially provided an isolated location to control potential lunar return

## INSTITUTIONAL CoF

contamination. This contributed to the failure of the building foundation system. In spite of past repairs, the building exhibits signs of wall cracks, window wall separation, and slab failure. The electrical distribution system of the building is undersized to support the instrument demand. Power spikes compromised samples and destroyed equipment, and unplanned outages caused sample loss. The steam system and plumbing system failures occur on a routine basis. The repair work orders increased at a rate of 30 percent per year, and over fiscal year 2012 and 2013 there were 1,088 repair work orders in building 37 alone.

The numerous system failures have impacted the research by compromising samples, damaging equipment, delaying crew tests, and causing work stoppages in the labs. The buildings are also located in the 500 year flood plain and are at high risk for extended downtime during a strong Category 4 hurricane. During Hurricane Ike (Category 2) building 37 was subject to power loss with backup generator failure. As a result some sample freezers have been relocated to a remote facility to prevent further loss of samples. Substandard lab conditions hamper both research and community partnering efforts.

Other Related Costs	Amount
PER/ Studies	\$1,119,387
Design	\$4,310,733
Outfitting	\$2.5M
Other	N/A

Estimated Schedule	Start	Complete
Design	Jul 2012	Jul 2014
Construction	Dec 2014	Dec 2016
Activation	Jan 2016	Jun 2016
Demolition	Oct 2017	Dec 2018

## SANITARY SEWER SYSTEM RECAPITALIZATION

Location: SSC, MS

FY 2015 Estimate: \$10.0 million

### Scope and Description

This project provides for refurbishments to the sanitary sewer system at SSC, including the following items: (a) Refurbishment of the South Lagoon to accommodate flow requirements and to increase retention time for proper sewage treatment; (b) Replacement and upgrade of energy management control systems (EMCS), electrical and mechanical equipment as required; (c) Modification of gravel access road as necessary; (d) Replacement of outdated lift stations and deteriorated sections of sewage piping.

### Basis of Need

Existing piping and equipment is original construction, exceeded life cycle, and became unreliable and beyond economic repair. Replacement of equipment is required to provide continued reliability, accommodate current flows, maintain proper retention time, and prevent environmental excursions. Also, under the current configuration, retention time within the lagoon is less than required through EPA permitting on many occasions. There is loss of reliability with many lift stations because the existing concrete and steel wells are deteriorating and need replacement with new fiberglass wells. Installation of EMCS capability for approximately 40 lift stations site-wide is needed to prevent excursions from high levels. In addition, deterioration of piping allowed for inflow and infiltration (I&I) in the base gravity system allowing excess storm water to be transferred into the lagoons. When excursions do occur, NASA can incur environmental fines of \$25,000 per day per excursion, leading to a potential shutdown of entire system.



## INSTITUTIONAL CoF

Other Related Costs	Amount
Design	\$0.7M
Outfitting	N/A
Other	N/A

Estimated Schedule	Start	Complete
Design	Jan 2013	Apr 2013
Construction	May 2015	Jul 2017
Activation	N/A	N/A

### REPAIR BY REPLACEMENT OFFICE BUILDING 4221

Location: MSFC, AL

FY 2015 Estimate: \$39.8 million

#### Scope/Description

The Repair by Replacement Office Building 4221 is the second major replacement building in the MSFC Main Administrative Complex. This facility completes the northern end of the North Campus portion of the Center Master Plan. Building 4221 replaces the 50-year-old Building 4201 with an energy and operationally efficient office structure. The building will provide state-of-the-art office space for approximately 450 people. The facility will meet LEED Silver criteria, as well as the MSFC standard energy conservation requirements to ensure low operating costs for the life of the facility. This project will include the demolition of building 4201 in FY 2016, totaling approximately 111,000 square feet and will eliminate over \$4.5 million of deferred maintenance.

#### Basis of Need

The new building will replace a deteriorated, high-maintenance, high operating cost building (B4201). It will provide state-of-the art offices to allow the efficient consolidation and co-location of a multi-discipline work force that has been widely dispersed throughout MSFC thereby improving functional efficiency and coordination between the various operations. Building 4201 was originally constructed in 1964 and is not suitable for renovation due to its advanced age, its configuration, the presence of friable asbestos, and code compliance issues such as Americans with Disabilities Act (ADA) compliance. A replacement facility is a more cost effective solution that will provide significant operating and energy cost savings. Construction of this new building at this location and the subsequent demolition of Building 4201 are both consistent with the MSFC Master Plan.

Other Related Costs	Amount
Design	\$1.0M
Outfitting	\$7.7M
Other	

Estimated Schedule	Start	Complete
Design	Feb 2013	Jan 2014
Construction	Oct 2014	Aug 2016
Activation	Sep 2016	Dec 2016

## INSTITUTIONAL CoF

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### REPAIR AIRFIELD, WFF (GSFC)

Location: WFF, VA

FY 2015 Estimate: \$19.5 million, Total Project FY 2015 to FY 2017 is \$29.5 million

#### Scope/ Description

This project will provide critical repairs to sections of the WFF Airfield to include runways, taxiways and aircraft parking aprons. This work includes: concrete slab reconstruction; full and partial depth concrete repairs; concrete spall repairs; concrete joint replacements and repairs; and asphalt crack sealing and overlays.

#### Basis of Need

A 2011 survey conducted by the Naval Facilities Engineering Command recommended \$29.5 million of repairs over the next few years. The survey rated sections of pavement as “very poor” and the survey also recommended reconstruction of large sections of the airfield. Foreign Object Damage hazard is evident on sections of the runways and taxiways. Without investment sections throughout the airfield will deteriorate to a point at which aircraft operations will not be recommended. Deterioration could result in a complete loss of this critical asset.

The WFF Airfield is used by multiple Airborne Science aircraft (P-3C, 2 C-23s, UH-1 helicopter and a C-130) and is critical to the east coast deployment of aircraft such as the DC-8, ER-2, and Global Hawk unmanned aerial system operations. The airfield provides support to the Wallops Range with clearance and recovery aircraft, International Space Station Resupply logistics for Cygnus capsules and air shipment for the Sounding Rocket Program field campaigns. The airfield supports projects such as the Science Mission Directorate HS3 and ICEBRIDGE. The airfield provides direct access into the restricted airspace of the launch range.

Other Related Costs	Amount
Studies/Design	\$2.5M
Outfitting	N/A
Activation	N/A
Other	N/A

Estimated Schedule	Start	Complete
Design	Sep 2013	Sep 2014
Construction	Sep 2015	Sep 2017
Activation	N/A	N/A

## INSTITUTIONAL POWER SYSTEMS SAFETY & RELIABILITY UPGRADE

### PHASE 1 OF 5

Location: KSC, Merritt Island, Florida

FY 2015 Estimate: \$15.0 million, Total Project FY 2015 to FY 2017 is \$61.0 million

#### Scope/Description

This is the first of a 5-phase project to upgrade and increase the reliability and safety of the KSC institutional power system. Phase 1 is to modify KSC's C5 and Orsino Substations to reduce arc-flash energy within KSC manholes; refurbish Launch Complex 39 Area Emergency Power Plant generator

## INSTITUTIONAL CoF

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control and load bank systems; repair and rehabilitate the C5 Substation bus structures; and, replace degraded and obsolete power cables, duct banks, switchgear, and transformers at various locations.

The five-phased approach allows work to commence in large but manageable geographic areas that reduces the number of power outages within that area; reduces construction disruptions by eliminating repetitive work in the same areas; and, allows for the correction of critical safety-related issues.

### Basis of Need

The KSC institutional power system is mission essential. The system provides electrical power to all facilities throughout the Center. The system is more than 50 years old and near the end of its useful life. The cables are submerged and electrical equipment corroded because of KSC's proximity to the coast. Delay in implementation of this project will lead to significant increases in unscheduled outages and maintenance cost.

System failure can result in injury or death, loss of workforce productivity, and impact to spacecraft processing or Center operations. These electrical systems support critical operations such as KSC Space Launch Systems and Ground Support Development Programs. The electrical system serves Launch Complex 39, Vertical Assembly Building, Launch Control Center, Rotation Processing Surge Facility, Assembly and Refurbishment Facility, Logistics Facility, Propellants North, Electrical Maintenance Facility, Orbiter Processing Facilities (1-3), Administrative Office, Buildings (OSB 1 and 2), Shuttle Landing Field, Saturn V Facility, Haulover Canal Bridge, Mid-Course Radar Facility, Operations and Checkout Building, Multi-Payload Processing Facility, Payload Hazardous Servicing Facility, and Space Station Processing Facility. The project will improve employee safety and system reliability by upgrading and modifying primary substations to reduce arc flash; replacing power systems to provide safe, reliable, and cost effective power to KSC facilities.

Other Related Costs	Amount
Studies/Design	\$1.2M
Related Equipment	
Activation	\$0.8M
Other	

Estimated Schedule	Start	Complete
Design	Sep 2013	Sep 2014
Construction	Jan 2015	Mar 2017
Activation	Jan 2016	Mar 2017

## REPLACE B1247E COMPRESSORS #1, #2, AND #3

Location: LaRC, VA

FY2015 Construction Estimate: \$15 million

### Scope/Description

Replacing B1247E Compressors #1, #2, and #3 will improve system performance, reliability, operational availability, and maintainability of the compressors and associated ancillary systems. The project will replace the compressors, associated foundations, and ancillary air-drying, backpressure control, power, coolant, lubricant, air, vent, and instrumentation systems. The project also replaces Oil-Water Separator and the Condensate Floor Drain systems. The project will make modifications to the building structure to facilitate crane upgrades. Compressors 1, 2, and 3 will be replaced with a single eight lb./sec (minimum) compressor rated at 6,000 psi. The compressors and ancillary systems will be designed and sized to efficiently operate as an integrated system.

## INSTITUTIONAL CoF

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### Basis of Need

The mission of the B1247E Compressor Station is to provide users with a dependable supply of high-pressure air on a daily basis in sufficient quantity and quality to support their research/operations. The B1247E Compressor Station is a critical asset that provides high-pressure air to approximately 25 research facilities (wind tunnels) at the Center. In 2004, several serious issues with the compressors and their infrastructure were discovered. A significant amount of resources were invested to return the facility to proper working order. The scope, duration, and expense of this refurbishment expanded as the work progressed and more issues were uncovered. The NASA Safety Center (NSC) performed an independent assessment of the operational reliability of the Compressor Station to determine the merits of continuing to refurbish the existing compressors and infrastructure or immediately begin a repair-by-replacement campaign. The NSC recommended replacing all of the compressors and the respective ancillary support systems since they are well beyond their design life. Based on the NSC recommendation, LaRC is pursuing the cost-effective approach of replacing the compressors and associated ancillary systems. This approach will increase system performance, reliability, operational availability, and maintainability enabling the Center to satisfy researcher high-pressure air demand in support of high-priority Agency programs.

Other Related Costs	Amount
Studies/Design	\$1.0M
Related Equipment	
Activation	\$0.1M
Other	

Estimated Schedule	Start	Complete
Design	Apr 2013	Jun 2014
Construction	Mar 2015	Oct 2016
Activation	Oct 2016	May 2017

### Minor Revitalization and Construction of Facilities

Minor revitalization and construction of facilities projects have initial cost estimates between \$1 million and \$10 million. These projects revitalize and construct facilities at NASA facility installations and government-owned industrial plants. Revitalization and modernization projects provide for the repair, modernization, and/or upgrade of facilities and collateral equipment. Repair projects restore facilities and components to a condition substantially equivalent to the originally intended and designed capability. Repair and modernization work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. Modernization and upgrade projects include restoration of current functional capability and enhancement of the condition of a facility so that it can more effectively accomplish its designated purpose, increase its functional capability, or so that it can meet new building, fire, and accessibility codes.

The minor revitalization and construction projects that comprise this request are of the highest priority, based on relative urgency, and expected return on investment. During the year, some rearrangement of priorities may be necessary, which may cause a change in some of the items to be accomplished.

## **INSTITUTIONAL CoF**

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### **MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, \$84.8 MILLION**

#### **ARC, \$10.0 million**

Replace Varnished Cabric Lead Cables  
Restore Electrical Reliability of Agency Telecom Gateway, Building N245

#### **AFRC, \$16.9 million**

Repair Electrical Substation #3  
Repair Communications, Building Electrical Systems  
Revitalize Industrial/Potable Water Distribution System

#### **GRC, \$14.1 million**

Repair Electrical Distribution System, Phase 2  
Repair Steam Distribution System

#### **GSFC, \$6.7 million**

Replace Fire Island Station, WFF

#### **JPL, \$4.5 million**

Fortify Security Gates

#### **JSC, \$5.7 million**

Repair Water System Infrastructure, Large Altitude Simulation System, White Sands Test Facility

#### **KSC, \$8.0 million**

Revitalize Water and Waste Water Systems, Various Locations, Phase 5 of 5  
Central Campus, Phase 1 Outfitting

#### **MSFC, \$15.4 million**

Revitalize Central Chilled Water Facility Electrical, Building 4473  
Revitalize Building Electrical Systems, Building 4708

#### **SSC, \$3.5 million**

Rehabilitate/Replace Cathodic Protection

## **Energy Savings Investments**

FY 2015 Estimate: \$12.0 million

Energy Savings Investments funds enable NASA to implement projects focused on reducing the energy cost and consumption of existing facilities and operations. Installation of a chilled water thermal energy storage system at KSC will reduce energy costs by generating and storing chilled water during off-peak electricity rate hours for use during more expensive peak hours. At MSFC, installation of a solar photovoltaic system will provide a renewable source of energy to reduce reliance on conventional electricity.

## **INSTITUTIONAL CoF**

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### **Demolition of Facilities**

FY 2015 Estimate: \$15.0 million

NASA will use the requested funding to eliminate inactive and obsolete facilities that are no longer required for NASA's mission. Abandoned facilities pose potential safety and environmental liabilities and are eyesores at the Centers. The Agency must maintain these facilities at minimal levels to prevent increasing safety and environmental hazards and these recurring maintenance costs impose a drain on the limited maintenance dollars available at the Centers. Demolishing these abandoned facilities allows the Agency to avoid non-productive operating costs required to keep abandoned facilities safe and secure. Furthermore, demolition is the most cost-effective way to reduce the Agency deferred maintenance.

NASA identifies facilities for the demolition program through special studies to determine if the facility is required for current or future missions. Facilities that are no longer needed are included in a five-year demolition plan that sets project schedules based on last need, annual costs avoided, potential liability, and project execution factors.

### **Facility Planning and Design**

FY 2015 Estimate: \$36.6 million

Facility planning and design funds provide for advance planning and design activities, special engineering studies, facility engineering research, preliminary engineering efforts required to initiate design-build projects, preparation of final designs, construction plans, specifications, and associated cost estimates associated with non-programmatic construction projects. This includes master planning; value engineering studies; design and construction management studies; facility operation and maintenance studies; facilities utilization analyses; engineering support for facilities management systems; and capital leveraging research activities. Funding also supports participation in facilities-related professional engineering associations and organizations.

The facilities planning and design activity is crucial to the implementation of NASA recapitalization strategy. These projects are necessary to make progress toward required sustainability, energy, and stewardship goals.

## EXPLORATION CoF

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>252.6</b>	<b>--</b>	<b>52.3</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.*



At Kennedy Space Center (KSC) the Launch Abort System Facility was modified to support processing of the Launch Abort System for EFT-1. Multiple contracts were awarded to modify the Vehicle Assembly Building (VAB), Launch Complex 39B, Hypergolic Maintenance Facility pump house, and other minor projects.

Exploration CoF provides construction required to achieve SLS, Orion MPCV, and Exploration Grounds Systems program activities. Funds required for the planning and design of out-year programmatic construction remain in the applicable program accounts.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

FY 2015 funds are lower than previous years because the majority of the construction projects required to support Exploration program requirements are being completed with prior year funds. Discrete construction funds are still required to complete the KSC VAB and Launch Complex 39B.

### ACHIEVEMENTS IN FY 2013

During FY 2013, NASA continued transitioning from the Space Shuttle and Constellation programs to Exploration. At the Michoud Assembly Facility (MAF) legacy Space Shuttle External Tank tooling and manufacturing areas were modified to support SLS Core Stage manufacturing. Construction was completed at the Vertical Weld Center (VWC) and the first SLS Core Stage tank barrel section was welded together for testing. Modifications continue to be made to accommodate the Vertical Assembly Center (VAC) for the SLS Core Stage elements; thermal protections system application; liquid oxygen and hydrogen tank cleaning, priming and proof testing; and final integration of the SLS Core Stage.

At MSFC, NASA began construction of two structural test stands that will be used to structurally test SLS Core Stage liquid hydrogen tank, liquid oxygen tank, and aft skirt.

## **EXPLORATION CoF**

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### **WORK IN PROGRESS IN FY 2014**

Exploration CoF activities in FY 2014 focuses on meeting the requirements of the Exploration program. At SSC, work will continue on the B-2 Test Stand and High Pressure Industrial Water system. At MAF construction will be completed at Building 131 Cells M, N and P for external cleaning, priming and thermal protection system application. Construction will also be completed in Building 451 for proof testing, Building 110 Cells B and C for the VAC, Cell E for tank internal cleaning and Cell F for liquid oxygen (LOX) hydrostatic proof load testing. Work will continue in Building 103 for SLS final assembly and integration, and will commence on improvements to the levee, roadways and aprons to accommodate SLS Core Stage transit.

At KSC, Exploration projects will continue in the VAB and Launch Complex 39B. In addition, work will commence to construct VAB high bay access platforms. The Orion Program will initiate a second phase project at KSC to modify the Launch Abort Test Facility. At MSFC, construction will commence on two SLS Core Stage Tank structural test stands.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

Major work in FY 2015 includes the construction of:

- Exploration discrete projects to modify the KSC VAB and Launch Complex 39B
- Exploration minor projects at KSC

### **Discrete Projects**

Discrete projects are construction projects with initial cost estimates greater than \$10 million.

### **MODIFICATIONS TO LAUNCH COMPLEX 39B**

Location: KSC, FL

FY 2015 Construction Estimate: \$33.1 million, Total Project FY 2010 to FY 2016 is \$85.0 million

#### **Scope/Description**

The project modifies and upgrades Launch Complex 39B to support launching of the NASA SLS, Orion crew vehicle, and other launch vehicles. Work elements include repairs to the pad surface and catacomb roof, modifications to the sound suppression system, modifications to replace the LOX vaporizer system, pad modifications to the interfaces with the new Mobile Launcher, replacement of fire and potable water piping systems, and refurbishment of the HVAC and control systems. Other planned work elements include modifications to the lightning protection and weather systems, refurbishment and modification of the flame trench, and replacement of the main flame deflector system.

This is the third phase of a four-phased project budgeted at \$85.0 million.



## EXPLORATION CoF

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### Basis of Need

The modifications and new construction are mandatory to transform the Launch Complex 39B from the Shuttle Program to meet the requirements for SLS, Orion, and other multi user launch vehicle operations and programs. Launch Complex 39B is over 40 years old and the deteriorated condition and inadequate configuration of many of the systems and infrastructure will not support use for the new launch program without the extensive repairs, modifications and upgrades identified above. Failure to implement this project will seriously impact our ability to transition and sustain the use of this launch complex to support SLS and Orion crew vehicle.

Other Related Costs	Amount	Estimated Schedule	Start	Complete
Studies/Design	\$8.0M	Design	Apr 2009	Jun 2012
Related Equipment	\$0.5M	Construction	Apr 2011	May 2015
Activation	\$3.5M	Activation	Apr 2015	Jun 2016

## REPAIRS AND MODIFICATIONS TO VEHICLE ASSEMBLY BUILDING

Location: KSC

FY 2015 Construction Estimate \$15.2 million, Total Project FY 2012 to FY 2016 is \$148.2 million

### Scope/Description

This project repairs and modifies selected facility systems in the VAB, Launch Control Center (LCC), and VAB Utility Annex (UA) area to enable SLS spacecraft processing and launch operations. Work elements in the VAB/LCC include demolition and removal of the existing Shuttle platforms and installation of a new platform system in High Bay 3, replacement of the fire suppression water supply distribution system supporting the VAB, refurbishment of the low voltage systems in Towers D & F of the VAB, repair of the VAB concrete ceiling, refurbishment of the VAB 175-ton bridge crane, repair and modification of the chilled/hot/potable water piping systems in the VAB, and a variety of other miscellaneous infrastructure and facility system repairs throughout the VAB/LCC complex including modification of the fire suppression water supply to the LCC. The project also includes system upgrades in the UA to improve energy efficiency, reduce operations and maintenance costs, and provide right-sized equipment capacity to support future program needs.

This is the fourth phase of the project budgeted at \$148.2 million. This phase continues construction of a re-configurable high bay facility to process, integrate and assemble the SLS launch vehicle.

### Basis of Need

The VAB is a fifty-story building with multi-level access platforms and associated support infrastructure. Facility systems such as power, water, compressed gasses, communications, and fire suppression, are located inside the building to support rocket assembly operations. The UA supplies the VAB, LCC, and other facilities in the LC-39 area with hot water, chilled water, compressed air, and fire suppression water. Launch operations are controlled within the LCC, which is physically attached to the VAB. The repairs and modifications provided for by this project must be completed in time to support future SLS launches because there are no other facilities that have the size or capabilities necessary to otherwise support SLS assembly operations.

## EXPLORATION CoF

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The VAB is uniquely designed to receive, assemble, integrate, process, and service large, complex launch vehicles. No other facility in the United States has this basic capability. The VAB must be reconfigured from the current Shuttle-support configuration to a configuration that can support the SLS. This includes the supporting utility systems as well as the facility itself. In addition, the fire suppression system in the VAB is about 50 years old and the piping has experienced significant internal corrosion, affecting the flow capacity and causing leaks that cumulatively amount to about 5,000 gallons per week. The system is no longer serviceable in its current state and will be restored to meet National Fire Protection Association life-safety code standards.

Other Related Costs	Amount	Estimated Schedule	Start	Complete
Studies/Design	\$9.0M	Design	Apr 2011	Feb 2013
Related Equipment	\$1.0M	Construction	Jun 2012	Jun 2016
Activation	\$4.0M	Activation	May 2015	Sep 2016

## Minor Revitalization and Construction of Facilities

Construction projects with initial cost estimates between \$1 million and \$10 million are included as minor revitalization and construction projects. These projects provide for the repair, modernization, or upgrade of facilities and collateral equipment required by Exploration activities. Repair projects restore facilities and components to a condition substantially equivalent to the originally intended and designed capability. Repair and modernization work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. Modernization and upgrade projects include both restoration of current functional capability and enhancement of the condition of a facility, so that it can more effectively serve its designated purpose, increase its functional capability, or so that it can meet new building, fire, and accessibility codes.

The FY 2015 request includes \$4.0 million dollars for projects focused on investments to refurbish support infrastructure to support Exploration program requirements.

### MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, \$4.0 MILLION

#### KSC, \$4.0 million

Replace Chillers, BFF

## Construction and Environmental Compliance and Restoration: Construction of Facilities

# SPACE OPERATIONS CoF

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>20.8</b>	<b>--</b>	<b>18.6</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

*Funds associated with out-year estimates for programmatic construction remain in programmatic accounts.*



The DSS -35 Antenna at Canberra, Australia, one of 2 new Antennas (the other being DSS-36) as part of the architecture upgrades. The project will support additional mission loading from spaceflight missions currently under development and scheduled for launch in 2015 and beyond. DSS-56 and DSS-53 in Madrid, Spain, will be similar.

Space Operations CoF provides construction to support 21st Century Space Launch Complex (21st CSLC) and Space Communications and Navigation (SCaN). Funds required for planning and design of out-year programmatic construction remain in the applicable program accounts.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

Construction for Deep Space Station (DSS) 56 at the Madrid Deep Space Communications Complex (MDSCC) is commencing one year earlier than planned due to deteriorating conditions of concrete pedestals which support the MDSSC 70 meter DSS-63 and 34 meter DSS-54. As a result, the third 34 meter antenna DSS-33 at Canberra, Australia will be delayed by 3 years.

### ACHIEVEMENTS IN FY 2013

In Canberra Australia, construction of DSS-35 antenna continued and construction of DSS-36 antenna commenced. At Goldstone, SCaN replaced azimuth tracks on a 34-meter antenna.

### WORK IN PROGRESS IN FY 2014

The SCaN discrete project to complete construction of the 34-meter antennas in Canberra, Australia continues. SCaN, 21st CSLC at KSC and Launch Services Program will have minor construction projects.

### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

The DSS- 35 Antenna in Canberra, Australia is scheduled for completion in October 2014. The SCan discrete project to construct the DSS-36 34-meter antennas in Canberra, Australia will continue. DSS-36 site work began in October 2012 and when excavation was completed, construction was redirected to DSS-35. Construction was then restarted in October 2013 with concrete work on the pedestal and steel fabrication for the antenna superstructure. DSS-36 completion is scheduled for December 2016.

SCaN will also begin construction of a multi-year funded discrete project to construct two new 34-meter Beam Wave Guide (BWG) DSS Antennas DSS-56 and DSS-53 at Madrid, Spain. SCan and 21st CSLC at KSC will have minor construction projects.

### **Discrete Projects**

Discrete projects are construction projects with initial cost estimates greater than \$10 million.

### **CONSTRUCTION OF 34 METER BEAM WAVE GUIDE ANTENNAS – CANBERRA**

Location: Canberra Deep Space Communications Complex, Canberra, Australia.

FY 2015 Construction Estimate: \$2.8 million, Total Project FY 2010 to FY 2021 is \$84.5 million.

#### **Scope/Description**

This project constructs two new 34-meter beam wave guide antennas at the Canberra Deep Space Communications Complex (CDSCC) with an option to build a third. The basic contract provides for the initial construction of DSS-35 and DSS-36. The third antenna DSS-33 may be an option to the contract. As DSS-33 is an option, actual location and approach to construction for this antenna are yet to be determined.

The project is divided into three contracts: excavation and roads, site infrastructure, and antenna related facilities. The funding for fiscal year 2015 is \$2.8 million of the total \$84.5 million.

The project includes the fabrication and installation of the antenna structures, panels, gearboxes, bearings, electric drives, encoders, beam wave guide mirrors, sub-reflectors and positioners, and related servomotors. The project also includes the construction of the pedestals, as well as all facilities in and around the antennas, including the paved access roads, trenches, drainage, flood control devices, water main and distribution system, antenna apron, perimeter security fence, HVAC systems, electrical power distribution, fire detection and suppression system, and surveillance system assembly.

#### **Basis of Need**

The construction of these antennas is planned as Phase 1 of the SCan Deep Space Network (DSN) Aperture Enhancement Project (DAEP). Analysis of outer planet declinations reveals a growing bias toward the southern declination well into the 2020's. It is projected that spacecraft mission needs in the southern hemisphere will begin to overload capacity at the CDSCC by 2015. This project is necessary to allow beam wave guide antennas to add resilience in the southern hemisphere for the Deep Space Network. Additionally, the 70-meter antennas at each Complex are closer to end of service. This project

## SPACE OPERATIONS CoF

will support additional mission loading from spaceflight missions currently under development and scheduled for launch in 2015 and beyond.

Other Related Costs	Amount
Studies/Design	\$0.5M
Related Equipment	N/A
Activation	N/A
Other	N/A

Estimated Schedule	Start	Complete
Design	Sep 2009	Oct 2010
Construction, DSS-35	Sep 2010	Dec 2013
Activation, DSS-35	Sep 2014	Sep 2014
Construction, DSS-36	Oct 2012	Dec 2015
Activation, DSS-36	Dec 2016	Dec 2016

### CONSTRUCTION OF 34 METER BEAM WAVE GUIDE ANTENNAS – MADRID

Location: Madrid Deep Space Communications Complex, Canberra, Australia.

FY 2015 Construction Estimate: \$4.1 million, Total Project FY 2015 to FY 2019 is \$57.75 million.

#### Scope/Description

This project constructs two new 34-meter beam wave guide antennas at the MDSCC and provides for the construction of DSS-56 and DSS-53.

The project is divided into three contracts: excavation and roads, site infrastructure, and antenna related facilities. The funding for fiscal year 2015 is \$4.1 million of the total \$57.75 million.

The project includes the fabrication and installation of the antenna structures, panels, gearboxes, bearings, electric drives, encoders, beam wave guide mirrors, sub-reflectors and positioners, and related servomotors. The project also includes the construction of the pedestals, as well as all facilities in and around the antennas, including the paved access roads, trenches, drainage, flood control devices, water main and distribution system, antenna apron, perimeter security fence, HVAC systems, electrical power distribution, fire detection and suppression system, and surveillance system assembly.

#### Basis of Need

The construction of these antennas is planned as Phase 2 of the SCan DAEP and was originally scheduled to begin after completion of the third optioned antenna at Canberra, however two existing antennas at Madrid are showing considerable concrete degradation in their pedestals; DSS-63 70-meter and DSS-54 34-meter. NASA decided to begin construction of the two 34-meter antennas at Madrid in FY15 as a contingency against future long-term maintenance downtimes of the existing 70-meter and 34-meter antennas.

## SPACE OPERATIONS CoF

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Other Related Costs	Amount
Studies/Design	\$0.5M
Related Equipment	N/A
Activation	N/A
Other	N/A

Estimated Schedule	Start	Complete
Design	Oct 2013	Sep 2014
Construction, DSS-56	Sep 2014	Dec 2017
Activation, DSS-56	Dec 2017	Dec 2017
Construction, DSS-53	Sep 2016	Dec 2019
Activation, DSS-53	Dec 2019	Dec 2019

### Minor Revitalization and Construction of Facilities

Construction projects with initial cost estimates between \$1 million and \$10 million are included as minor revitalization and construction projects. These projects provide for the repair, modernization, or upgrade of facilities and collateral equipment required by Space Operations activities. Repair projects restore facilities and components to a condition substantially equivalent to the originally intended and designed capability. Repair and modernization work includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. Modernization and upgrade projects include both restoration of current functional capability and enhancement of the condition of a facility, so that it can more effectively serve its designated purpose, increase its functional capability, or so that it can meet new building, fire, and accessibility codes.

### **MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, \$11.7 MILLION**

#### **JPL, \$6.9 Million**

Seismic Upgrades to Various Buildings, Goldstone Deep Space Communication Complex  
Site-wide Uninterruptible Power Supply, Canberra Deep Space Communication Complex

#### **KSC, \$4.8 Million**

Mechanical Upgrades  
Lighting Upgrades

## ENVIRONMENTAL COMPLIANCE AND RESTORATION

### FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>57.0</b>	<b>--</b>	<b>75.5</b>	<b>76.3</b>	<b>77.0</b>	<b>77.8</b>	<b>78.6</b>

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*



NASA is working with the State of Virginia Department of Environmental Quality and EPA Region III to clean up contaminated soils and groundwater at Wallops Island, Virginia. Pictured here is the removal of one of two 125,000 gallon fuel tanks being demolished and removed in an effort to restore the site. All contaminated materials were removed and approximately 805 tons of concrete and 270 tons of metal were recycled. Groundwater sampling and testing verified that no groundwater contamination was present.

NASA's Environmental Compliance and Restoration (ECR) program cleans up hazardous materials and wastes that have been released to the surface or groundwater at NASA installations, NASA-owned industrial plants supporting NASA activities, current or former sites where NASA operations have contributed to environmental problems, and other sites where the Agency is legally obligated to address hazardous pollutants. ECR program activities include projects, studies, assessments, investigations, sampling, plans, designs, construction, related engineering, program support, monitoring, and regulatory Agency oversight. Funding also covers land acquisitions necessary to ensure operation of remedial treatment processes and sites as part of remediation and cleanup measures.

For additional information concerning NASA's ECR program, go to: <http://www.nasa.gov/offices/emd/home/ecr.html>.

### EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

### ACHIEVEMENTS IN FY 2013

In FY 2013, NASA continued to execute restoration activities at all NASA Centers and Facilities. Most notably, the following restoration activities were accomplished in FY13:

## **ENVIRONMENTAL COMPLIANCE AND RESTORATION**

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- At the SSFL, the ECR program issued a Draft Environmental Impact Statement for the Proposed Demolition and Environmental Cleanup Activities, completed the multi-year interim soil removal action program by removing approximately 15,000 cubic yards of contaminated soil, continued ongoing groundwater sampling to investigate seeps, faults, source zone areas, and to refine flow models, continued operation of the Groundwater Extraction and Treatment System, which removes contaminants from groundwater and helps prevent off-site migration and continued ongoing long-term monitoring of groundwater wells and seeps for the purposes of verifying contaminant movement.
- The MSFC completed a record of decision for the cleanup of petroleum contaminated sites and began implementation of cleanup activities at the former Stauffer Chemical Plant site.
- The White Sands Test Facility continued operating the plume front and mid-plume front treatment systems to capture and treat contaminated groundwater. They also continued source area investigations and began closure activities of the sewage lagoon.
- At the JPL, the program continued to operate and maintain systems to clean up contaminated groundwater emanating from JPL as well as to continue operations of the Lincoln Avenue and Monk Hill drinking water treatment systems.

### **WORK IN PROGRESS IN FY 2014**

Major restoration project achievements planned for FY 2014 include:

- Investigation and cleanup of contaminated groundwater, soils, and demolition at SSFL in accordance with the consent order with the State of California, completion of the Environmental Impact Statement, and begin implementing demolition of facilities
- Continued operations and maintenance of systems to clean up contaminated groundwater emanating from JPL; achievements include installation of two new recovery wells, connection of existing backwash system to the treatment facility, and continued operations of the Lincoln Avenue and Monk Hill drinking water treatment systems
- Continued investigation and cleanup of groundwater and soil contamination at KSC in accordance with State of Florida requirements; key achievements planned include the installation of new groundwater treatment systems, extensive contaminated soil removal, investigation of additional sites for potential contamination, continued sampling of over 400 monitoring wells, and continued operations of groundwater cleanup systems
- Continued cleanup of ground water contamination and investigation of soil contamination at White Sands Test Facility, to comply with the facility permit issued by the State of New Mexico; key achievements include completion of closure activities, implementation of source area facility investigations, and continued operation of the plume front and mid-plume ground water treatment systems
- Continued cleanup studies, investigations and completion of the cleanup of the peninsula solid waste disposal site at the ARC



## **ENVIRONMENTAL COMPLIANCE AND RESTORATION**

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### **KEY ACHIEVEMENTS PLANNED FOR FY 2015**

Key projects and achievements in the FY 2015 request include:

- \$12.0 million for continuing cleanup of ground water contamination and investigation of soil contamination at White Sands Test Facility, to comply with the facility permit issued by the State of New Mexico; key achievements include completion of closure activities, implementation of source area facility investigations, long term monitoring of groundwater and continued operation of the plume front and mid-plume ground water treatment systems.
- \$10.5 million for continuing investigation and cleanup of groundwater and soil contamination at KSC in accordance with State of Florida requirements; key achievements planned include the installation of new groundwater treatment systems, removal of contaminated soils, investigation of additional sites for potential contamination, continued sampling of over 400 monitoring wells, and continued operations of groundwater cleanup systems
- \$12.1 million to operate and maintain systems to clean up contaminated groundwater emanating from JPL; and continued operations of the Lincoln Avenue and Monk Hill drinking water treatment systems;
- \$15.4 million for investigation and cleanup of contaminated groundwater and soils, operations of groundwater treatments systems and continued long term monitoring of the groundwater at SSFL in accordance with the consent order with the State of California.

### **Program Elements**

#### **RESTORATION**

Restoration projects address cleanup liabilities at all NASA Centers and component facilities. As of the start of FY 2014, known liabilities totaled \$1.1 billion with many of the individual cleanup projects estimated to take more than 30 years to complete. NASA policy is to address these liabilities using a “worst first” approach to ensure human health and the environment are protected and to facilitate mission readiness. Plans for FY 2015 are based on a prioritized, risk-based approach for incrementally addressing NASA’s cleanup portfolio. Projects are ranked according to the relative urgency and the potential health and safety hazards related to each individual cleanup. As studies, assessments, investigations, plans, regulatory approvals, and designs progress, and as new discoveries or regulatory requirements change, NASA expects that program priorities may change.

#### **ENVIRONMENTAL COMPLIANCE & FUNCTIONAL LEADERSHIP**

These projects invest in environmental methods and risk reduction practices that ensure NASA may continue to carry out its scientific and engineering missions. This includes methodologies for sustainably reducing energy intensity and greenhouse gas emissions, and supporting operational activities by ensuring that advances in chemical risk management are incorporated early in mission design phases. For example, NASA is working with the European Space Agency on an international agreement to investigate methods of increasing energy and water resiliency in critical space mission supporting infrastructure thus, increasing that infrastructure reliability. This is being done through proposed sustainability projects with the above design emphasis in mind.

## INSPECTOR GENERAL

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Budget Authority (in \$ millions)	Actual	Enacted	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Total Budget	35.3	37.5	37.0	37.4	37.7	38.1	38.5

**Inspector General..... IG-2**

# INSPECTOR GENERAL

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## FY 2015 Budget

Budget Authority (in \$ millions)	Actual FY 2013	Enacted FY 2014	Request FY 2015	FY 2016	Notional		
					FY 2017	FY 2018	FY 2019
<b>Total Budget</b>	<b>35.3</b>	<b>37.5</b>	<b>37.0</b>	<b>37.4</b>	<b>37.7</b>	<b>38.1</b>	<b>38.5</b>
Change from FY 2014			<b>-0.5</b>				
Percentage change from FY 2014			<b>-1.3%</b>				

*Note: As reflected in the August 2013 Operating Plan, FY 2013 includes rescissions per P.L. 113-6 Division G, Section 3001(b)(1)(B) and Division G, Section 3004(c)(1) and reductions due to sequestration per BBEDCA Section 215A.*

*FY 2014 reflects funding amounts specified in P.L. 113-76, Consolidated Appropriations Act, 2014, including amounts noted in the Explanatory Statement. Where amounts were not specified, no amount is shown in the budget table.*

For fiscal year (FY) 2015, the NASA Office of Inspector General (OIG) requests \$37.0 million to support the work of 197 auditors, investigators, analysts, specialists, lawyers, and support staff located at NASA Headquarters in Washington, D.C. and 12 other locations throughout the United States.

The OIG conducts audits, investigations, and reviews of NASA programs to prevent and detect fraud, waste, abuse, and mismanagement and to assist NASA management in promoting economy, efficiency, and effectiveness in its programs and operations. Our two primary offices are the Office of Audits (OA) and the Office of Investigation (OI).

OA conducts independent and objective audits of NASA programs, projects, operations, and contractor activities and oversees the work of the independent public accounting firm that conducts the annual audit of NASA's financial statements. In its work, OA targets high-risk areas and NASA's top management challenges. OIG audits provide independent assessments and actionable recommendations that help NASA achieve its space exploration, scientific, and aeronautics research missions.

OI pursues allegations of cybercrime, fraud, waste, abuse, and misconduct related to NASA programs, projects, personnel, operations, and resources. OI refers its findings to the Department of Justice for criminal prosecution and civil litigation or to NASA management for administrative action. Through its investigations, OI develops recommendations for NASA management to reduce the Agency's vulnerability to criminal activity or administrative inefficiency. Given that NASA spends approximately 80 percent of its budget on contracts and grants, OI targets its resources to maintaining the integrity of NASA's procurement process and the safety of NASA's mission and information systems. In the procurement area, OI's caseload includes investigations of suspected false claims submitted by NASA contractors, product substitution and counterfeit parts, and conflict of interest cases involving NASA employees who place private gain before public service.

## EXPLANATION OF MAJOR CHANGES IN FY 2015

None.

# INSPECTOR GENERAL

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## ACHIEVEMENTS IN FY 2013

In FY 2013, the OIG issued 18 audit products and identified \$184 million in potential savings for NASA.

Audit products included reports examining NASA's:

- Efforts to develop commercial cargo and crew transportation capabilities to the International Space Station;
- Progress in reducing underutilized facilities and infrastructure;
- Information technology governance, which is critical to ensuring its computer systems are secure and operate efficiently;
- Explosives Safety Program;
- Progress in adopting cloud-computing technologies;
- Use of award fee contracts; and
- Actions to comply with federal requirements governing conferences.

In FY 2013, OI investigated a wide variety of criminal and administrative matters involving procurement fraud, theft, counterfeit parts, ethics violations, and computer intrusions leading to more than \$40 million in criminal, civil, and administrative penalties and settlements. More than \$7.3 million of these funds were returned directly to NASA. Overall, OI's efforts in FY 2013 resulted in 27 indictments, 25 convictions, 13 civil settlements, 48 administrative actions, and 22 suspensions and debarments.

Examples of OI's work over the past year include:

- Convictions of six corporate executives from two Virginia security firms who illegally obtained more than \$31 million in government contracts intended for disadvantaged small businesses. The executives were ordered to pay more than \$7.8 million in restitution and four of them received prison sentences ranging from 24 to 72 months.
- A government contractor agreed to a \$2 million civil settlement and to provide the Government with \$2.4 million worth of electronic parts to resolve allegations under the False Claims Act. The company submitted false claims to the Department of Defense and NASA for defective and non-conforming aviation life-saving equipment.
- Indictments of two Nigerian hackers in their home country for their involvement in an international phishing and spamming group that targeted U.S. Government agencies, including NASA.
- A former NASA scientist agreeing to pay \$15,000 to settle charges that he violated Federal conflict of interest laws by drafting a statement of work shortly before retiring that created a position for him with a NASA contractor.

## WORK IN PROGRESS IN FY 2014

During FY 2014, the OIG will continue to conduct audits, reviews, and investigations of NASA programs and operations to prevent and detect fraud, waste, abuse, and mismanagement and to assist NASA in promoting economy, efficiency, and effectiveness. Ongoing audit work includes reviews of NASA's plans to extend the life of the International Space Station, its management of Space Act Agreements, efforts to ensure the security of the Agency's public websites, and its actions to identify and mitigate

# INSPECTOR GENERAL

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near-Earth objects. In addition, the OIG is conducting the first in a series of planned audits examining NASA's oversight and management of its space communication networks.

## KEY ACHIEVEMENTS PLANNED FOR FY 2015

Going forward, the OIG will continue to focus its audit work in the areas the OIG identifies as NASA's top management and performance challenges. For 2014 we listed those challenges as:

- Considering Whether to Further Extend the International Space Station;
- Developing the Space Launch System and its Component Programs;
- Securing Commercial Crew Transportation Services;
- Maintaining Cost and Schedule for the James Webb Space Telescope;
- Ensuring Continued Efficacy of the Space Communications Networks;
- Overhauling NASA's Information Technology Governance Structure;
- Ensuring the Security of NASA's Information Technology Systems;
- Managing NASA's Infrastructure and Facilities; and
- Ensuring the Integrity of the Contracting and Grants Processes.

The FY 2015 request is \$37.0 million. The OIG will continue to identify opportunities for more efficient spending in accordance with the November 2011 Executive Order on "Promoting Efficient Spending."

The FY 2015 request includes:

- \$31.1 million (84 percent of the proposed budget) for personnel and related costs including salaries, benefits, monetary awards (if permitted), worker's compensation, permanent change of station costs, and Government contributions for Social Security, Medicare, health and life insurance, retirement accounts, and Thrift Savings Plan accounts. Salaries include the required additional 25 percent law enforcement availability pay for criminal investigators.
- \$0.9 million (2 percent) for travel, associated per diem at current rates, and related expenses. This is a reduction from prior years because of OIG success in using videoconferencing and other technologies to reduce the need for travel.
- \$3.0 million (8 percent) to fund the required annual audit of NASA's financial statements.
- \$2.0 million<sup>1</sup> (6 percent) for equipment, training, government vehicles, special equipment for criminal investigators, transit subsidies, and information technology equipment unique to the OIG.

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<sup>1</sup> In accordance with Public Law 110-409, the Inspector General Reform Act of 2008, the Inspector General certifies that \$0.4 million for staff training and \$0.1 million to support the Council of Inspectors General on Economy and Efficiency satisfy all known training requirements and planned contributions to the Council.

## OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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Through the Bipartisan Budget Act of 2013 (BBA), Congress came together on a bipartisan basis and took an important first step toward replacing the damaging cuts caused by sequestration with longer-term reforms. Recognizing the importance of the two-year budget agreement Congress reached, the President's Budget adheres to the BBA's discretionary funding levels for 2015, giving Congress a roadmap for how to write a budget at those levels that promotes growth and opportunity, enhances national security, and makes important reforms.

However, the BBA levels are not sufficient to expand opportunity to all Americans or to drive the growth our economy needs. The BBA replaced half the sequestration cut for 2014 but just one-fifth of the scheduled cut in the discretionary funding level for 2015. As a result, taking into account unavoidable growth in programs such as veterans' medical care and other factors, the BBA non-defense discretionary funding levels for 2015 are below the levels Congress provided in the bipartisan Consolidated Appropriations Act of 2014. They are also below the 2007 funding levels adjusted for inflation, even though the need for pro-growth investments in infrastructure, education, and innovation has only increased due to the Great Recession and its aftermath.

For that reason, the Budget also includes a separate, fully paid for \$56 billion Opportunity, Growth, and Security Initiative. The Opportunity, Growth, and Security Initiative, which will be split evenly between defense and non-defense funding, shows how additional discretionary investments in 2015 can spur economic progress, promote opportunity, and strengthen national security.

Moreover, the Opportunity, Growth, and Security Initiative is fully paid for with a balanced package of spending cuts and tax loophole closers, showing that additional pro-growth investments are easily affordable without increasing the deficit if Congress will enact common-sense spending and tax reforms.

At NASA, the Opportunity, Growth, and Security Initiative will support progress in the areas outlined below.

### Summary Budget Table:

Budget Authority (in \$ millions)	FY2015
Science	187.3
Aeronautics	43.9
Space Technology	100.0
Exploration	350.0
Space Operations	100.6
Education	10.0
Construction of Facilities and Environmental Compliance Restoration	93.7
<b>NASA Total</b>	<b>885.5</b>

# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## SCIENCE

Within the Science account, the Opportunity, Growth, and Security Initiative would provide \$187.3 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Orbiting Carbon Observatory (OCO)-3	29.3
Pre-Aerosols, Carbon and Ecosystems (PACE)	50.0
Planetary Science - extended mission funding	35.0
Radioisotope Power Systems	15.0
Research and Analysis	20.0
Wide-Field Infrared Survey Telescope (WFIRST)/Astrophysics Focused Telescope Assets (AFTA)	20.0
Earth Science research and efforts related to the Big Earth Data Initiative and Climate Data Initiative	18.0
<b>Science Total</b>	<b>187.3</b>

This funding would be utilized in the following areas:

- **OCO-3:** Provide an additional \$29.3 million to continue development of the OCO-3 mission, planned as an attached payload to the International Space Station. While other nations are planning or considering carbon dioxide-monitoring missions, OCO-3 has some unique instrument capabilities and flying OCO-3 would continue the measurements initiated by OCO-2. The funding augmentation would enable development activities to continue, including a mission Critical Design Review in FY 2015.
- **PACE:** Make available an additional \$50.0 million to accelerate PACE formulation activities, including definition of the mission design concept and initial performance requirements. These activities will ensure that the mission is ready for launch in 2020. Launching PACE in 2020 will be key to a continuous global ocean color climate data record, currently provided by the Aqua and Suomi-NPP missions. The funding augmentation would ensure that the PACE System Requirements Review occurs in FY 2015, a critical milestone in the formulation phase of the mission.
- **Planetary Science Extended Mission Funding:** Provide an additional \$35.0 million to increase support for extended missions prioritized in the upcoming 2014 Senior Review. The Budget provides funding for high priority extended missions such as Cassini and Curiosity. However, it does not provide funding to continue all missions that are likely to be highly rated in Senior Review. The funding augmentation would allow robust funding for all extended missions that are highly ranked by the 2014 Senior Review, enabling high science return at relatively low cost, instead of potentially terminating up to two missions or reducing science across many or all of them.
- **Radioisotope Power Systems:** Make available an additional \$15.0 million to accelerate technology development of Stirling power converters for future power systems for planetary or human exploration. The funding augmentation would enable completion of an engineering model for the electronic controller, and use of it to conduct qualification testing for the Stirling power converter, including environmental testing. Qualification of the Stirling converter is a critical step

## OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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in establishing any next generation radioisotope or fission power systems for planetary or human exploration.

- **Research and Analysis:** Provide an additional \$20.0 million to expand support for Research & Analysis programs that analyze data from science missions and develop new theories and concepts that enable the next generation of flight missions. This investment represents about a 2.3% increase over the requested level for all competed research, across all Science Themes. The funding augmentation would ensure that NASA makes approximately 100-150 additional research awards during FY 2015.
- **WFIRST/AFTA:** Make available an additional \$20.0 million to continue progress in pre-formulation of this mission during FY 2015. WFIRST/AFTA is the highest priority space mission recommended for this decade in the 2010 Astronomy and Astrophysics Decadal Survey of the National Academy of Sciences. The funding augmentation would enable NASA to complete risk reduction activities and additional trade studies, resulting in lowered cost and schedule risk and therefore lower (probabilistic) mission cost – or a lower likelihood of a mission cost overrun.
- **Earth Science:** Provide an additional \$18.0 million to allow a more robust implementation of NASA's contribution to the Big Earth Data Initiative and the Climate Data Initiative portion of the President's Climate Action Plan. Together, these activities promise great improvements in the tools and techniques needed to access, organize, and glean discoveries from huge volumes of digital data. This funding would also allow 15% more new selections in important research areas within the Earth science portfolio, including analysis and interpretation of data from NASA satellites, calibration and validations activities, field campaigns, and mission science teams.



# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## AERONAUTICS

Within the Aeronautics account, the Opportunity, Growth, and Security Initiative would provide \$43.9 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Vertical Lift Project	7.9
UAS operations in low-altitude airspace	6.0
Advance CFD and simulator capabilities	24.0
Flight testing advancements	6.0
<b>Aeronautics Total</b>	<b>43.9</b>

This funding would be utilized in the following areas:

- **Vertical Lift Project:** Providing an additional \$7.9 million to complete the Tiltrotor Test Rig (TTR), which is a joint effort by NASA and industry, and have it ready for testing in FY 2016. The funding would also enhance NASA's planned technology transfer to DOD on advanced propulsion concepts that are being considered for next generation vertical lift vehicles. DOD is providing a transition opportunity to develop these technologies quickly.
- **UAS operations in low-altitude airspace:** Making available an additional \$6.0 million would allow NASA to increase research to enable small UAS operations in low-altitude airspace and over populated areas.
- **Advance CFD and simulator capabilities:** Providing an additional \$24.0 million would allow NASA to add or improve capabilities associated with computational fluid dynamics including model fabrication and ground and flight testing; and laboratory and simulator advancements to improve capabilities and efficiencies in air traffic management research.
- **Flight Testing Advancements:** Making available an additional \$6.0 million would allow for flight testing advancements to add or improve mobile telemetry capability, research into autonomous flight, supersonic test capability, data acquisition and processing, and dual use capability of the support aircraft.

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## SPACE TECHNOLOGY

Within the Space Technology account, the Opportunity, Growth, and Security Initiative would provide \$100.0 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Closed Loop Life Support System: ISS Utilization	21.0
Composite Structural Technologies	18.0
Robotics Challenge	10.0
Advanced Manufacturing	7.0
Small Spacecraft Technology Demonstrations	10.0
In-Space Assembled and Manufactured Structures	6.0
NASA Innovative Advanced Technologies	6.0
HIAD-Commercial Cargo Vehicles	18.0
Lander and Ascent Vehicle Composites	4.0
<b>Space Technology</b>	<b>100.0</b>

This funding would be utilized in the following areas:

- **Closed Loop Life Support System:** ISS Utilization: Providing an additional \$21.0 million allows for a rapid prototyping effort designed to develop and test air revitalization and water recovery technologies that will reclaim precious consumables and allow NASA to more fully “close” the life support loop. As an example of the motivation for this work, current air revitalization methods on the ISS only recover about 40% of oxygen. The funding augmentation in 2015 would ensure that NASA develops prototype technologies utilizing open competition to select multiple candidate technical approaches from inside and outside of the Agency, and then down select successful prototypes for follow-on flight hardware development. Space Technology will target infusion on the ISS starting in FY 2018 as a demonstration test bed prior to use on future exploration missions. Past NASA efforts in these areas have led to advancement in equipment utilized by deep sea divers and emergency response providers, advanced water processing systems for rural and remote areas, and better indoor air purification systems.
- **Composite Structural Technologies:** Making available an additional \$18.0 million would allow Space Technology, in partnership with SLS and AES, to develop a prototype integrated composite approach for major structural components in space vehicles. The funding augmentation would enable the incorporation of composites, which would result in important programmatic enhancements by freeing up mass, allowing missions to increase capability leading to accelerated expansion of exploration and science mission objectives. More specifically, the incorporation of composites would reduce the mass of the upper stage by 25% to 30% yielding an equivalent increase of the overall on-orbit payload delivery mass. This project would have widespread applicability across industry and manufacturing domains.
- **Robotics Challenge:** Providing an additional \$10.0 million would allow the development of robots that support the continuation of DARPA’s Robotic Challenge (DRC). NASA would join DARPA in a partnership to continue the challenge by developing robots for disaster relief. The funding augmentation would ensure that NASA could provide up to eight R5 robots (an all-electric, untethered lightweight design considered the most advanced humanoid robot in existence to top competitors) and move NASA from participation as a stand along competitor to a challenge

## OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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co-sponsor partner with DARPA. This partnership would dramatically advance the maturity of these humanoid robots for future space exploration needs by leveraging multiple competitors to improve the software control and conduct hardware upgrades to R5. This will help NASA and DARPA as they develop robots that can take on some of the most dangerous tasks supporting humans in extreme environments in critical situations.

- **Advanced Manufacturing:** Making available an additional \$7.0 million would allow NASA to leverage the expertise of U.S. industry, academia, and other government agencies, via the public-private partnership of the National Network for Manufacturing Innovation (NNMI), to support the acceleration of technology development pursued within the Institutes for Manufacturing Innovation (IMIs). The funding augmentation would enable NASA to select additional technologies from NNMI solicitations thereby increasing the number of collaborators working to address the manufacturing challenges for space applications and contribute to modernizing the overall aerospace industry.
- **Small Spacecraft Technology Demonstrations:** Providing an additional \$10.0 million would allow NASA to initiate an additional new Small Spacecraft Technology solicitation to perform in-space demonstrations of small spacecraft technologies. The cost reductions possible by extending the capabilities of small spacecraft offer the potential of radically opening space to new entrants, essentially creating new markets and transforming space enterprise. The funding augmentation would ensure a new Small Spacecraft Technology solicitation in FY 2015 to perform in-space demonstrations of small spacecraft technologies. The new call will offer proposers the option to utilize the Phonesat/EDSN bus (or derivatives/equivalents) as open source architecture to reduce the cost of spacecraft design and development, keeping resources focused on technology advancement. Technology topics areas for the solicitation would include Nano Deployable Entry Technologies, Precision Formation Flying Technologies, and High Resolution Multi-Spectral Imaging.
- **In-Space Assembled and Manufactured Structures:** Making available an additional \$6.0 million would allow competitive awards to increase the technology readiness of on-orbit assembly and fabrication capabilities. A large fraction of the engineering cost and launch mass of space systems comes exclusively from the need to ensure the system survives the launch environment. Developing on-orbit assembly and fabrication capabilities would realize large reductions in costs due to the removal of the need for launch load design and testing.
- **NASA Innovative Advanced Technologies:** Providing an additional \$6.0 million would allow the NASA Innovative Advanced Concepts (NIAC) the ability to conduct a pilot solicitation open to all sources targeting innovative, very early stage, advanced technologies. This competitive opportunity will allow NASA to select innovative unanticipated technologies from a wide range of sources, bringing a much needed pathway for NASA to provide seed funding to innovative early stage technologies that offer the potential to transform future space missions. This opportunity would create an on ramp for individual entrepreneurs, NASA employees, and industry technologists ready to take early stage technologies from paper to bench testing.
- **HIAD-Commercial Cargo Vehicles:** Making available an additional \$18.0 million would allow the GCD Program the ability to build on the successful FY 2012 demonstration of a Hypersonic Inflatable Aerodynamic Decelerator (HIAD). HIADs would allow spacecraft to carry larger, heavier, and more capable, scientific instruments and other tools for exploration. The technology could also be used by commercial industry to return payloads to Earth from the International Space Station or other low Earth orbit locations. In addition, the unique materials and inflation mechanisms could have benefit in the development of other deployable and inflatable structures in many industries. The funding augmentation would ensure GCD's ability to conduct a high

## OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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energy, re-entry flight test with a 4 meter HIAD to significantly advance the technology readiness of this novel re-entry concept as early as October 2015.

- **Lander and Ascent Vehicle Composites:** Providing an additional \$4.0 million would allow Space Technology to design and develop composite primary structures and propellant tanks applicable to lander and vertical ascent vehicles. The resulting components may see demonstration on the AES-funded Morpheus lander, or other commercial vertical ascent and landing testbeds. This effort would target the replacement of metallic primary structures and tanks with lower mass composite materials. This effort would allow NASA to quantify the expected mass reduction for landers and better understand the utility and benefit of composites when scaled up to larger systems.

# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## EXPLORATION

Within the Exploration account, the Opportunity, Growth, and Security Initiative will provide \$350.0 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Commercial Crew	250.0
Space Launch System/Orion MPCV	100.0
<b>Exploration</b>	<b>350.0</b>

This funding would be utilized in the following areas:

- **Commercial Crew:** Providing an additional \$250.0 million to enhance competition in the program, and reduce the risk of a schedule slip. Through the Commercial Crew Program, NASA is partnering with industry during the crew transportation system development phase, while certifying these provider systems to carry NASA astronauts to and from the ISS. Specifically, additional funds at this time will enable early investments in necessary testing and analysis, which, along with competition, is important for astronaut safety as the crew transportation system is being developed.
- **Space Launch System/Orion:** Providing an additional \$100.0 million to Exploration Systems Development, which will support and address long lead procurements, reduce or retire technical and programmatic risks, and maintain concurrent development between Orion, Space Launch Systems, and Exploration Ground Systems. The Orion spacecraft and Space Launch System will support missions to multiple deep-space destinations extending beyond our Moon, to Mars and across our solar system. This approach aligns with NASA's mission to design and build the capability to extend human existence into deep-space. This additional investment will reduce life cycle cost and retire some risk related to the current Exploration Mission-1 and 2 launch dates.

# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## SPACE OPERATIONS

Within the Space Operations account, the Opportunity, Growth, and Security Initiative will provide \$100.6 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
International Space Station (ISS) - Cargo Flights	100.6
<b>Space Operations</b>	<b>100.6</b>

This funding would be utilized in the following areas:

- **ISS:** Providing an additional \$100.6 million, for transportation to and from ISS will prevent additional Commercial Resupply Service (CRS) flight deletions. Maintaining an adequate number of CRS flights is key to operating ISS and conducting research. These flights provide ISS with critical supplies (such as food and water), maintenance hardware, and research experiments; enable the return of science samples and hardware to Earth; and facilitate waste disposal. Not having an adequate number of resupply flights significantly reduces the amount of research that can be brought to and conducted on ISS.

# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## EDUCATION

Within the Education account, the Opportunity, Growth, and Security Initiative would provide \$10.0 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Science, Technology, Engineering, Mathematics (STEM) Education and Accountability Projects	10.0
<b>Education</b>	<b>10.0</b>

This funding would be utilized to support a diverse set of activities that complement the Agency's FY 2015 Coordinated Education portfolio and align with the goals, objectives and strategies of the Administration's Five-Year Strategic Plan on STEM Education.

- **STEM Education and Accountability Projects:** Providing an additional \$10.0 million would increase support for activities that take advantage of unique NASA assets and knowledge to advance learning and engagement in STEM via partnerships or forms of direct financial assistance for youth, including undergraduates, and for youth-serving informal education institutions. Specifically, this funding would bolster resources to support the most effective NASA education activities, as identified through internal competition. Education projects and activities previously funded by the Aeronautics Research Mission Directorate (ARMD) and Human Exploration and Operations Mission Directorate (HEOMD) may be eligible to compete for this funding.

# OPPORTUNITY, GROWTH, AND SECURITY INITIATIVE

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## CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION (CECR)

Within the CECR account, the Opportunity, Growth, and Security Initiative would provide \$93.7 million for the following activities:

Budget Authority (in \$ millions)	FY 2015
Langley Research Center Measurement Sciences Laboratory	93.7
<b>Construction and Environmental Compliance and Restoration</b>	<b>93.7</b>

This funding would be utilized in the following areas:

- **Langley Research Center (LaRC) Measurement Sciences Laboratory (MSL):** Provide an additional \$93.7 million for construction of the MSL. Facility construction would begin in 2015, providing this unique capability in 2018. The facility will correct deficiencies identified by the Aerospace Safety Advisory Panel (ASAP) and 2009 National Research Council (NRC) laboratory assessment by replacing a significant number of old and poorly maintained laboratories with modern, efficient space for engineering and research personnel. The proposed new multi-story facility will be approximately 175,000 square feet and will accommodate approximately 275 permanent staff, itinerant students, and a varying number of daily visiting Center employees, members of the public, government, academia, and industry. The new facility will provide state-of-the-art lab facilities supporting research and development initiatives unique to the Agency in support of all of NASA's mission areas.

Construction of the MSL will enable advancements in the technical areas of optics and laser/lidar, advanced sensors, electromagnetics, electronics and software intense flight systems. The MSL will integrate technical groups and functions from the Research Directorate and Engineering Directorate facilitating systems engineering solutions that span concept-to-flight. The MSL will utilize high-density office solutions that will be organized to maximize collaboration and provide approximately 40 modular research labs for numerous critical research and development functions such as electronics, lasers, clean rooms, and instrumentation. The MSL will incorporate features to pursue a certification level of Silver in accordance with the United States Green Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) program. This proposed facility will allow the consolidation of many laboratories that currently are dispersed throughout the Center. The construction of MSL has an associated demolition of approximately 283,600 square feet. As a key element in the LaRC 20-Year Revitalization Plan, the MSL enables LaRC to continue the drive towards satisfying Agency-established goals for reducing cost of ownership, facility total square footage and current replacement value (CRV). The Measurement Sciences Laboratory is an important national investment.



## **SUPPORTING DATA**

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### **Supporting Data**

<b>Funds Distribution by Installation .....</b>	<b>SD-2</b>
<b>Civil Service Full Time Equivalent Distribution.....</b>	<b>SD-5</b>
<b>Working Capital Fund.....</b>	<b>SD-7</b>
<b>Budget by Object Class.....</b>	<b>SD-10</b>
<b>Status of Unobligated Funds .....</b>	<b>SD-12</b>
<b>Reimbursable Estimates .....</b>	<b>SD-13</b>
<b>Enhanced Use Leasing.....</b>	<b>SD-14</b>
<b>Budget for Microgravity Science .....</b>	<b>SD-16</b>
<b>Budget for Safety Oversight .....</b>	<b>SD-18</b>
<b>Physicians' Comparability Allowance.....</b>	<b>SD-20</b>
<b>Budget for Public Relations .....</b>	<b>SD-22</b>
<b>Consulting Services .....</b>	<b>SD-23</b>
<b>E-Gov Initiatives and Benefits .....</b>	<b>SD-24</b>

## FUNDS DISTRIBUTION BY INSTALLATION

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### FUNDS BY MISSION BY NASA CENTER

Budget Authority (\$ in millions)	FY 2015*
Science	\$143.1
Aeronautics	\$126.8
Space Technology	\$53.3
Exploration	\$63.1
Space Operations	\$21.5
Education	\$1.0
Cross Agency Support	\$202.9
Construction and Environmental Compliance and Restoration	\$11.5
<b>Ames Research Center (ARC) Total</b>	<b>\$623.2</b>
Science	\$28.5
Aeronautics	\$56.6
Space Technology	\$14.3
Exploration	\$6.3
Education	\$0.8
Cross Agency Support	\$62.8
Construction and Environmental Compliance and Restoration	\$17.6
<b>Armstrong Flight Research Center (AFRC) Total</b>	<b>\$187.0</b>
Science	\$27.5
Aeronautics	\$128.3
Space Technology	\$97.3
Exploration	\$45.2
Space Operations	\$56.3
Education	\$1.0
Cross Agency Support	\$213.2
Construction and Environmental Compliance and Restoration	\$19.0
<b>Glenn Research Center (GRC) Total</b>	<b>\$587.7</b>
Science	\$2,141.1
Space Technology	\$88.6
Exploration	\$3.7
Space Operations	\$328.8
Education	\$1.3
Cross Agency Support	\$410.4
Construction and Environmental Compliance and Restoration	\$28.4
<b>Goddard Space Flight Center (GSFC) Total</b>	<b>\$3,002.4</b>

## FUNDS DISTRIBUTION BY INSTALLATION

Budget Authority (\$ in millions)	FY 2015*
Science	\$870.6
Space Technology	\$37.9
Exploration	\$3.6
Space Operations	\$174.2
Cross Agency Support	\$15.9
Construction and Environmental Compliance and Restoration	\$29.7
<b>Jet Propulsion Laboratory (JPL) Total</b>	<b>\$1,132.0</b>
Science	\$19.4
Space Technology	\$34.7
Exploration	\$1,200.9
Space Operations	\$2,835.3
Education	\$1.4
Cross Agency Support	\$358.4
Construction and Environmental Compliance and Restoration	\$73.6
<b>Johnson Space Center (JSC) Total</b>	<b>\$4,523.7</b>
Science	\$287.4
Space Technology	\$12.6
Exploration	\$1,156.2
Space Operations	\$178.4
Education	\$0.9
Cross Agency Support	\$355.0
Construction and Environmental Compliance and Restoration	\$95.9
<b>Kennedy Space Center (KSC) Total</b>	<b>\$2,086.3</b>
Science	\$172.2
Aeronautics	\$212.8
Space Technology	\$36.6
Exploration	\$31.8
Space Operations	\$0.4
Education	\$1.2
Cross Agency Support	\$289.7
Construction and Environmental Compliance and Restoration	\$15.6
<b>Langley Research Center (LaRC) Total</b>	<b>\$760.4</b>

## FUNDS DISTRIBUTION BY INSTALLATION

Budget Authority (\$ in millions)	FY 2015*
Science	\$140.0
Space Technology	\$40.5
Exploration	\$1,317.8
Space Operations	\$192.7
Education	\$0.9
Cross Agency Support	\$385.0
Construction and Environmental Compliance and Restoration	\$70.6
<b>Marshall Space Flight Center (MSFC) Total</b>	<b>\$2,147.6</b>
Science**	\$1,139.3
Aeronautics	\$26.6
Space Technology	\$288.1
Exploration	\$92.4
Space Operations	\$83.7
Education	\$79.5
Cross Agency Support	\$431.5
Construction and Environmental Compliance and Restoration	\$69.5
Office of Inspector General	\$37.0
<b>NASA Headquarters (HQ) and Inspector General (IG) Total</b>	<b>\$2,247.5</b>
Science	\$2.9
Space Technology	\$1.6
Exploration	\$55.0
Space Operations	\$34.1
Education	\$0.7
Cross Agency Support	\$53.8
Construction and Environmental Compliance and Restoration	\$14.7
<b>Stennis Space Center (SSC) Total</b>	<b>\$162.7</b>
<b>Total</b>	<b>\$17,460.6</b>

Note: \*Totals may not add due to rounding.

\*\*Funds will not be fully distributed to Centers until after future acquisition decisions are made. Thus, Center FY 2015 allocations should not be considered final or directly comparable to prior year allocations.

## CIVIL SERVICE FULL-TIME EQUIVALENT DISTRIBUTION

NASA's workforce continues to be one of its greatest assets for enabling missions in space and on Earth. The Agency remains committed to applying this asset to benefit society, address contemporary environmental and social issues, lead or participate in emerging technology opportunities, collaborate and strengthen the capabilities of commercial partners, and communicate the challenges and results of Agency programs and activities. The civil service staffing levels proposed in the FY 2015 budget support NASA's scientists, engineers, researchers, managers, technicians, and business operations workforce. It includes civil service personnel at NASA Centers, Headquarters, and NASA-operated facilities. The mix of skills and distribution of workforce across the Agency is, however, necessarily changing.

NASA continues to adjust its workforce size and mix of skills to address changing mission priorities, with an emphasis on industry and academic partnerships, transferring work in-house from on and near site support contracts, and a leaner fiscal environment. A civil service workforce is critical for conducting mission-essential work in research and technology. Some reduction to workforce levels in FY 2015 is necessary as the Agency seeks to match its workforce with its needs. NASA will reduce the size of the civil service workforce by more than 300 full-time equivalents from FY 2014 to FY 2015, stabilizing the workforce at approximately 17,400 full-time equivalents.

The Agency will apply the valued civil service workforce to priority mission work, adjusting the mix of skills where appropriate. Centers will explore cross-mission retraining opportunities for employees whenever possible, offer targeted buyouts in selected surplus skill areas, and continue to identify, recruit, and retain a multi-generational workforce of employees who possess skills critical to the Agency.

### CIVIL SERVICE FULL-TIME EQUIVALENT DISTRIBUTION BY CENTER

	Actual*	Estimate**	Request**	Notional**			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
ARC	1,206	1,196	1,177	1,177	1,178	1,178	1,178
AFRC	543	550	548	548	549	549	549
GRC	1,621	1,594	1,564	1,564	1,565	1,565	1,565
GSFC	3,307	3,330	3,280	3,280	3,281	3,281	3,281
JSC	3,105	3,098	3,034	3,034	3,035	3,035	3,035
KSC	2,037	2,024	1,993	1,993	1,994	1,994	1,994
LaRC	1,875	1,878	1,844	1,845	1,846	1,846	1,846
MSFC	2,420	2,406	2,358	2,358	2,363	2,363	2,363
SSC	310	317	317	317	313	313	313
HQ	1,136	1,164	1,138	1,138	1,129	1,129	1,129
NSSC	136	141	138	138	138	138	138
<b>NASA Total</b>	<b>17,697</b>	<b>17,699</b>	<b>17,392</b>	<b>17,392</b>	<b>17,391</b>	<b>17,391</b>	<b>17,391</b>
OIG	197	213	213	213	213	213	213

## CIVIL SERVICE FULL-TIME EQUIVALENT DISTRIBUTION

### FY 2015 FTE DISTRIBUTION BY ACCOUNT BY CENTER

	Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Cross Agency Support	Reimbursable / Working Capital Fund	NASA-Funded Total	Agency TOTAL
ARC	138	233	98	112	25	6	544	22	1,155	<b>1,177</b>
AFRC	114	162	18	21		5	213	15	533	<b>548</b>
GRC	79	362	153	188	159	7	613	3	1,561	<b>1,564</b>
GSFC	1,181		130	15	150	7	1,572	224	3,056	<b>3,280</b>
JSC	30		78	874	1,187	7	858		3,034	<b>3,034</b>
KSC	1		61	699	352	7	861	14	1,979	<b>1,993</b>
LaRC	221	489	130	145	3	8	838	10	1,834	<b>1,844</b>
MSFC	131		109	904	200	7	1,008		2,358	<b>2,358</b>
SSC	5		7	73	38	5	151	39	279	<b>317</b>
HQ							1,138		1,138	<b>1,138</b>
NSSC								138		<b>138</b>
<b>NASA Total</b>	<b>1,899</b>	<b>1,247</b>	<b>784</b>	<b>3,030</b>	<b>2,114</b>	<b>59</b>	<b>7,795</b>	<b>465</b>	<b>16,927</b>	<b>17,392</b>
OIG										213

## WORKING CAPITAL FUND

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NASA established the Working Capital Fund (WCF) to satisfy specific recurring needs for goods and services through use of a business-like buyer and seller approach under which NASA's WCF entities provide goods or services pursuant to contracts and agreements with their customers. The overarching aim of WCF is to promote economy, efficiency, and accountability with fully reimbursed rates by focusing on streamlining operations, extending resources, measuring performance, and improving customer satisfaction.

NASA's WCF is comprised of three entities:

- NASA Shared Services Center (NSSC);
- Solutions for Enterprise-Wide Procurement (SEWP) Government-Wide Acquisition Contract; and
- Information Technology (IT) Infrastructure Integration Program (I3P).

### WORKING CAPITAL FUNDS BUDGET SUMMARY

Spending Authority from Offsetting Collections (\$ millions)	Actual	Estimate	Request
	FY 2013	FY 2014	FY 2015
NSSC	78	83	85
SEWP	9	10	11
I3P	307	299	293
<b>Total Spending Authority</b>	<b>394</b>	<b>392</b>	<b>389</b>
Unobligated Brought Forward, Oct. 1	7	7	10
Recoveries of Prior Yr. Unpaid Obligations	2	4	0
<b>Total Budgetary Resources</b>	<b>403</b>	<b>403</b>	<b>399</b>
NSSC	79	81	85
SEWP	10	13	11
I3P	307	299	293
<b>Total Obligations</b>	<b>396</b>	<b>393</b>	<b>389</b>
<b>Unobligated Balance (end-of-year)*</b>	<b>7</b>	<b>10</b>	<b>10</b>

*\*Unobligated balance end-of-year is budgetary resources less obligation*

## **WORKING CAPITAL FUND**

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### **NASA SHARED SERVICES CENTER (NSSC)**

NSSC opened in March 2006 to provide centralized administrative processing services and customer contact center operations for support of human resources, procurement, financial management, Agency information technology (IT), and Agency business support services. NASA established NSSC, a function under the NASA Headquarters Mission Support Directorate, as a public/private partnership. NSSC has awarded its major business management and IT services contract to Computer Sciences Corporation. Typical expenditures are related to civil service workforce, support contractor, other direct procurements, and Agency training purchases.

NSSC is located on the grounds of SSC and operates in a manner that provides for transparency and accountability of costs and services. NASA has reduced its administrative costs through centralized processing at NSSC. The work performed by NSSC frees Agency resources that can then be redirected to NASA's mission of space exploration, scientific discovery, and Aeronautics.

NSSC's revenue streams include funding from the NASA Centers, mission directorates, and various NASA mission support offices. During FY 2015, NSSC will continue to offer similar services as in FY 2014 with no significant scope changes anticipated.

### **SOLUTIONS FOR ENTERPRISE-WIDE PROCUREMENT (SEWP)**

SEWP refers to operations related to the Government-Wide Acquisition Contract that was established under the authority of section 5112 of the Information Technology Management Reform Act (40 U.S.C. 1412(e)) enacted in 1996, under which NASA is designated by the Office of Management and Budget as a Federal Government Executive Agent for SEWP contracts.

SEWP was established as a WCF entity to allow all Federal agencies use of a best value tool to purchase IT product solutions and services. Under this approach, the buying power of Federal Agencies is combined to acquire best value for IT products and services very efficiently. Typical acquisitions include a wide range of advanced technologies such as UNIX-Linux, and Windows-based desktops and servers, along with peripherals, network equipment, storage devices, security tools, software, and other IT products and product-based solutions.

SEWP promotes aggressive pricing using online tools to obtain multiple, competitive quotes from vendors. On average for FY 2014, SEWP quotes have a 25-percent savings for any Federal customer using SEWP contracts. In addition, SEWP offers a low surcharge to recover NASA's costs to operate the program with an average 0.37 percent fee as compared to the Government standard of 0.75 percent. SEWP revenue is generated solely from the surcharge fees on all transactions processed. For FY 2014, the Federal government is projected to save about \$3 million in service fees (based on the difference between General Service Administration and SEWP surcharge fees) and \$32 million in overall costs for IT product solutions and services using NASA SEWP contracts.

### **IT INFRASTRUCTURE INTEGRATION PROGRAM (I3P)**

WCF operations supporting I3P began in early FY 2012. WCF enables I3P to improve the efficiency and economy in which contract services and management are provided to support NASA's IT strategic



## WORKING CAPITAL FUND

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initiatives and to increase visibility into NASA's IT budget and expenditures. Under I3P, NASA has consolidated 19 separately managed contracts into four centrally managed ones described as follows:

- The Enterprise Applications Service Technologies contract supports NASA Enterprise Applications Competency Center (NEACC) applications hosted by MSFC. The NEACC operates and maintains a broad spectrum of NASA's enterprise applications, with an emphasis on fully integrating business process expertise with application and technical knowledge. A small team of civil servants and support contractors sustain operations, implement new applications and capabilities, and provide business readiness support to the stakeholders and end-users.
- The NASA Integrated Communications Services contract provides wide and local area network, telecommunications, video, and data services hosted at MSFC.
- The Web Enterprise Service Technologies contract provides public Web site hosting, Web content management and integration, and search services. Services are hosted by GSFC and ARC. This contract transitioned to the NSSC in February 2014.
- The Agency Consolidated End-User Services contract provides program management, provisioning and support of desktops, laptops, cell phones, personal digital assistants, office automation software, and video conferencing. Services are hosted by NSSC.

I3P's consolidated contracting approach benefits NASA by providing cost saving opportunities such as the reduction in administrative burden involved with the business management of contracts and a significant reduction in procurement request transaction volume. Other I3P benefits include: the streamlining of budgeting, funding, and costing I3P services; achieving transparency through the provision of detailed customer monthly billings; and providing consolidated, consistent reporting of Agency-wide consumption of I3P-related goods and services.

I3P is unique in that revenue streams and expenditures are limited to contract costs for its four service contracts. Revenue streams include funding from the NASA Centers, NASA Mission Directorates, and various NASA mission support offices. As reflected in the FY 2015 anticipated funding level, the I3P WCF will continue to offer similar services as in FY 2014.

# BUDGET BY OBJECT CLASS

FY 2015 Estimated Direct  
Discretionary Obligations  
(\$ millions)

Code Object Class

		Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Cross Agency Support	Construction & Environmental Compliance & Restoration	Office of Inspector General	NASA Total
11.1	Full-time permanent	231	144	91	342	269	7	910	0	26	2,018
11.3	Other than full-time permanent	7	4	2	3	3	0	23	0	0	42
11.5	Other personnel compensation	2	1	1	1	1	0	7	0	0	12
11.8	Special personal service payments	0	0	0	0	0	0	1	0	0	1
11.9	<i>Subtotal Personnel Compensation</i>	<i>240</i>	<i>149</i>	<i>94</i>	<i>346</i>	<i>273</i>	<i>7</i>	<i>940</i>	<i>0</i>	<i>26</i>	<i>2,074</i>
12.1	Civilian personnel benefits	67	39	26	101	78	2	260	0	9	582
13.0	Benefits to former personnel	0	0	0	1	0	0	3	0	0	4
	<b>Total Personnel Compensation &amp; Benefits</b>	<b>307</b>	<b>188</b>	<b>120</b>	<b>447</b>	<b>351</b>	<b>9</b>	<b>1,203</b>	<b>0</b>	<b>35</b>	<b>2,659</b>
21.0	Travel & transport. of persons	19	6	5	14	12	1	15	0	1	73
22.0	Transportation of things	3	1	1	1	1,034	0	5	0	0	1,045
23.1	Rental payments to GSA	0	0	0	0	0	0	30	0	0	30
23.2	Rental payments to others	2	0	0	0	2	0	3	0	0	7
23.3	Communications, utilities & misc.	4	7	0	8	4	0	72	1	0	96
24.0	Printing & reproduction	1	0	0	0	1	0	4	0	0	6
25.1	Advisory & assistance services	107	9	26	234	98	2	171	17	0	664
25.2	Other services	212	22	21	27	86	4	261	8	1	642
25.3	Other purchases of goods & services from Government accounts	189	8	4	44	42	0	45	9	0	341
25.4	Operation & maintenance. of facilities	16	30	5	152	99	1	240	80	0	625
25.5	Research & development contracts	3,352	190	471	2,846	1,887	6	188	24	0	8,964
25.6	Medical care	0	0	0	0	0	0	6	0	0	6
25.7	Operation & maintenance of equipment	85	26	6	79	230	2	411	2	0	841
26.0	Supplies & materials	27	9	6	26	20	0	17	0	0	105

**BUDGET BY OBJECT CLASS**

FY 2015 Estimated Direct  
Discretionary Obligations  
(\$ millions)

Code Object Class

		Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Cross Agency Support	Construction & Environmental Compliance & Restoration	Office of Inspector General	NASA Total
31.0	Equipment	36	23	7	19	14	0	34	1	0	134
32.0	Land & structures	6	5	0	5	7	0	54	304	0	382
41.0	Grants, subsidies, & contributions	606	28	30	72	17	64	19	0	0	836
99.5	Below reporting threshold	0	0	4	1	0	0	0	0	0	5
<b>Other Object Classes</b>		<b>4,665</b>	<b>363</b>	<b>586</b>	<b>3,529</b>	<b>3,554</b>	<b>80</b>	<b>1,576</b>	<b>446</b>	<b>2</b>	<b>14,801</b>
<b>NASA Total, Direct</b>		<b>4,972</b>	<b>551</b>	<b>706</b>	<b>3,976</b>	<b>3,905</b>	<b>89</b>	<b>2,779</b>	<b>446</b>	<b>37</b>	<b>17,461</b>

## STATUS OF UNOBLIGATED FUNDS

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The table below displays actual and estimated unobligated balances of direct discretionary budget authority in each NASA appropriation account at the end of each fiscal year. The data is non-comparable, or based solely on an appropriation account's activity or projected activity with no adjustment to the FY 2013 or FY 2014 amounts to make them comparable to the budget structure underlying the FY 2015 request.

### UNOBLIGATED FUNDS SUMMARY BY APPROPRIATIONS ACCOUNT

Budget Authority (\$ millions)	Unobligated Balances Sept. 30, 2013	Estimated Unobligated Balances Sept. 30, 2014	Estimated Unobligated Balances Sept. 30, 2015
Science	171	125	120
Aeronautics	13	16	15
Space Technology	11	12	14
Exploration	32	68	66
Space Operations	111	84	87
Education	15	15	11
Cross Agency Support	12	15	14
Construction and Environmental Compliance and Restoration	206	170	148
Science, Exploration, & Aeronautics	0	0	0
Office of Inspector General	1	1	1
<b>NASA Total</b>	<b>572</b>	<b>505</b>	<b>476</b>

## REIMBURSABLE ESTIMATES

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NASA undertakes reimbursable agreements, where the NASA costs associated with the undertaking are borne by the non-NASA partner, when it has equipment, facilities, and services that it can make available to others in a manner that does not interfere with NASA mission requirements. As most reimbursable requests to NASA do not occur until the year of execution, the FY 2014 to FY 2015 estimates are based on an annual survey of Centers' anticipated reimbursable agreements. NASA separately budgets for and executes the three categories of reimbursable agreements listed below. Supporting data for Enhanced Use Leasing is provided on pages SD-14 to SD-15 of this section.

### REIMBURSABLE ESTIMATES BY APPROPRIATIONS ACCOUNT

Spending Authority from Offsetting Collections (\$ millions)	Actual	Estimate	Request
	FY 2013	FY 2014	FY 2015
Cross Agency Support (non-EUL)	2,250.1	2,714.7	2,564.2
Cross Agency Support (EUL)	11.5	22.1	20.4
Office of Inspector General	1.0	1.3	1.3
<b>Total</b>	<b>2,262.6</b>	<b>2,738.1</b>	<b>2,585.9</b>

## ENHANCED USE LEASING

In 2003, Congress authorized NASA to demonstrate leasing authority and collections at two Centers. In 2007 and in 2008, Congress amended that authority such that NASA may enter into leasing arrangements at all Centers. After deducting the costs of administering the leases, Centers are then permitted to retain 65 percent of net receipt revenue, and the balance is made available agency-wide for NASA. These funds are in addition to annual appropriations. To ensure annual oversight and review, the 2010 Consolidated Appropriations Act, P.L. 111-117 contains a provision that requires NASA to submit an estimate of gross receipts and collections and proposed use of all funds collected in the annual budget justification submission to Congress. There are no civil servants funded from Enhanced Use Leasing (EUL) income. The table below depicts the estimated FY 2015 EUL expenses and revenues. The amounts identified under Capital Asset Account Expenditures may be adjusted between projects listed based on actual contract award.

### SUMMARY OF FY 2015 EUL ACTIVITY

FY2015 EUL Expenses and Revenues (\$ thousands)	ARC	GSFC	KSC	MSFC	SSC	Agency	Total
Base Rent	6,329.0	29.4	527.2	250.0	82.2	4,295.1	11,512.9
Institutional Support Income	1,781.8	5.3	52.1		24.2		1,863.4
Additional Reimbursable Demand Services Requested by Lessees (including overhead)	6,678.8		252.6	53.9			6,985.3
<b>Total Lease Income</b>	<b>14,789.6</b>	<b>34.7</b>	<b>831.9</b>	<b>303.9</b>	<b>106.4</b>	<b>4,295.1</b>	<b>20,361.6</b>
Institutional Support Costs	(1,781.8)	(5.3)	(52.1)	(197.1)	(24.2)		(2,060.5)
Lease Management and Administration							
Tenant Building Maintenance and Repair	(1,851.6)						(1,851.6)
Cost to Fulfill Reimbursable Demand Services (including overhead)	(6,678.8)		(525.6)	(53.9)			(6,985.3)
<b>Total Cost Associated with Leases</b>	<b>(10,312.2)</b>	<b>(5.3)</b>	<b>(304.7)</b>	<b>(251.0)</b>	<b>(24.2)</b>		<b>(10,897.4)</b>
<b>Net Revenue from Lease Activity</b>	<b>4,477.4</b>	<b>29.4</b>	<b>527.2</b>	<b>52.9</b>	<b>82.2</b>	<b>4,295.1</b>	<b>9,464.2</b>
<b>Beginning Balance, Capital Asset Account</b>			<b>11.8</b>	<b>30.0</b>	<b>78.1</b>		<b>119.9</b>
<b>Net Revenue from Lease Activity Retained at Center</b>	<b>2,910.3</b>	<b>19.1</b>	<b>342.7</b>	<b>34.4</b>	<b>53.4</b>	<b>6,104.3</b>	<b>9,464.2</b>
<b>Total Available, Capital Assets Account</b>	<b>2,910.3</b>	<b>19.1</b>	<b>354.5</b>	<b>64.4</b>	<b>131.5</b>	<b>6,104.3</b>	<b>9,584.1</b>
Planned Maintenance, Various Buildings	1,836.1	19.1					1,855.2
Replace Roofs on Various Buildings	1,074.2						1,074.2
Repair and Modify Various Buildings			345.0				345.0
Priority Maintenance and Repair Items- All Centers						4,295.1	4,295.1
Energy and Sustainability Upgrades, Various Buildings (Various Centers)						1,809.2	1,809.2
Unobligated Carryover To Complete Prior Year Projects							
<b>Capital Asset Account Expenditures</b>	<b>2,910.3</b>	<b>19.1</b>	<b>345.0</b>			<b>6,104.3</b>	<b>9,378.7</b>
<b>Capital Asset Account Ending Balance</b>			<b>9.5</b>	<b>64.4</b>	<b>131.5</b>		<b>205.4</b>
<b>In Kind Activity</b>			<b>40.0</b>				<b>40.0</b>

## ENHANCED USE LEASING

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### DEFINITIONS

#### **Base Rent**

Revenue collected from tenant for rent of land or buildings.

#### **Institutional Support Costs**

Cost for institutional shared services such as fire, security, first responder, communications, common grounds, road, and infrastructure maintenance, and routine administrative support and management oversight (i.e., environmental).

#### **Total Rental Income**

Total gross proceeds from EUL activities for expenses due to renting NASA property.

#### **In-Kind**

Consideration accepted in lieu of rent payment (only applies to selected leases signed prior to January 1, 2009).

#### **Reimbursable Demand Services**

Services such as janitorial, communications, and maintenance that solely benefit the tenant and provided for their convenience. There is no net income received by NASA, as these payments may only cover the costs of NASA and its vendors providing these services.

## BUDGET FOR MICROGRAVITY SCIENCES

### BUDGET FOR INTERNATIONAL SPACE STATION RESEARCH

The Human Exploration and Operations Mission Directorate supports research which takes advantage of the unique environment of reduced gravity on International Space Station (ISS). Research is conducted in two broad categories of Exploration ISS Research and Non-Exploration ISS Research.

### BUDGET SUMMARY

	Actual	Estimate	Request	Notional			
Budget Authority (\$ millions)	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Exploration ISS Research	164	132	141	138	136	136	133
Non-Exploration ISS Research	151	127	146	140	142	149	148
<b>Total</b>	<b>315</b>	<b>259</b>	<b>287</b>	<b>278</b>	<b>278</b>	<b>284</b>	<b>281</b>
% of Non-Exploration to Total	48%	49%	51%	51%	51%	52%	53%

#### Exploration ISS Research

Exploration ISS Research supports the Agency's need for improved knowledge about working and living in space to enable future long-duration human exploration missions.

The Human Research Program provides research results that reduce risks to crew health and performance from prolonged exposure to reduced gravity, space radiation, and isolation during exploration missions. Research on ISS is mitigating risks to humans in space and on Earth by conducting research in human health countermeasures, space human factors and habitability, behavioral health and performance, and exploration medicine, tools, and technologies.

ISS Research investigates the underlying gravity-dependent phenomena in the following areas: fire prevention, detection, and suppression; boiling; multiphase flow of fluids; and capillary driven flow. These applied research investigations will provide the necessary data for the future design of the following space technology areas: life support systems; propellant storage; power generation; thermal control; and advanced environmental monitoring and control.

Funding for the Multi-User System Support (MUSS), which supports Exploration ISS Research, is included in the table above. The MUSS function is responsible for the integration of all ISS payloads including NASA, international partners, and non-NASA users. This includes coordinating payload completion schedules, ISS mission schedules, and the space available on the launch vehicles.

#### Non-Exploration ISS Research

NASA allocates at least 15 percent of the funds budgeted for ISS research to ground-based, free-flyer, and ISS life and physical science research that is not directly related to supporting the human space exploration program, in accordance with Section 204 of the NASA Authorization Act of 2005. The purpose is to ensure the capacity to support ground-based research leading to space-based basic and applied scientific research in a variety of disciplines with potential direct national benefits and applications that can be advanced significantly from the uniqueness of microgravity and the space environment. Additionally, this allocation allows basic ISS research in fields including physiological research, basic fluid physics, combustion science, cellular biotechnology, low-temperature physics,



## BUDGET FOR MICROGRAVITY SCIENCES

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cellular research, materials science, and plant research to be carried out to the maximum extent possible. This research helps to sustain existing U.S. scientific expertise and capability in microgravity research.

The Non-Exploration ISS Research line in the previous table also includes the Alpha Magnetic Spectrometer (AMS), and costs for MUSS support. The AMS is a particle physics and astrophysics experiment, planned for the ISS, which is searching for dark matter, anti-matter, and strange matter.

### **Center for the Advancement of Science in Space (CASIS)**

The Center for the Advancement of Science in Space (CASIS), the organization selected by NASA to manage non-NASA use of the ISS National Laboratory in conformance with direction in the 2010 NASA Authorization Act, made substantial progress toward full operating capability in 2013. They announced research selections from solicitations they received in protein crystal growth and materials research; delivered the first CASIS-funded research payloads (student investigations from three US schools) to ISS; established relationships with high tech business ecosystems in Houston, Denver and Boston; and successfully prioritized assignments to non-NASA payloads for ISS increments 37 and 38. CASIS continues to explore new opportunities to develop new research concepts for the ISS, and to implement a value-driven utilization program that brings new users to the ISS research community.

## BUDGET FOR SAFETY OVERSIGHT

The following table provides the safety and mission assurance budget estimates. This includes the agency-wide safety oversight functions as well as the estimated project specific safety, reliability, maintainability and quality assurance elements embedded within individual projects. NASA does not have a single safety oversight budget line item, but instead estimates are embedded in program, project, and mission support budgets.

### BUDGET SUMMARY FOR SAFETY OVERSIGHT

Budget Authority (\$ millions)	Actual	Estimate	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
Safety and Mission Assurance (AMO)	46.3	48.7	46.9	46.9	46.9	46.9	46.9
Institutional Operational Safety (CMO)	38.6	33.2	32.1	32.4	32.5	33.0	33.2
SMA Technical Authority (CMO)	46.8	52.1	52.7	53.1	53.4	54.0	55.0
<b>Agency-wide Safety Oversight</b>	<b>131.7</b>	<b>134.0</b>	<b>131.7</b>	<b>132.4</b>	<b>132.8</b>	<b>133.9</b>	<b>135.1</b>
<b>Program Specific</b>	<b>300.0</b>	<b>300.0</b>	<b>300.0</b>	<b>300.0</b>	<b>300.0</b>	<b>300.0</b>	<b>300.0</b>
<b>NASA Total, Safety</b>	<b>431.7</b>	<b>434.0</b>	<b>431.7</b>	<b>432.4</b>	<b>432.8</b>	<b>433.9</b>	<b>435.1</b>

### DEFINITIONS

#### Agency-Wide Safety Oversight

Agency level programs and activities that support the overarching NASA Safety and Mission Success program.

#### Safety and Mission Assurance (S&MA)

The Safety and Mission Assurance program administers and refines the pertinent policies, procedural requirements, and technical safety standards. The program participates in forums that provide advice to the Administrator, Mission Directorates, Program Managers and Center Directors who are ultimately accountable for the safety and mission success of all NASA programs, projects, and operations. Specific program responsibilities include, among other activities, managing NASA's Orbital Debris program, NASA's Electronic Parts program, and the NASA Safety Center.

#### Institutional Operational Safety

NASA's institutional operational safety program is driven by OSHA 29 CFR 1960, OSHA Standards, NPR 8715.1, NASA Safety and Health Handbook Occupational Safety and Health Programs, NPR 8715.3, and NASA's general safety program requirements. The program includes construction safety, mishap prevention program including reporting and investigations, safety training, safety awareness, the voluntary protection program, safety metrics and trend analysis, contractor insight/oversight, support to safety boards and committees, support to emergency preparedness and fire safety program, aviation safety, explosives and propellants safety, nuclear safety requirements, radiation safety protection, confined space entry, fall protection, lifting devices, pressure vessel safety, hazard reporting and abatement systems, cryogenic safety, electrical safety requirements (lock out/tag out), facility systems

## BUDGET FOR SAFETY OVERSIGHT

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safety, risk management, institutional safety policy development, visitor and public safety, and institutional safety engineering. The institutional operational safety program requires significant federal state and local coordination.

### **S&MA Technical Authority and S&MA Support**

The S&MA technical authority program includes travel and labor only for all S&MA supervisors, branch chiefs or above and designated deputies. In addition, where the principal job function of a non-supervisory S&MA person consists of rendering authoritative decisions on S&MA requirements matters relating to the design or operation of a program or project, that person's salary is included. These positions often are the lead S&MA manager positions for large programs where the decision making process is nearly a full time demand. This category does not include salary for those whose work only occasionally falls as an authority task. This includes travel funds in direct support of these individuals.

S&MA is mission support, including administrative support, which cannot be directly charged to a program. This budget includes policy development across the programs, range safety, payload safety (ground processing), independent assessments, metrology and calibration (for center), reliability and maintainability policy, center wide S&MA program integration and analysis, business and administrative support to S&MA Directorates, and quality assurance for facilities and ground support hardware.

### **Program Specific**

Project specific safety and mission assurance costs are included in individual project budgets. These costs include the technical and management efforts of directing and controlling the safety and mission assurance elements of the project. This incorporates the design, development, review, and verification of practices and procedures and mission success criteria intended to assure that the delivered spacecraft, ground systems, mission operations, and payload(s) meet performance requirements and function for their intended lifetimes. This element excludes mission and product assurance efforts directed at partners and subcontractors other than a review/oversight function, and the direct costs of environmental testing.

## PHYSICIAN'S COMPARABILITY ALLOWANCE

The Physicians' Comparability Program permits agencies to provide allowances to certain Federal physicians who enter into service agreements with their agencies to address recruitment and retention problems. Physicians' comparability allowances (PCAs) are critical to NASA's ability to retain flight surgeons and physicians, as well as support NASA's goal of maintaining a stable, high quality physician workforce. NASA's physicians are required to acquire and maintain specialized experience vital to supporting the Agency's missions on the ISS. JSC, NASA's primary user of PCAs is located in Houston, Texas and competes with some of the best medical facilities in the country. The following report summarizes NASA's use of this authority.

### PCA DATA SUMMARY

		Actual	Estimate	Request
		FY 2013	FY 2014	FY 2015
1) Number of Physicians Receiving PCAs		23	24	24
2) Number of Physicians with One-Year PCA Agreements		23	24	24
3) Number of Physicians with Multi-Year PCA Agreements				
4) Average Annual PCA Physician Pay (without PCA payment)		\$153,836	\$155,561	\$157,291
5) Average Annual PCA Payment		\$19,468	\$18,466	\$18,291
6) Number of Physicians Receiving PCAs by Category (non-add)	Category I Clinical Position	21	22	22
	Category II Research Position			
	Category III Occupational Health			
	Category IV-A Disability Evaluation			
	Category IV-B Health and Medical Admin.	2	2	2

*Note: FY 2015 data will be approved during the FY 2016 Budget cycle.*

*Average Annual PCA Physician Pay (without PCA payment) estimated with 1 percent pay increases in 2014 and 2015.*

### MAXIMUM ANNUAL PCA AMOUNT PAID TO EACH CATEGORY OF PHYSICIAN

The allowance amount authorized will be the minimum amount necessary to address the recruitment or retention problem and will be determined by considering the factors listed in 5 CFR 595.105(a).

Allowance amounts may not exceed:

- \$14,000 per annum if the employee has served as a Government physician for 24 months or less;
- \$24,000 per annum if the employee has served as a Government physician for 24-48 months; or
- \$30,000 per annum if the employee has served as a Government physician for more than 48 months.

## PHYSICIAN'S COMPARABILITY ALLOWANCE

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### RECRUITMENT AND RETENTION ISSUES

#### Category 1 Clinical Positions

There are a number of recruitment and retention challenges at JSC in Houston, TX.

- The Houston area has world-renowned medical facilities with considerably higher physician salaries than NASA is able to offer at JSC.
- Time and effort to train a new physician to fully support a mission is approximately two years. JSC's current needs for clinical physicians continue to be re-evaluated in the post-Space Shuttle era, but include the need to support the health and well-being of the International Space Station crew, support of the active astronaut corps (which gained eight new astronauts in 2013) and the operation of the Lifetime Surveillance of Astronaut Health program (which includes all retired astronauts).

JSC filled one clinical position in 2013 and the ability to offer PCA was an important factor in the candidate's accepting the employment offer. JSC plans to hire three to four physicians in the next two years in order to fully serve the Agency's needs. However, with limited hiring ability, JSC cannot backfill all vacancies. JSC's focus will be on retaining current physicians and filling positions that become vacant due to resignations and/or retirement. Being able to offer PCA has become increasingly crucial in competing with the private sector for the most qualified physicians.

#### Category IV-B Health and Medical Administration

NASA currently has two physicians receiving PCA at KSC and PCA has been an effective retention tool.

### HOW PCA ALLEVIATES RECRUITMENT AND RETENTION PROBLEMS

PCA has been very effective at NASA. The attrition rate at JSC for FY 2012 was 11.5 percent (three losses including two transfers and one retirement); for FY 2013 the attrition rate is 14 percent (three losses including one resignation and two retirements). While the attrition rate increased, it is important to note that two of the physicians who left each had 20 years of service at NASA, which demonstrates that PCA is instrumental in retaining physicians for a significant period of time. JSC anticipates that three additional physicians will retire in FY 2014 and several others will reach retirement eligibility in the next five years.

KSC is not currently experiencing retention issues. KSC plans to decrease the current PCA amounts in FY 2014 and continue decreasing the amount of PCA in FY 2015 to prevent a negative impact on the net income of the two physicians.

### ADDITIONAL INFORMATION

With decreasing procurement funds expected in FY 2014 and beyond, retaining essential civil service physicians will become increasingly critical to maintaining core competencies and fulfilling mission objectives. The Federal pay freeze of the past three years and prospect of a continuing pay freeze or small pay increases in the next few years affect the ability to retain qualified physicians at NASA, making the need for PCA even greater.

## BUDGET FOR PUBLIC RELATIONS

The NASA budget for Public Affairs is funded within Cross Agency Support under Center Management and Operations and Agency Management and Operations. All the Installations listed below, except for Headquarters, are in the Center Management and Operations account and the Headquarters budget is in the Agency Management and Operations account.

These budgets include dissemination of information to the news media and the general public concerning NASA programs. Content includes support for public affairs/public relations, Center newsletters, internal communications, guest operations (including bus transportation), public inquiries, NASA TV, the <http://www.nasa.gov> portal, and other multimedia support.

### NASA PAO BUDGET SUMMARY, BY CENTER

Budget Authority (\$ millions)	Actual	Estimate	Request	Notional			
	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
AFRC	1.3	1.2	1.2	1.3	1.3	1.3	1.4
ARC	2.6	2.5	2.5	2.5	2.5	2.5	2.5
GRC	2.6	2.9	2.9	2.9	2.9	2.9	2.9
GSFC	5.2	4.7	4.9	5.1	5.3	5.5	5.7
HQ	14.8	14.4	12.9	12.9	12.9	12.9	12.9
JSC	7.5	7.3	7.4	7.6	7.6	7.6	7.6
KSC	5.4	5.6	5.7	5.8	5.9	6.0	6.2
LaRC	2.5	2.6	2.6	2.6	2.6	2.7	2.8
MSFC	4.5	4.7	4.7	4.7	4.7	4.8	4.8
SSC	1.9	2.0	2.0	1.9	1.9	1.7	1.8
<b>NASA Total</b>	<b>48.3</b>	<b>47.8</b>	<b>46.9</b>	<b>47.4</b>	<b>47.7</b>	<b>48.0</b>	<b>48.6</b>

*Note: Public Affairs per baseline service level definition, as part of the Cross Agency Support Budget*

## CONSULTING SERVICES

NASA uses paid experts and consultants to provide advice and expertise beyond that which is available from its in-house civil service workforce. Management controls ensure that there is ample justification for consulting services before these services are obtained. Much of the Agency's expert and consultant support is for the NASA Advisory Council and the Aerospace Safety Advisory Panel. NASA uses experts and consultants to provide expertise on the selection of experiments for future space missions. The use of these experts and consultants provides the Agency with an independent view that assures the selection of experiments likely to have the greatest scientific merit. Other individuals provide independent views of technical and functional problems in order to provide senior management with the widest possible range of information to support making major decisions.

### NASA CONSULTING SERVICES BUDGET SUMMARY

	Actual	Estimate	Request
	FY 2013	FY 2014	FY 2015
Number of Paid Experts and Consultants	32.0	32.0	32.0
Annual FTE Usage	7.0	7.0	7.0
Salaries	\$0.3M	\$0.3M	\$0.3M
Total Salary and Benefits Costs	\$0.3M	\$0.3M	\$0.3M
Travel Costs	\$0.1M	\$0.1M	\$0.1M
<b>Total Costs</b>	<b>\$0.4M</b>	<b>\$0.4M</b>	<b>\$0.4M</b>

A broader definition of consulting services could include the total object class "Advising and Assistance Services" as shown in the Supporting Data Budget by Object Class section of this volume.

	Actual	Estimate	Request
(Cost in \$ millions)	FY 2013	FY 2014	FY 2015
Advisory and Assistance Services	694.0	698.0	664.0

### DEFINITIONS\*

#### Consultant

A person who can provide valuable and pertinent advice generally drawn from a high degree of broad administrative, professional, or technical knowledge or experience. When an agency requires public advisory participation, a consultant also may be a person who is affected by a particular program and can provide useful views from personal experience.

#### Expert

A person who is specially qualified by education and experience to perform difficult and challenging tasks in a particular field beyond the usual range of achievement of competent persons in that field. An expert is regarded by other persons in the field as an authority or practitioner of unusual competence and skill in a professional, scientific, technical, or other activity.

\* These definitions are located under 5 CFR 304.102. The appointments are made under 5 U.S.C. 3109, and the use of this authority is reported annually to Office of Personnel Management (OPM).

## E-GOV INITIATIVES AND BENEFITS

### E-GOVERNMENT FUNDING CONTRIBUTIONS AND SERVICE FEES BY INITIATIVE

NASA is providing funding contributions in FY 2015 for each of the following E-Government initiatives:

<b>Initiative</b>	<b>2015 Contributions (Includes In-Kind) (\$ millions)</b>	<b>2015 Service Fees* (\$ millions)</b>
E-Rulemaking 026-999990060		10,000
Grants.gov 026-999990160	155,066	10,000
Grants Management LoB (Research.gov) 026-999991300		
E-Training 026-999991217		1,465,000
Recruitment One-Stop 026-999991218		111,438
Enterprise HR Integration 026-999991219		308,800
E-Payroll 026-9999991221		
E-Travel 026-999990220		1,932,319
Integrated Acquisition Environment (IAE) 026-999990230	1,891,996	42,500
IAE-Loans and Grants 026-999994300	15,632	
Financial Management LoB 026-999991100	124,236	
Human Resources Management LoB 026-999991200	65,217	500,000
Geospatial LoB 026-999993100	225,000	
Budget Formulation and Execution LoB 026-999993200**	105,000	
<b>NASA Total</b>	<b>2,582,147</b>	<b>4,380,057</b>

*Note: \*Service fees are estimates as provided by the E-Government initiative managing partners*

*\*\*Final FY 2015 funding sources, commitments, and details regarding the shared solution will be determined by a Performance Management LoB Executive Steering Committee*

After submission of the budget, NASA will post FY 2015 Exhibit 300 IT business cases on the IT Dashboard, located at: <http://it.usaspending.gov/>.

The E-Government initiatives serve citizens, businesses, and federal employees by delivering high quality services more efficiently at a lower price. Instead of expensive “stove-piped” operations, agencies work together to develop common solutions that achieve mission requirements at reduced cost, thereby making resources available for higher priority needs. Benefits realized through the use of these initiatives for NASA in FY 2015 are described in the following.

#### **eRulemaking (Managing Partner EPA) FY 2015 Benefits**

NASA’s benefits for the eRulemaking initiative are largely focused on public benefits by providing one-stop access to NASA and other federal agency information on rulemakings and non-rulemaking activities on Regulations.gov.

In addition to the process benefits the eRulemaking solution offers, it is estimated to provide cost avoidance benefits over traditional baseline paper processes to a level of \$30 million over five years. The



## E-GOV INITIATIVES AND BENEFITS

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electronic docket solution selected by eRulemaking governance bodies is a centralized architecture that is configurable for each participating entity allowing role-based access to develop workflow and collaboration processes to manage their content. This centrally managed solution is estimated to save a range of \$106 – \$129 million over five years as compared to other alternatives that seek the same benefits but are based on decentralized architectures. These figures were calculated in the summer of 2007 by an independent economist hired by the eRulemaking Program to develop a Cost-Benefit Model.

NASA benefits through its participation and reliance on FDMS and Regulations.gov. NASA reaps substantial benefits by improving the transparency of its rulemaking actions while increasing public participation in the regulatory process. Direct budget cost savings and cost avoidance result from NASA's transition to Federal Document Management System and Regulations.gov, enabling the Agency to discontinue efforts to develop, deploy, and operate specific individual online docket and public comment systems. Over a five-year period, NASA is estimated to save over \$700,000 over alternative options that would provide similar services.

### **Grants.gov (Managing Partner HHS) FY 2015 Benefits**

The Grants.gov initiative benefits NASA and its grant programs by providing a single location with broader exposure to publish grant (funding) opportunities and application packages, making the process easier for applicants to apply to multiple agencies. All 26 major Federal grant making agencies posted 100 percent of their synopses for discretionary funding opportunity announcements on Grants.gov.

In addition, Grants.gov provides a single site for the grantee community to apply for grants using a standard set of forms, processes and systems giving greater access and ability to apply for Federal funding. Through the use of Grants.gov, NASA is able to reduce operating costs associated with online posting and application of grants. Additionally, the Agency is able to improve operational effectiveness through the use of Grants.gov by increasing data accuracy and reducing processing cycle times.

### **e-Training (Managing Partner OPM) FY 2015 Benefits**

The e-Training initiative provides access to premier electronic training systems and tools that support the training and development of the Federal workforce. The initiative supports agency missions through efficient one-stop access to e-Training products and services. The availability of an electronic training environment enhances the ability of the Federal government and NASA to attract, retain, manage, and develop highly skilled professionals needed for a flexible and high-performing government workforce.

The e-Training initiative benefits NASA by reducing redundancies and achieving economies of scale in the purchase and development of e-learning content and in the purchase of learning technology infrastructure. In 2006, NASA streamlined three online training systems into a centralized, learning management system – System for Administration, Training, and Educational Resources at NASA. SATERN, is a “one-stop” approach offering web-based training and career development resources and serves as NASA's training system of record. This centralized approach allows NASA to reduce and leverage training costs by eliminating unique systems, standardizing training processes, and valid data.

Through SATERN, employees can view required training, launch online content, view training history, and self-register for approved courses and conferences. In addition, the system allows NASA officials to identify groups and individuals who have not met basic training requirements and ensure accountability for mission critical and federally mandated training and development. SATERN also offers employees access to career planning tools, individual development plans, and competency management assistance.

## E-GOV INITIATIVES AND BENEFITS

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Currently SATERN offers learners access to more than 2,500 online courses and 14,000 online books and training videos. SATERN is available at all times and can be accessed from work or at home.

Through SATERN, employees can view required training, launch online content, view training history, and self-register for approved courses and conferences. In addition, the system allows NASA officials to identify groups and individuals who have not met basic training requirements and ensure accountability for mission critical and federally mandated training and development. SATERN also offers employees access to career planning tools, individual development plans, and competency management assistance. Currently SATERN offers learners access to more than 2,500 online courses and 14,000 online books and training videos. SATERN is available at all times and can be accessed from work or at home.

### **Recruitment One-Stop (Managing Partner OPM) FY 2015 Benefits**

USAJOBS simplifies the Federal Job Search Process for Job Seekers and Agencies. The USAJOBS.gov website provides a place where citizens can search for employment opportunities throughout the Federal Government. USAJOBS is a fully operational, state-of-the-art recruitment system that simplifies the Federal job search process for job seekers and agencies. Through USAJOBS.gov users have access to:

- A centralized repository for all competitive service
- Job vacancies;
- A resume repository used by agencies to identify critical skills;
- A standardized online recruitment tool and services;
- A standard application Process; and
- Intuitive job searches including e-mail notifications for jobs of interest.

Integration with Recruitment One-Stop allows NASA to better attract individuals who can accomplish the Agency's mission. The USAJOBS interface allows job seekers to view and apply for all NASA employment opportunities, as well as those from other federal agencies. On average, USAJOBS.gov has over 400,000 visitors per day (the online portal serviced over 21 million applications during FY 2010) and over 500,000 resumes are created monthly.

NASA adopted the USAJOBS resume as the basic application document for all NASA positions, except for astronaut positions (in 2005). To date NASA has not identified any specific savings, either in terms of budgeted savings or cost avoidance. Although the Agency believes that implementation of Recruitment One-Stop has resulted in significant intangible benefits in terms of providing better vacancy information to applicants, it has not resulted in any specific cost savings to NASA. However, the numerous intangible benefits Recruitment One-Stop provides to NASA and other agencies include:

- Decreasing hiring time for managers;
- Providing an integrated solution to agency applicant assessment systems;
- Providing a cost effective marketing and recruitment tool;
- Realizing cost savings over commercial job posting boards;
- Reducing the delay associated with filling critical agency vacancies; and
- Enhancing competition with the private sector for the best and brightest talent for Federal service.

### **Enterprise HR Integration (Managing Partner OPM) FY 2015 Benefits**

The Enterprise HR Integration (EHRI) Program supports the strategic management of human capital by providing agency customers with access to timely and accurate federal workforce data. In support of this

## E-GOV INITIATIVES AND BENEFITS

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objective, EHRI has the following goals: 1) Streamline and automate the exchange of federal employee human resources (HR) information Government wide; 2) Provide comprehensive knowledge management and workforce analysis, forecasting, and reporting across the Executive Branch; 3) Maximize cost savings captured through automation; and 4) Enhance retirement processing throughout the Executive Branch.

A key initiative of EHRI is the electronic Official Personnel Folder (eOPF), a web-based application capable of storing, processing, and displaying the OPFs of all current, separated, and retired Federal Employees. When fully implemented, the eOPF will cover the entire Executive Branch as well as other Federal and Local Governments with a total user population of more than 1.9 million. The system will replace the existing manual process by automating the Federal Government's HR processes and thereby creating a streamlined Federal HR system for all Federal Employees. The initiative is achieving cost savings that are recognized on a per-folder basis. The total cost avoidance per folder is estimated at \$55.56.

Specific EHRI/eOPF benefits to NASA include improved convenience in searching, better security and safety to electronic files, more economical, streamlined business processes, and the ability to have a central repository of OPF records for the Agency. During FY 2010, NASA also deployed the eOPF capability of electronic transfer of eOPFs between agencies. Specific NASA employee benefits include secure online access to OPFs, automatic notification when documents are added, exchange of retirement and HR data across agencies and systems, and the elimination of duplicate and repetitive personnel data in personnel folders. NASA completed its implementation to eOPF in March 2008, and transitioned personnel actions processing to the NASA Shared Service Center.

### **E-Travel (Managing Partner GSA) FY 2015 Benefits**

The E-Gov Travel Service 2 (ETS2), planned to be implemented in the summer of 2014, is a government-wide web-based service that provides standardized travel management practices across the Agency to consolidate federal travel, minimize cost and produce customer satisfaction. From travel planning and authorizations, to the review and approval of post-travel reimbursements (vouchers), this end-to-end service streamlines travel management and ultimately enables the government to capture real-time visibility into the buying choices of travelers and assist agencies in optimizing their travel budgets while saving taxpayers money.

The benefits of this uniformed ETS2 system include:

- Increased cost savings associated with overall reduction in Travel Management Center transaction service fees;
- Improved strategic source pricing through cross-government purchasing agreements;
- Improved business process functionality as a result of streamlined travel policies and processes;
- Enhanced security and privacy controls for the protection of government and personal data; and
- Improved agency oversight and audit capabilities.

The ETS2 is a fully integrated end-to-end travel resolution system, which program cost avoidance is realized by a reduction of traveler and manager time for planning, arranging, authorizing, approving and post-travel reimbursement processing. Travelers also benefit from ETS2's increased efficiency in the end-to-end electronic solution as their reimbursements are expedited through the ETS2 process. Additionally initiative savings are realized from the elimination of costly paper-based systems, the decommissioning of

## E-GOV INITIATIVES AND BENEFITS

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legacy travel systems, standardization, greater efficiency, better focus on traveler needs with enhanced services and the reduction of agency overhead by consolidating the number of travel contracts.

NASA completed migration of its travel services to ETS2 - Concur Government Edition (CGE) (formerly HP Enterprise Services (FedTraveler)). Completing this migration has allowed NASA to provide more efficient and effective travel management services. Potential benefits include cost savings associated with cross-government purchasing agreements and improved functionality through streamlined travel policies and processes, strict security and privacy controls, and enhanced Agency oversight and audit capabilities. NASA employees are also benefitting through a more efficient travel planning approach, web-based reimbursement reporting, online booking tools, mobile applications/connectivity, travel authorizations, and E-Receipt capability processes.

### **Integrated Acquisition Environment (Managing Partner GSA) FY 2015 Benefits**

The Integrated Acquisition Environment (IAE) initiative is designed to streamline the process of reporting on subcontracting plans and provide agencies with access to analytical data on subcontracting performance. Use of the IAE common services allows agencies to focus on agency-specific needs such as strategy, operations, and management while leveraging shared services for common functions. Furthermore, use of a government-wide business focused service environment reduces funding and resources for technical services and support for acquisition systems originally housed by individual agencies.

IAE facilitates and supports cost-effective acquisition of goods and services by agencies. The IAE initiative provides common acquisition functions and shared services that benefit all agencies, such as the maintenance of information about business-partner organizations (e.g., banking, certifications, business types, capabilities, performance). IAE provides benefits to the government and business-partner organizations by improving cross-agency coordination that helps to improve the government's buying power, while providing business partners maximum visibility and transparency into the process. IAE provides various services, tools and capabilities that can be leveraged by the acquisition community including buyers, sellers, and the public to conduct business across the federal government space.

Government buyers can:

- Search for commercial and government sources
- Post synopses and solicitations
- Securely post sensitive solicitation documents
- Access reports on vendors' performance
- Retrieve vendor data validated by SBA and Internal Revenue Service (IRS)
- Identify excluded parties
- Report contract awards

Business suppliers can:

- Search business opportunities by product, service, agency, or location
- Receive e-mail notification of solicitations based on specific criteria
- Register to do business with the federal government
- Enter representations and certifications one time
- Revalidate registration data annually

## E-GOV INITIATIVES AND BENEFITS

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- Report subcontracting accomplishments

Citizens can:

- Retrieve data on contract awards
- Track federal spending
- Search to find registered businesses
- Monitor business opportunities

Through adoption of the tools and services provided by IAE, NASA improves its ability to make informed and efficient purchasing decisions and allows it to replace manual processes. If NASA did not use IAE systems, the Agency would need to build and maintain separate systems to record vendor and contract information, and to post procurement opportunities. Agency purchasing officials would not have access to databases of important information from other agencies on vendor performance and could not use systems to replace paper-based and labor-intensive work efforts.

### **Integrated Acquisition Environment – Loans & Grants FY 2015 Benefits**

All agencies participating in the posting and/or awarding of Contracts and Grants & Loans are required by the Federal Funding Accountability and Transparency Act (FFATA) of 2006 as well as the American Recovery and Reinvestment Act of 2009 (ARRA) reporting requirements to disclose award information on a publicly accessible website. FFATA requires OMB to lead the development of a single, searchable website through which the public can readily access information about grants and contracts provided by Federal government agencies<sup>1</sup>.

Based on the recommendations of the Transparency Act Taskforce, the website leverages functionality provided by the Integrated Acquisition Environment (IAE) initiative to provide Data Universal Numbering System (DUNS) numbers as the unique identifier. An existing IAE Dun and Bradstreet (D&B) transaction-based contract for the contract community was expanded to provide government-wide D&B services for the Grants & Loans community. These services include parent linkage, help desk support, world database lookup, business validation and linkage monitoring, matching services, as well as the use of DUNS numbers. The enterprise D&B contract provides substantial savings to the participating agencies over their previous agency transaction-based D&B contracts.

On December 14, 2007, OMB launched [www.USASpending.gov](http://www.USASpending.gov) to meet the Federal Funding Accountability and Transparency Act (FFATA) statutory requirements, ahead of schedule. Since that launch, OMB has and will continue to work with agencies to improve the quality, timeliness, and accuracy of their data submissions and has released a series of enhancements to the site. USASpending.gov complements other websites providing the public Federal program performance information (e.g., USA.gov, Results.gov and ExpectMore.gov).

USASpending.gov provides:

- The name of the entity receiving the award;

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<sup>1</sup> More information on the development of this website can be found at: <http://www.federalspending.gov>.

## E-GOV INITIATIVES AND BENEFITS

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- The amount of the award;
- Information on the award including transaction type, funding agency, etc.;
- The location of the entity receiving the award;
- A unique identifier of the entity receiving the award.

All agencies participating in the posting and/or awarding of Contracts and Grants & Loans are required by the FFATA as well as the American Recovery and Reinvestment Act of 2009 (ARRA) reporting requirements to disclose award information on a publicly accessible website. Cross government cooperation with OMB's Integrated Acquisition Environment initiative allows agencies and contributing bureaus to meet the requirements of the FFATA by assigning a unique identifier, determining corporate hierarchy, and validating and cleaning up incorrect or incomplete data.

The FY 2015 funding requirements as it relates to the IAE – Loans and Grants funding line supports the FFATA for the relationship with D&B and DUNS support services. In addition to provision of DUNS numbers, D&B is now providing business and linkage data seamlessly, and the business arrangement supports the quality of data by real-time updates. NASA and other agencies will leverage the linkages to corporate organizational rollups based on parental and subsidiary relationships.

### **LINEs OF BUSINESS**

#### **Financial Management LoB (Managing Partners DOE and DOL) FY 2015 Benefits**

Treasury's Office of Financial Innovation and Transformation (FIT) served as Managing Partner and the Program Management Office (PMO) for the FMLoB. In accordance with OMB's guidance on shared services (the Federal IT Shared Services Strategy), the Treasury's FIT will lead efforts to transform Federal financial management, reduce costs, increase transparency, and improve delivery of agencies' missions by operating at scale, relying on common standards, shared services, and using state-of-the-art technology. Under the guidance of the CFOC and COFAR, partner agencies will work with the FMLOB's support to standardize core financial business processes (including financial assistance) and data elements across the Federal Government to provide: (1) reliable and accessible financial data to the public; (2) adequate training and development resources to agency workforces; and (3) strong oversight of Federal programs using tools such as the Single Audit. The FMLoB will also play a role in implementing OMB's Memorandum M-13-08, *Improving Financial Systems Through Shared Services*. NASA benefits from the FM LOB because it provides a forum in which federal agencies can share information and weigh pros and cons of various initiatives (for example, shared services).

#### **Human Resources Management LoB (Managing Partner OPM) FY 2015 Benefits**

The HR LoB vision is to create government-wide, modern, cost-effective, standardized, and interoperable HR solutions to provide common core functionality to support the strategic management of Human Resources through the establishment of Shared Service Centers (SSC). Driven from a business perspective, the solutions will address distinct business improvements enhancing the government's performance of HR and payroll services in support of agency missions delivering services to citizens. The HR LoB concept of operations calls for agencies to receive core services from an HR LoB provider. These core services are defined as personnel action processing, compensation management (payroll) and benefits management. Leveraging shared services solutions will allow the HR LoB to significantly improve HR and payroll service delivery, save taxpayer dollars, and reduce administrative burdens.

## E-GOV INITIATIVES AND BENEFITS

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NASA works in partnership with one of the approved service providers, the Department of Interior's National Business Center. Through this partnership, NASA shares and receives "best-in-class" HR solutions. The National Business Center delivers NASA-developed solutions to their customer agencies, enabling improved efficiencies and system integrations at a fraction of the cost and delivery time than similar solutions could have been produced by National Business Center. NASA achieves the benefits of "best-in-class" HR solutions through implementation and integration of National Business Center and NASA-developed HR solutions. NASA's participation in HR LoB provides the Agency opportunities to implement modern HR solutions and benefit from best practices government-wide strategic HR management. In 2014, NASA will be participating in the development of a 10-year Federal Human Resources Strategic Plan with the HRLOB managing partner (OPM) and member agencies.

### **Geospatial LoB (Managing Partner DOL) FY 2015 Benefits**

The Geospatial LoB will better serve the agencies' missions and the Nation's interests developing a more strategic, coordinated, and leveraged approach to producing, maintaining, and using geospatial data and services across the Federal government. Specific goals of the Geospatial LoB include establishing a collaborative governance mechanism, coordinating a government-wide planning and investment strategy, and optimizing and standardizing geospatial data and services.

Contributing agencies and bureaus will receive value from the development of the LoB primarily through improved business performance and cost savings. Enhanced governance processes, improved business planning and investment strategies, and optimization and standardization of geospatial business data and services will produce the following results:

- Collaborative management of geospatial investments will be made more adaptable, proactive and inclusive;
- Enterprise business needs and agency core mission requirements will be identified, planned, budgeted, and exploited in a geospatial context;
- Long-term costs of geo-information delivery and access will be reduced while minimizing duplicative development efforts;
- Effective, yet less costly commercial off the shelf systems and contractual business support operations will replace legacy geospatial applications; and
- Business processes will be optimized and knowledge management capabilities will exist for locating geospatial data and obtaining services.

As a science agency, the work of NASA's science and mission professionals is inherently different from duties and functions performed by operational agencies. These differences lead NASA to organize and manage data to best facilitate science activities rather than a central focus of data dissemination. Scientific inquiry often leads scientists to use different schemas for analyzing data and information produced from remote sensing data (e.g. a common grid or projection). NASA will continue to apply the elements of Federal Geographic Data Committee standards where these are appropriate. In FY 2008, NASA signed an MOU with the Department of Labor to continue its active participation in the Geospatial LOB.

### **Budget Formulation & Execution LOB (Managing Partner Education) FY 2015 Benefits**

The Budget Formulation and Execution LoB (BFELoB) provides significant benefits to NASA and other partner agencies by encouraging best practices crossing all aspects of Federal budgeting – from budget formulation and execution to performance to human capital needs. To benefit all agencies, BFELoB

## **E-GOV INITIATIVES AND BENEFITS**

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continues to support the idea of shared service budget systems. As NASA currently has its own budgeting tools, the Agency has not chosen to move to a new budget system; however, a shared service budget system is an option moving forward.

BFELoB's "MAX Federal Community," a secure government-only collaborative website, provides significant benefits for collaboration across and within agencies, as well as knowledge management. The Community site is commonly used for sharing information, collaboratively drafting documents (including the direct-editing of documents posted on the site).



# COMPARABILITY ADJUSTMENT TABLES

## FY2013 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Science</b>	<b>4,781.6</b>	<b>4,781.6</b>
<b>Earth Science</b>	<b>1,659.2</b>	<b>1,659.2</b>
<u>Earth Science Research</u>	<u>422.9</u>	<u>422.9</u>
<u>Earth Systematic Missions</u>	<u>823.5</u>	<u>816.2</u>
Global Precipitation Measurement (GPM)	91.4	91.4
Ice, Cloud, and land Elevation Satellite (ICESat-II)	165.9	165.9
Soil Moisture Active and Passive (SMAP)	210.3	210.3
<b>Landsat Data Continuity Mission</b>	<b>23.6</b>	
<b>GRACE Follow On</b>		
Other Missions and Data Analysis	332.4	298.5
OMDA - ESM Projects	274.9	274.9
<b>OCO-3</b>	<b>7.4</b>	
<b>GRACE Follow On</b>	<b>50.1</b>	
<b>Landsat Data Continuity Mission</b>		
<u>Earth System Science Pathfinder</u>	<u>169.3</u>	<u>176.7</u>
OCO-2	80.3	80.3
Venture Class Missions	51.5	51.5
Other Missions and Data Analysis	37.5	44.8
<b>OCO-3</b>		
OMDA - ESSP Projects	37.5	37.5
<u>Earth Science Multi-Mission Operations</u>	<u>162.2</u>	<u>162.2</u>
<u>Earth Science Technology</u>	<u>48.9</u>	<u>48.9</u>
<u>Applied Sciences</u>	<u>32.5</u>	<u>32.5</u>
<b>Astrophysics</b>	<b>617.0</b>	<b>617.0</b>
<u>Astrophysics Research</u>	<u>155.8</u>	<u>155.8</u>
<u>Cosmic Origins</u>	<u>218.9</u>	<u>218.9</u>
<u>Physics of the Cosmos</u>	<u>124.5</u>	<u>124.5</u>
<u>Exoplanet Exploration</u>	<u>52.8</u>	<u>52.8</u>
<u>Astrophysics Explorer</u>	<u>65.1</u>	<u>65.1</u>
<b>Nuclear Spectroscopic Telescope Array</b>	<b>1.9</b>	
<b>Gravity &amp; Extreme Magnetism</b>	<b>2.0</b>	
<b>Transiting Exoplanet Survey Satellite (TESS)</b>		
Other Missions and Data Analysis	61.2	30.3
OMDA - Astrophysics Explorer Projects	26.4	26.4
<b>Transiting Exoplanet Survey Satellite (TESS)</b>	<b>34.8</b>	
<b>Nuclear Spectroscopic Telescope Array</b>		
<b>Gravity and Extreme Magnetism</b>		
<b>James Webb Space Telescope</b>	<b>627.6</b>	<b>627.6</b>

# COMPARABILITY ADJUSTMENT TABLES

## FY2013 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Planetary Science</b>	<b>1,271.5</b>	<b>1,274.6</b>
<u>Planetary Science Research</u>	<u>192.7</u>	<u>195.8</u>
Planetary Science Research and Analysis	128.6	128.6
Directorate Management	3.9	3.9
Near Earth Object Observations	20.5	20.5
Other Missions and Data Analysis	39.7	42.8
<b>Science Data and Computing</b>		<b>3.1</b>
OMDA- Planetary Science Research Projects	39.7	39.7
<u>Lunar Quest Program</u>	<u>71.8</u>	<u>63.8</u>
Lunar Science	20.3	12.2
<b>Lunar Reconnaissance Orbiter Science Mission</b>	<b>8.1</b>	
Lunar Management	1.5	1.5
Lunar Science	10.8	10.8
Lunar Atmosphere and Dust Environment Explorer	48.7	48.7
Surface Science Lander Technology	2.8	2.8
<u>Discovery</u>	<u>207.4</u>	<u>215.5</u>
<b>InSight</b>		<b>122.7</b>
Other Missions and Data Analysis	207.4	92.8
<b>InSight</b>	<b>122.7</b>	
<b>Lunar Reconnaissance Orbiter Science Mission</b>		<b>8.1</b>
OMDA - Discovery Projects	84.7	84.7
<u>New Frontiers</u>	<u>158.8</u>	<u>158.8</u>
<u>Mars Exploration</u>	<u>369.5</u>	<u>369.5</u>
<b>Mars Atmosphere and Volatile EvolutionN</b>	<b>86.5</b>	
Other Missions and Data Analysis	283.0	369.5
OMDA - Mars Exploration Projects	283.0	283.0
<b>Mars Atmosphere and Volatile EvolutionN</b>		<b>86.5</b>
<u>Outer Planets</u>	<u>147.8</u>	<u>147.8</u>
<b>Jupiter Europa Mission</b>	<b>69.7</b>	
<b>Other Missions and Data Analysis</b>	<b>78.1</b>	
<u>Technology</u>	<u>123.4</u>	<u>123.4</u>

# COMPARABILITY ADJUSTMENT TABLES

## FY2013 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Heliophysics</b>	<b>606.3</b>	<b>↑</b>	<b>603.2</b>
<u>Heliophysics Research</u>	<u>176.1</u>		<u>165.3</u>
Heliophysics Research and Analysis	35.1		35.1
Sounding Rockets	56.1		56.1
Research Range	20.5		20.5
Other Missions and Data Analysis	64.4		53.5
OMDA - Heliophysics Research Projects	53.5		53.5
<b>Science Data and Computing</b>	<b>3.1</b>		
<b>TIMED</b>	<b>2.8</b>		
<b>RHESSI</b>	<b>2.0</b>		
<b>ACE</b>	<b>3.0</b>		
<u>Living with a Star</u>	<u>174.9</u>		<u>174.9</u>
Solar Probe Plus	108.2		108.2
Solar Orbiter Collaboration	19.1		19.1
<b>Van Allen Probes (RBSP)</b>	<b>7.7</b>		
Other Missions and Data Analysis	39.9		47.6
OMDA - LWS Projects	39.9		39.9
<b>Van Allen Probes (RBSP)</b>			<b>7.7</b>
<u>Solar Terrestrial Probes</u>	<u>201.1</u>		<u>203.9</u>
Magnetospheric Multiscale (MMS)	183.3		183.3
Other Missions and Data Analysis	17.8		20.6
OMDA - STP Projects	17.8		17.8
<b>TIMED</b>			<b>2.8</b>
<u>Heliophysics Explorer Program</u>	<u>54.1</u>		<u>59.1</u>
<b>Interface Region Imaging Spectograph (IRIS)</b>	<b>15.1</b>		
<b>ICON</b>			<b>18.2</b>
Other Missions and Data Analysis	39.0		40.9
OMDA - Heliophysics Explorer Projects	20.8		20.8
<b>Interface Region Imaging Spectograph (IRIS)</b>			<b>15.1</b>
<b>ICON</b>	<b>18.2</b>		
<b>RHESSI</b>			<b>2.0</b>
<b>ACE</b>			<b>3.0</b>
<b>Aeronautics</b>	<b>529.5</b>		<b>529.5</b>
<b>Space Technology</b>	<b>614.5</b>		<b>614.5</b>
<b>Education</b>	<b>116.3</b>		<b>116.3</b>
<b>Cross Agency Support</b>	<b>2,711.0</b>		<b>2,711.0</b>
<b>Construction and Environmental Compliance and Restoration</b>	<b>646.6</b>		<b>646.6</b>
<b>Inspector General</b>	<b>35.3</b>		<b>35.3</b>

# COMPARABILITY ADJUSTMENT TABLES

## FY2013 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Exploration</b>	<b>3,705.5</b>	<b>3,705.5</b>
<b>Exploration Systems Development</b>	<b>2,883.8</b>	<b>2,883.8</b>
<u>Orion Multi-Purpose Crew Vehicle</u>	<u>1,113.8</u>	<u>1,113.8</u>
Crew Vehicle Development	1,113.8	1,089.9
MPCV Program Integration and Support		23.9
<u>Space Launch System</u>	<u>1,770.0</u>	<u>1,414.9</u>
Exploration Ground Systems	355.1	
Launch Vehicle Development	1,414.9	1,376.4
SLS Program Integration and Support		38.5
<u>Exploration Ground Systems</u>		<u>355.1</u>
<b>Commercial Spaceflight</b>	<b>525.0</b>	<b>525.0</b>
<b>Exploration Research and Development</b>	<b>296.7</b>	<b>296.7</b>
<u>Human Research Program</u>	<u>146.7</u>	<u>146.7</u>
<u>Advanced Exploration Systems</u>	<u>150.0</u>	<u>150.0</u>
<b>Space Operations</b>	<b>3,724.9</b>	<b>3,724.9</b>
<b>Space Shuttle</b>	<b>38.8</b>	<b>38.8</b>
<b>International Space Station</b>	<b>2,775.9</b>	<b>2,775.9</b>
<u>International Space Station Program</u>	<u>2,775.9</u>	<u>2,775.9</u>
ISS Systems Operations and Maintenance	1,451.5	1,418.2
ISS Systems Operations and Maintenance Projects	1,418.2	1,418.2
Spacecraft Servicing Demonstrations	33.3	
ISS Research	284.2	317.5
Biological and Physical Sciences	78.7	78.7
Multi-User System Support (MUSS)	205.4	205.4
In-Space Robotic Servicing		33.3
ISS Crew and Cargo Transportation	1,040.3	1,040.3
<b>Space and Flight Support (SFS)</b>	<b>910.2</b>	<b>910.2</b>
<u>21st Century Space Launch Complex</u>	<u>39.0</u>	<u>39.0</u>
<u>Space Communications and Navigation</u>	<u>641.4</u>	<u>641.4</u>
Space Communications Networks	450.8	574.3
Space Communications Networks Projects	450.8	450.8
TDRS Replenishment		123.5
Space Communications Support	67.0	67.0
TDRS Replenishment	123.5	
<u>Human Space Flight Operations</u>	<u>102.6</u>	<u>102.6</u>
<u>Launch Services</u>	<u>81.2</u>	<u>81.2</u>
<u>Rocket Propulsion Test</u>	<u>45.9</u>	<u>45.9</u>
<b>Grand Total</b>	<b>16,865.2</b>	<b>16,865.2</b>

# COMPARABILITY ADJUSTMENT TABLES

## FY2014 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Science</b>	<b>5,148.2</b>	<b>5,148.2</b>
<b>Earth Science</b>	<b>1,824.9</b>	<b>1,824.9</b>
<b>Planetary Science</b>	<b>1,343.4</b>	<b>1,345.7</b>
<u>Planetary Science Research</u>	219.5	219.5
<u>Planetary Science Research and Analysis</u>	130.0	130.0
<u>Directorate Management</u>	45.0	45.0
<u>Near Earth Object Observations</u>	4.0	4.0
<u>Other Missions and Data Analysis</u>	40.5	42.8
<b>Science Data and Computing</b>		<b>2.3</b>
OMDA – Planetary Science Research Projects	40.5	40.5
<u>Lunar Quest Program</u>	23.8	23.8
<u>Discovery</u>	285.0	285.0
<u>New Frontiers</u>	231.6	231.6
<u>Mars Exploration</u>	288.0	288.0
<b>Mars Atmosphere and Volatile EvolutionN</b>	<b>32.0</b>	
<b>Other Missions and Data Analysis</b>	<b>256.0</b>	<b>288.0</b>
<u>Outer Planets</u>	152.4	152.4
<b>Jupiter Europa Mission</b>	<b>80.0</b>	
<b>Other Missions and Data Analysis</b>	<b>72.4</b>	
<u>Technology</u>	143.1	143.1
<b>Astrophysics</b>	<b>678.3</b>	<b>678.3</b>
<u>Astrophysics Research</u>	145.2	145.2
<u>Cosmic Origins</u>	224.2	224.2
<u>Physics of the Cosmos</u>	112.6	112.6
<u>Exoplanet Exploration</u>	106.7	106.7
<u>Astrophysics Explorer</u>	89.6	89.6
<b>Transiting Exoplanet Survey Satellite (TESS)</b>		<b>35.9</b>
Other Missions and Data Analysis	89.6	53.7
OMDA - Astrophysics Explorer Projects	53.7	
<b>Transiting Exoplanet Survey Satellite (TESS)</b>	<b>35.9</b>	
<b>Heliophysics</b>	<b>643.3</b>	<b>641.0</b>
<u>Heliophysics Research</u>	187.4	185.1
<u>Heliophysics Research and Analysis</u>	33.5	33.5
<u>Sounding Rockets</u>	53.4	53.4
<u>Research Range</u>	21.8	21.8
<u>Other Missions and Data Analysis</u>	78.7	76.4
<b>Science Data and Computing</b>	<b>2.3</b>	
OMDA – Heliophysics Research Projects		76.4
<u>Living with a Star</u>	212.5	212.5
<u>Solar Terrestrial Probes</u>	143.3	143.3
<u>Heliophysics Explorer Program</u>	100.2	100.2
<b>ICON</b>		<b>59.8</b>
Other Missions and Data Analysis	100.2	40.4
OMDA - Heliophysics Explorer Projects	40.4	
<b>ICON</b>	<b>59.8</b>	
<b>James Webb Space Telescope</b>	<b>658.2</b>	<b>658.2</b>

# COMPARABILITY ADJUSTMENT TABLES

## FY2014 Operating Plan Crosswalk to FY2015 Budget Structure

<b>Aeronautics</b>	<b>566.0</b>		<b>566.0</b>
<b>Space Technology</b>	<b>576.0</b>		<b>576.0</b>
<b>Exploration</b>	<b>4,113.2</b>		<b>4,113.2</b>
<b>Human Exploration Capabilities</b>	<b>3,115.2</b>		<b>3,115.2</b>
Orion Multi-Purpose Crew Vehicle	1,197.0		1,197.0
Crew Vehicle Development	1,197.0	→	1,165.8
MPCV Program Integration and Support		→	31.2
Space Launch System	1,918.2		1,600.0
Launch Vehicle Development	1,600.0	→	1,527.7
SLS Program Integration and Support		→	72.3
Exploration Ground Systems	318.2		
Exploration Ground Systems		→	318.2
<b>Commercial Spaceflight</b>	<b>696.0</b>		<b>696.0</b>
<b>Exploration Research and Development</b>	<b>302.0</b>		<b>302.0</b>
<b>Space Operations</b>	<b>3,776.4</b>		<b>3,776.4</b>
<b>International Space Station</b>	<b>2,964.1</b>		<b>2,964.1</b>
<b>Space and Flight Support (SFS)</b>	<b>812.3</b>		<b>812.3</b>
21st Century Space Launch Complex	38.6		38.6
Space Communications and Navigation	539.5		539.5
Space Communications Networks	433.3	→	479.0
Space Communications Support	60.5		60.5
TDRS Replenishment	45.7	→	
Human Space Flight Operations	106.5		106.5
Launch Services	80.9		80.9
Rocket Propulsion Test	46.8		46.8
<b>Education</b>	<b>116.6</b>		<b>116.6</b>
<b>Cross Agency Support</b>	<b>2,793.0</b>		<b>2,793.0</b>
<b>Construction and Environmental Compliance and Restoration</b>	<b>519.6</b>		<b>519.6</b>
<b>Inspector General</b>	<b>37.5</b>		<b>37.5</b>
<b>Grand Total</b>	<b>17,646.5</b>		<b>17,646.5</b>

## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

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NASA's FY 2015 Management and Performance section<sup>1,2</sup> is an appendix to NASA's 2015 Congressional Justification. This section summarizes NASA as an organization and NASA's approach to performance management, strategic planning, and performance reporting. The overview of NASA explains how the Agency is organized, governed, and managed; and how the Agency uses data, evaluations, and reporting to manage performance. Two additional sections describe NASA's management priorities and challenges and NASA's reported performance for FY 2013 and performance measures for FY 2014 and FY 2015.

### **A Performance-Based Organization**

NASA is a performance-based organization, as defined and described by the Office of Management and Budget's (OMB's) [Circular A-11](#). A performance-based organization commits to management towards specific measurable goals derived from a defined mission, using performance data to continually improve operations. The concept of a performance-based organization was initiated and codified in the Government Performance and Results Act (GPRA) of 1993, and was updated in the [GPRA Modernization Act of 2010](#). As a performance-based organization, NASA is dedicated to results-driven management focused on optimizing value to the American public. It sets concrete goals and holds itself accountable to those goals through a transparent framework of how to measure progress.

### **NASA VISION AND MISSION**

NASA's Vision and Mission are defined collaboratively through internal and external stakeholder input. NASA last revised these Vision and Mission statements in the 2014 Strategic Plan (available at <http://www.nasa.gov/news/budget/index.html>).

NASA's Vision is:

We reach for new heights and reveal the unknown for the benefit of humankind.

NASA's Mission is to:

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

### **ORGANIZATIONAL STRUCTURE**

NASA's organizational structure is designed to accomplish its Mission through sound business, management, and safety oversight. Under the leadership of the [Administrator](#), NASA offices at [Headquarters](#) in Washington, DC, guide and direct the Agency. The Office of the Administrator provides

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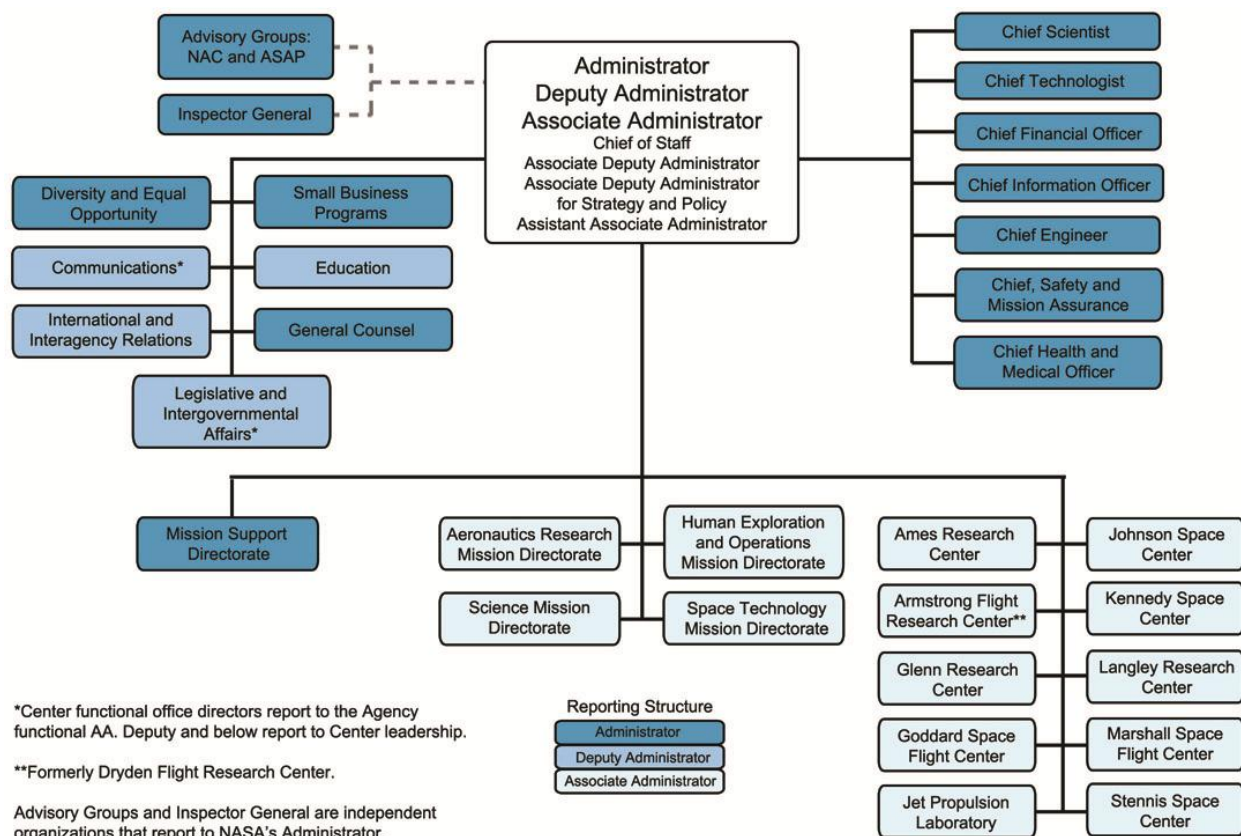
<sup>1</sup> Printed versions of NASA's 2015 Congressional Justification only will include a section of NASA's FY 2015 Management and Performance appendix titled "NASA's Approach to Performance Management." For the full version of the Management and Performance section, see: <http://www.nasa.gov/news/budget/index.html>.

<sup>2</sup> The Management and Performance appendix is produced by NASA's Office of the Chief Financial Officer with contractor support by The Tauri Group.

# NASA'S APPROACH TO PERFORMANCE MANAGEMENT

top-level strategy and direction for the Agency. The Administrator and his staff give programmatic direction for NASA's missions and guide the operations of the Centers. NASA's [Centers](#) and installations conduct the Agency's day-to-day work. Figure 1 depicts NASA's organizational structure, current as of March 2014.

**Figure 1: NASA's Organization**



NASA Policy Directive 1000.3D, "The NASA Organization," establishes the roles and responsibilities of NASA senior management. The following components have unique portfolios, budget oversight, and performance management responsibilities in executing the Mission.

- **Science Mission Directorate (SMD)** manages the Agency's Science portfolio budget account and focuses on programmatic work on Earth, planetary, astrophysics, and heliophysics research. SMD engages the U.S. science community, sponsors scientific research, and develops and deploys satellites and probes in collaboration with NASA's international partners to answer fundamental scientific questions and expand the understanding of space. Additional information on SMD is available at <http://science.nasa.gov/>.
- **Aeronautics Research Mission Directorate (ARMD)** manages the Agency's aeronautics research account and portfolio of activities that enable game-changing technology innovation and development, allowing the U.S. aviation industry to continue to grow and maintain global competitiveness. Research programs conduct cutting-edge research at both the fundamental and



## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

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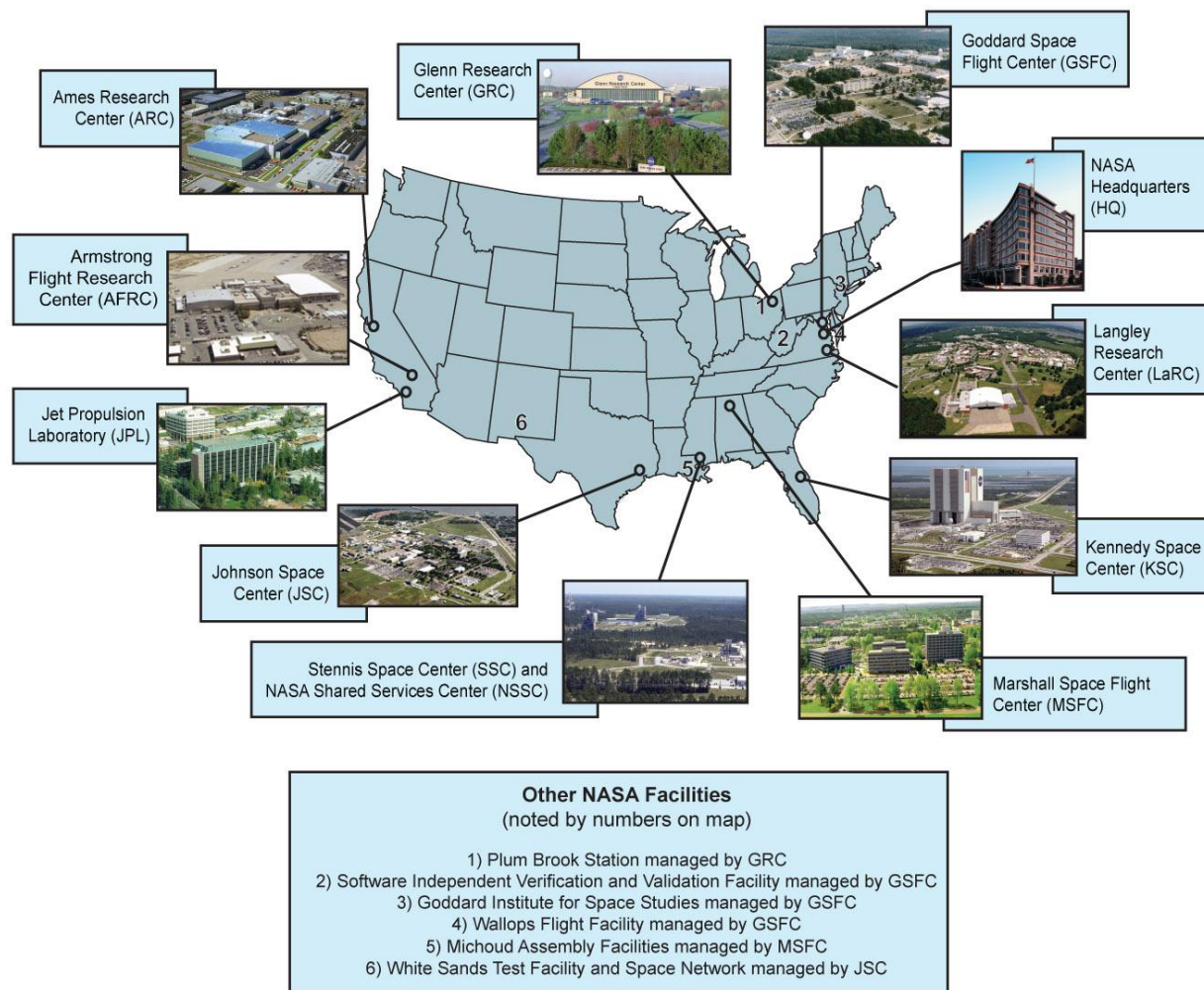
integrated systems levels to address national and global challenges. ARMD guides its research efforts using a strategic vision that embraces the multiple roles of aviation and expands the understanding of those roles to the global stage, while working to address tomorrow's challenges. Additional information on ARMD is available at <http://www.aeronautics.nasa.gov/>.

- Space Technology Mission Directorate (STMD) manages the Space Technology account, which also funds the crosscutting activities of the Office of the Chief Technologist. STMD pioneers new technologies and capabilities needed by the Agency and commercial sector. It complements technology development in NASA's other mission directorates, delivering solutions to NASA's technology needs for future science and exploration missions. Additional information on STMD is available at <http://www.nasa.gov/directorates/spacetech/home/index.html>. Additional information on the Office of the Chief Technologist is available at <http://www.nasa.gov/offices/oct/home/index.html>.
- Human Exploration and Operations Mission Directorate (HEOMD) manages the budget account for the Exploration and Space Operations portfolio. HEOMD manages development of the Space Launch System (SLS), Orion, future exploration technologies, and works with U.S. commercial space industry partners to develop commercial systems for providing crew and cargo transportation services to and from low Earth orbit. HEOMD also manages operations and research for the International Space Station (ISS), and communications systems and networks that enable deep space and near-Earth exploration. Additional information on HEOMD is available at <http://www.nasa.gov/directorates/heo/home/index.html>.
- Mission Support Directorate (MSD) supports all NASA missions in a crosscutting manner. For example, MSD manages the Cross Agency Support (CAS) and Construction and Environmental Compliance and Restoration (CECR) accounts, which cut across all mission directorates. CAS and CECR accounts fund operations at Headquarters and the Centers, as well as institutional and programmatic construction of facilities. MSD reports progress on major national initiatives to the Administrator and other senior Agency officials, provides independent reviews and investigations, and liaises with the public and other Federal agencies. MSD is based at Headquarters, but has representatives at the Centers to provide coordination and control. Additional information on MSD is available at <http://msd.hq.nasa.gov/>.
- Office of Education (Education) develops and manages a portfolio of educational programs for students and teachers at all levels. Education seeks to develop a vibrant pool of individuals for the future workforce for sustainable support of national and NASA missions by attracting and retaining students in science, technology, engineer, and mathematics disciplines, and raising public awareness of NASA's activities. To achieve these goals, Education works in partnership with other Government agencies, nonprofit organizations, museums, and the education community at large. Additional information on the Office of Education is available at <http://www.nasa.gov/offices/education/about/>.
- The Administrator's Staff Offices support the Administrator's responsibilities by providing a range of high-level guidance and support in critical areas like safety and mission assurance, technology planning, equal opportunity, information technology, financial administration, small business administration, international relations, and legislative and intergovernmental affairs. Additional information on the Administrator's Staff Offices is available at [http://www.nasa.gov/about/org\\_index.html](http://www.nasa.gov/about/org_index.html).
- The Office of Inspector General conducts audits, reviews, and investigations of NASA programs to prevent and detect fraud, waste, abuse, and mismanagement and to assist NASA management in promoting economy, efficiency, and effectiveness. Additional information on the Office of Inspector General is available at <http://oig.nasa.gov/>.

## NASA's APPROACH TO PERFORMANCE MANAGEMENT

A dedicated workforce transforms NASA's Mission into reality. NASA employs about 18,000 civil servants at Headquarters in Washington, DC, its Centers, and other facilities across the country. NASA staffs each location with a contractor workforce for technical and business operations support. Figure 2 shows the distribution of NASA's Centers and major facilities. NASA also has many other facilities throughout the country and around the world.

**Figure 2: NASA Centers and Facilities Nationwide**



## **NASA'S APPROACH TO PERFORMANCE MANAGEMENT**

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### **Governance and Strategic Management**

#### **GOVERNANCE**

Agency governance is critical to mission success and delivering on the Agency's commitment to good stewardship of taxpayer resources. Governance is the way decisions are made and the foundation on which NASA is managed. Good governance is indispensable for NASA's success, and it requires consistent management, cohesive policies, guidance, and process. NASA governs through a combination of councils and key executive roles, whose decisions are implemented by a unique organizational structure and decision authorities.

NASA governs through three Agency-level councils, each with distinct charters and responsibilities. Councils evaluate issues and support decision authorities when topics require high levels of integration, visibility, and approval. Councils are used to provide high-level oversight, set requirements and strategic priorities, and guide key assessments of the Agency. The three councils are the Executive Council (EC), the Program Management Council (PMC), and the Mission Support Council (MSC). The EC focuses on major Agency-wide decisions; the MSC focuses on mission-enabling decisions; and the PMC focuses on program and mission decisions as programs reach Key Decision Points (KDPs). Regardless of organizational position, senior managers are accountable to the respective council chairs.

NASA's governance policy ensures that leadership approaches strategic management decisions with rigor and reliable data. As shown in Figure 3, the governance councils affect all phases of the performance management cycle.

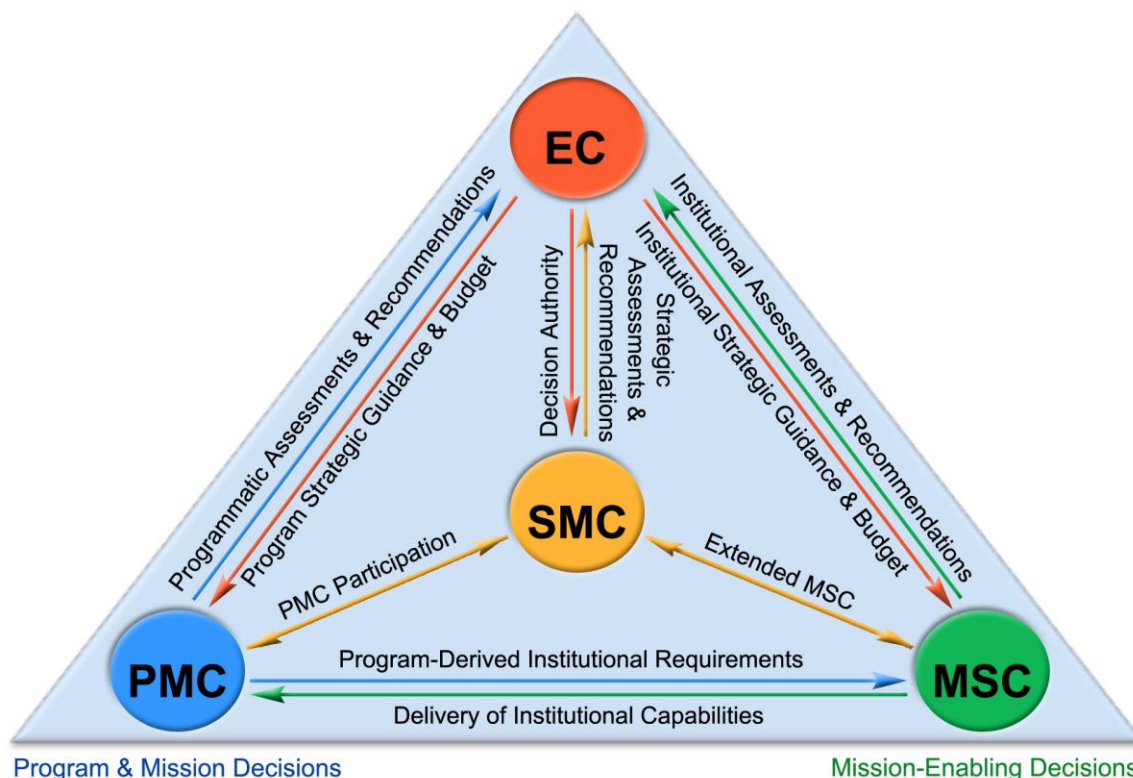
While governing through councils, NASA's Mission-driven organization relies on the line organization for implementation. Stemming from the mission directorates and Centers, implementation takes place primarily at the program or project level, where requirements, budget, and schedule are managed. Managers make and implement decisions within their area of responsibility and within the context of the larger organization. Accordingly, they have authority over their approved budgets, schedules, workforce, and capital assets. However, managers also work across organizational lines to achieve program and project integration and to ensure appropriate synergy and effective resource utilization.

Each month, NASA conducts an internal assessment, the Baseline Performance Review (BPR), that tracks performance against Agency decisions. The BPR, led by the Associate Administrator, is a bottom-up review of how well the Agency has performed against its strategic goals and other performance metrics, such as cost, schedule, contract, and technical commitments. Additional advice and assessment is solicited from external bodies within the science and research communities.

At the request of the Office of the Administrator, elements in the formal organization or special ad hoc teams address integration issues that cross-organizational responsibilities of mission directorates, mission support offices, and Centers.

## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

**Figure 3: Functional Relationships Between NASA's Governing Councils**



In addition to the governing councils, the Strategic Management Council (SMC) is a larger body of internal subject matter experts that provides advice and counsel to senior leadership on key issues of the Agency; provides input on the formulation of Agency strategy; and when delegated by the EC, serves as the Agency senior decision-making body on specific topics of strategic direction and planning.

The Administrator leads the Agency and is accountable to the President for all aspects of the Agency's Mission, including establishing and articulating the Agency's Vision, strategy, and priorities and overseeing successful implementation of supporting policies, programs, and performance assessments. The Administrator performs all necessary functions to govern NASA operations and exercises the powers vested in NASA by law.

The GPRA Modernization Act requires all agency heads to designate an Agency Chief Operating Officer (COO) and Performance Improvement Officer (PIO) for managing Agency performance. The Administrator appoints the COO and the PIO to ensure the Agency's mission is achieved through management of activities in accordance with the GPRA Modernization Act. NASA's Associate Administrator is the current COO and the Director of the Strategic Investments Division in the Office of the Chief Financial Officer is the current PIO. NASA's PIO reports to the COO.

The three primary responsibilities of NASA's performance leaders are goal setting, assuring timely, actionable performance information is available to decision-makers at all levels of the organization, and

## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

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conducting frequent data-driven reviews that guide decisions and actions to improve performance outcomes and reduce costs. NASA's COO provides organizational leadership to improve performance; helps the Agency meet the Mission and goals of the Agency through performance planning, measurement, analysis, and regular assessment of programs; chairs data-driven performance reviews; and redirects resources to priorities, including budget and staffing, to improve performance. The PIO supports the Administrator and COO by leading efforts to set goals; conducting quarterly, data-driven performance reviews and analysis; coordinating cross-agency collaboration and Agency leadership on performance; ensuring alignment of personnel performance; communicating performance goals; and collaborating with mission directorates, mission support offices, leadership, and OMB to set meaningful goals.

### STRATEGIC MANAGEMENT

NASA's performance management activities follow a continuous cycle to ensure strategic management and accountability. Figure 4 depicts how the three phases of NASA's performance management cycle relate.

**Figure 4: Performance Management Cycle**



The planning phase is a continuous, iterative process of assessment and adjustment of NASA's Mission objectives at both the strategic and detailed levels to reflect national priorities, Congressional guidance,

## **NASA'S APPROACH TO PERFORMANCE MANAGEMENT**

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and other stakeholder input. Forming the foundation of the Strategic Management System are the processes for strategic long- and near-term planning. These processes take into account differing time spans and the complex interactions of guidance and requirements, independent assessments and analyses, and specific needs of a multi-faceted organization. Strategic long-term planning analyses and initiatives are focused on the timeframes of 10 years or beyond and provide context and input to the NASA Strategic Plan and near-term planning efforts.

In the evaluation phase, NASA holds leadership accountable for near-term performance standards and metrics and progress towards long-term objectives. Program authorities hold internal reviews on a regular basis to monitor and evaluate performance. The results support internal management processes and decision-making. The COO reviews progress towards the Agency program and project plans and addresses crosscutting concerns that may affect performance. Additionally, NASA's COO and PIO review progress towards strategic objectives annually.

The reporting phase connects evaluation to planning efforts. NASA managers present performance information to senior leaders, such as council members, and other stakeholders. Performance results inform investment, policy, and performance decisions made in the planning phase of the next performance management cycle.

The Strategic Plan, as set by the EC, establishes a strategy and performance framework that aligns short-term performance targets with the Agency's long-term commitments. The current strategy and performance framework consists of the elements of the Strategic Plan and Annual Performance Plans as seen in Figure 5. The strategy and performance framework has four elements:

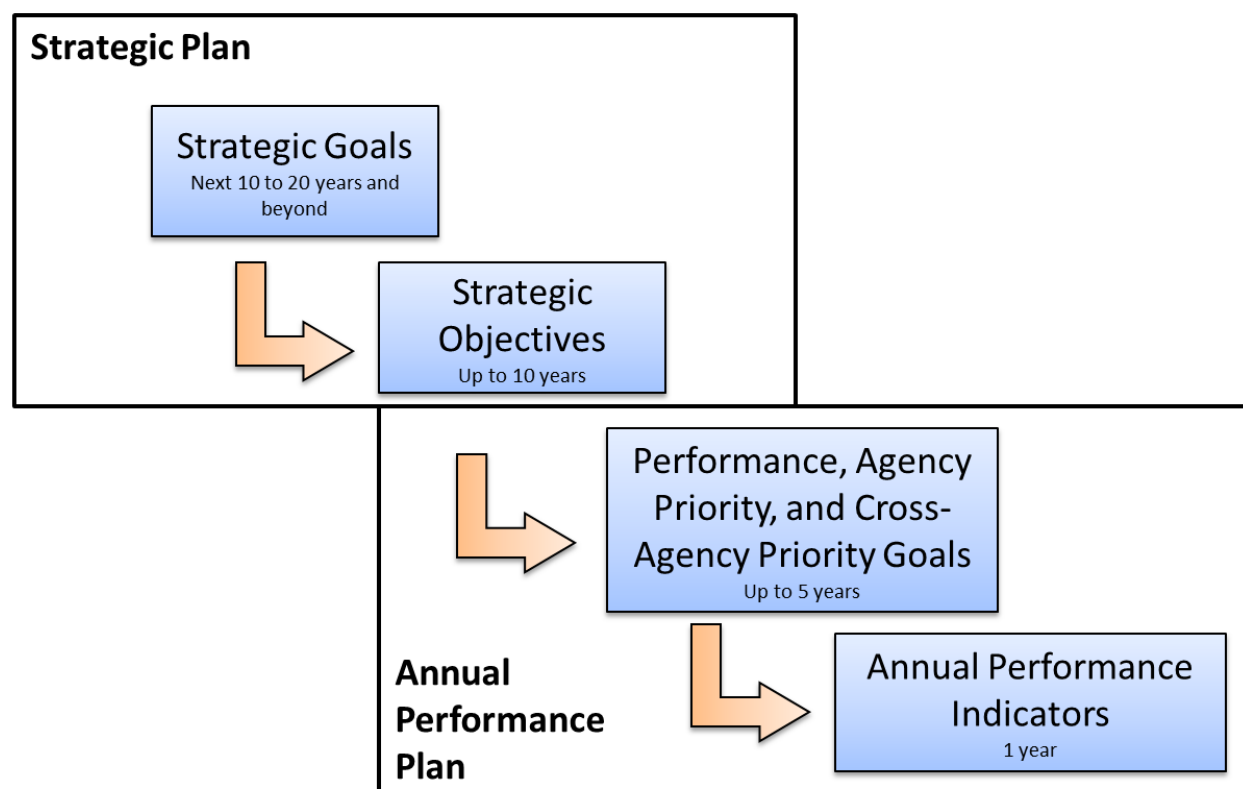
- Strategic goals,
- Objectives,
- Performance goals, including agency priority goals and cross-agency priority goals, and
- Annual performance indicators.

The internal implementation plans of individual offices and NASA Centers derive from this framework. Internal implementation plans guide each organization's activities toward achieving performance goals and annual performance indicators. As these plans are very technical, they generally remain internal to the Agency.



## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

Figure 5: NASA's Strategy and Performance Framework



NASA's [2014 Strategic Plan](#) reflects the top levels in the strategy and performance framework. The strategic goals and strategic objectives result from rigorous internal planning and external consultation with the Agency's stakeholders. Strategic objectives align with NASA's programs in the Congressional Justification.

The Agency's senior leaders set the Strategic Plan to reflect the Agency's direction and priorities, as agreed to with Congress and the Administration. Updates occur according to the timelines set by the GPRA Modernization Act. As such, the Agency plans to update its Strategic Plan again in 2018 with input from stakeholders, including Congress and OMB.

In accordance with the GPRA Modernization Act, NASA also delivers its agency priority goals with its Strategic Plan, to signify the importance of these ambitious, short-term goals in the overall achievement of NASA's strategy. Agency priority goals are discussed in more detail in "Management Priorities and Challenges."

### ANNUAL PERFORMANCE PLANS

NASA's Annual Performance Plans set near-term targets for programs, projects, and organizations through performance goals, agency priority goals, cross-agency priority goals, and annual performance indicators. Performance goals, agency priority goals, and cross-agency priority goals focus on planned progress over the next two to four years. Annual performance indicators align to NASA's budget themes

## **NASA'S APPROACH TO PERFORMANCE MANAGEMENT**

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and programs in the Congressional Justification. NASA publishes these measures in Annual Performance Plans, which also identify each responsible program or office. The FY 2014 and FY 2015 Performance Plans are included in the “Performance Reporting and Planning” section of this appendix. In its Annual Performance Plans, NASA also sets targets for mission support activities that sustain program and project activities. These performance commitments span the mission support portfolio in a range of areas, including human capital, information technology, infrastructure, and operating activities.

### **Using Evidence, Evaluation, and Research to Set Strategies and Measure Progress**

NASA uses laws, executive orders, governance, and management best practices to promote a strong culture of results and accountability. NASA is committed to demonstrating that its programs and activities are managed and operated effectively and efficiently. This is done through a dynamic process of collecting evidence (data, research, or end product) and conducting rigorous independent evaluations of the evidence. These processes of verification and validation support strategic planning and determine general accuracy and reliability of performance information. These processes provide a level of confidence to stakeholders that the information the Agency provides is credible.

NASA's performance evaluation processes consist of internal and external reviews, including independent assessments and verification. NASA conducts evidence, evaluation, and research activities summarized below.

#### **INTERNAL REVIEWS**

- NASA monitors and assesses the engineering process of designing, building, and operating spacecraft and other major assets. Measures of performance for such investments focus on comparisons of actual versus planned schedule and cost. The Agency holds formal independent assessments as the project progresses through a series of gatekeeping KDPs. Such KDPs provide managers time to review all aspects of performance and thoughtfully promote (or delay, or even terminate) work on a project. These points can occur at any time of the year, depending on the formulation, development, or construction plan. NASA conducts additional set technical reviews between the KDPs to assess progress and continually monitor overall performance through the Baseline Performance Review.
- NASA's research programs often have broad goals, such as “understand the origin of the universe.” To measure performance of these types of investments, NASA establishes and measures performance against smaller achievable goals to help demonstrate impact and overall contribution to the knowledge on the subject. It conducts assessments on these programs yearly, and lessons learned are captured as part of a yearly strategic review process.
- NASA assesses technology research and development (R&D) programs against incremental milestones (technology readiness levels, or TRLs). It regularly measures the TRL advancement of an individual technology investment, with overall technology portfolio assessments occurring each year.
- The Agency's operational or support and service type programs generally assess progress on meeting their specific objectives. They can measure performance against targets for output or capacity of the activity, quantifiable estimates of improvement with aggressive targets (e.g.,



## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

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reducing operating costs by two percent in two years), customer satisfaction, or routine on-site assessments. These assessments are often done annually.

- As part of end-of-fiscal year reporting, NASA's mission directorates and mission support offices within MSD and the Education office submit evidence supporting all performance measure ratings and rating explanations. This information is stored in the Performance Warehouse.

### EXTERNAL REVIEWS AND ASSESSMENTS

- NASA relies on evaluations by the external community. Papers from NASA-supported research undergo independent peer-review for publication in professional journals. The Agency uses external peer review panels to objectively assess and evaluate proposals for new work in its science areas, technology development, and education. NASA often leverages internal and external evaluators to assess strategies, impact, implementation, efficiency and effectiveness, cost to benefit ratio, and relevance of work being performed. NASA relies on Senior Reviews by external scientists for advice on the most productive uses of funding for extended operations of science missions.
- Evaluations are a routine business activity in NASA. A series of decadal surveys and other analyses, conducted by the National Academies, help inform decisions about the Science Mission Directorate's investment portfolio and other aspects of NASA's R&D efforts. These external evaluations of user needs and requirements, in combination with performance assessments of on-going activities, help ensure that NASA's research priorities and investments stay current with the needs of the research community. The Technology Roadmaps are a similar planning tool, reflecting the R&D and technology needs of NASA, the government, and industry.

### INNOVATIVE USE OF DATA FOR IMPROVED PERFORMANCE

NASA has answered the President's 2013 call to promote performance solutions that deliver a smarter, more innovative, and more accountable government for its citizens.<sup>3</sup> A critical component of this effort is strengthening NASA's ability to continually improve program performance by applying existing evidence about what works, generating new knowledge, and using experimentation to test new approaches to program delivery. NASA's strong commitment to this effort can be seen in a variety of a tools aimed at increasing its ability to use relevant performance information for budget and programming decisions.

In 2012, NASA implemented a Performance Management System comprised of the Performance Warehouse, a database designed in partnership with the Department of Treasury, and a companion system, the Performance Dashboard. These are internal NASA tools, but they produce reports that are publicly available at <http://www.nasa.gov/news/budget/index.html>. The Performance Warehouse standardizes data collection and archiving, streamlines performance reporting (both internally and to sites such as <http://performance.gov/>), and enables advanced data analytics. Beyond supporting NASA's internal management processes, these capabilities facilitate compliance with legislative and executive branch requirements, such as preparing machine-readable formats of performance information, and carrying out verification and validation of performance data. The Performance Dashboard automates ad hoc performance analysis, including production of mandated reports and plans such as the combined

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<sup>3</sup> OMB Memorandum-13-17, "[Next Steps in the Evidence and Innovation Agenda](#)," July 26, 2013.

## **NASA'S APPROACH TO PERFORMANCE MANAGEMENT**

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Annual Performance Plans and Annual Performance Report included in the “Performance Reporting and Planning” section in this appendix.

NASA is implementing an effort to enhance its program planning and control capability, including the use of earned value management, a project management technique for measuring project performance, progress, and risk. NASA collects program and project cost-estimating data, including project joint confidence levels, through its Cost Analysis Data Requirement (CADRe) and the One NASA Cost Engineering (ONCE) database. NASA is analyzing CADRe information collected in the ONCE database to gain insight into program and project growth over time. The objective is to use this analysis to improve cost estimation techniques and assessments of program and project planning and lifecycle reviews. NASA continues to strengthen the use of this tool.

### **PERFORMANCE MANAGEMENT**

Once NASA organizations begin executing against commitments in the Strategic Plan and Annual Performance Plan, Agency managers and performance analysts monitor and evaluate performance. Internal reporting requirements drive the evaluation phase and call for analysis of results against planned performance. NASA continuously measures the Agency's progress in pursuit of its strategic goals, strategic objectives, and performance measures, and reports progress towards its targets to Congress and the public in the Annual Performance Report. The Agency shares its report combined with future Annual Performance Plans to provide a holistic view of NASA's performance.

The Agency monitors and evaluates performance toward plans and commitments using assessments, through which managers identify issues, gauge programmatic and organizational health, and provide appropriate data and evidence to NASA decision-makers. Assessments include:

- On-going monthly and quarterly analysis and reviews of Agency activities;
- Annual program/project assessments in support of budget formulation;
- Annual reporting of performance, management issues, and financial position;
- Strategic reviews of each strategic objective (starting in spring 2014);
- Periodic, in-depth program or special purpose assessments; and
- Recurring or special assessment reports to internal and external organizations.

### **QUARTERLY REPORTING**

Each quarter, program officials submit to NASA management a self-evaluation that includes a rating for each performance measure and the supporting information that justifies the rating. The results of the quarterly performance assessments are presented to NASA's PIO and COO. This quarterly Executive Review keeps the PIO and COO informed of NASA's performance progress, allows them to make course corrections through the year to maintain alignment with strategic goals, and informs budget discussions. The PIO and COO review and approve the fourth quarter performance ratings before they are sent to OMB for review and subsequently published in the Agency Financial Report. The process culminates with the Annual Performance Report, comprised of the ratings (including any changes made after publication of the Agency Financial Report), rating explanations, and performance improvement plans.

# NASA'S APPROACH TO PERFORMANCE MANAGEMENT

## ANNUAL ASSESSMENT RATING SCALES AND CRITERIA

NASA evaluates progress toward achieving performance goals and annual performance indicators against the Agency's standard rating scale, summarized in Figure 6. NASA bases performance ratings on internal assessments, mentioned above. External entities, such as scientific review committees and aeronautics technical evaluation bodies, validate the ratings prior to publication by NASA.

**Figure 6: Performance Goal Rating Scale**

Rating	Rating Criteria for Performance Goals
<b>Green</b> (On Track)	NASA achieved or expects to achieve the intent of the performance goal within the estimated timeframe. NASA achieved the majority of key activities supporting this performance goal.
<b>Yellow</b> (At Risk)	NASA expects to achieve the intent of the performance goal within the timeframe; however, there is at least one likely programmatic, cost, or schedule risk to achieving the performance goal.
<b>Red</b> (Not on Track)	NASA does not expect to achieve this performance goal within the estimated timeframe.
<b>White</b> (Canceled or Postponed)	NASA senior management canceled this performance goal and the Agency is no longer pursuing activities relevant to this performance goal or the program did not have activities relevant to the performance goal during the fiscal year.

In FY 2013, NASA began defining custom success criteria for each annual performance indicator. Previously, rating criteria were based on a program completion percentage: 100 percent for Green, above 80 percent for Yellow, and below 80 percent for Red. In the current system, mission directorates and mission support offices collaboratively define their own parameters for the color ratings (Green, Yellow, and Red) when the measures are developed. NASA uses these success criteria, combined with explanations of the ratings and sources provided by the mission directorates and mission support offices, to review and validate each rating.

## SUMMARY OF FY 2013 PERFORMANCE

NASA reviewed progress toward its 76 performance goals and 94 annual performance indicators for FY 2013. (Performance goals have a two- to five-year timeline.) The results in Figure 7 show actual performance for these measures in FY 2013 and the two prior fiscal years. For both performance goals and APIs, NASA met 93 percent of its targets in FY 2013, represented by Green ratings. Other highlights include:

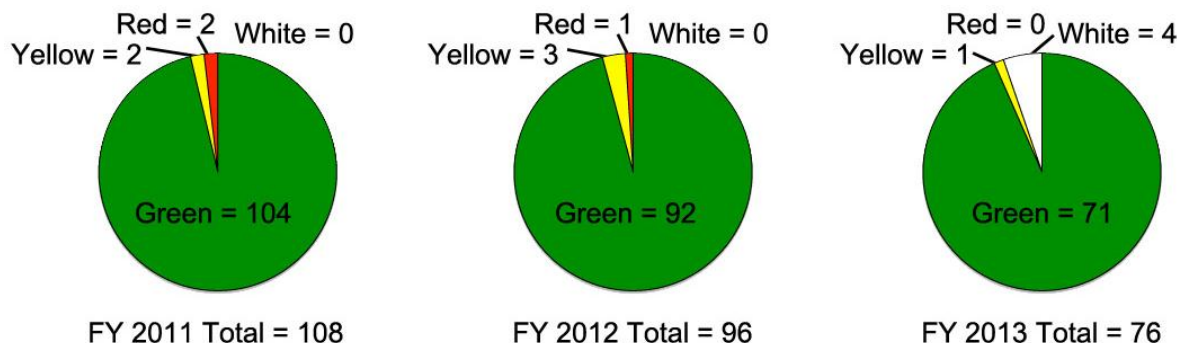
- At the performance goal level, NASA met 96 percent of its targets in both FY 2011 and FY 2012, representing a slight decrease in FY 2013.
- At the annual performance indicator level, NASA met 82 percent of its targets in FY 2011 and 91 percent of its targets in FY 2012, a 13 percent improvement over the two-year period.
- In FY 2013, one percent of NASA's performance goals and three percent of its annual performance indicators fell below expectations, represented by Yellow and Red ratings. The remainder were rated White, which represents measures canceled by NASA senior management.

## NASA'S APPROACH TO PERFORMANCE MANAGEMENT

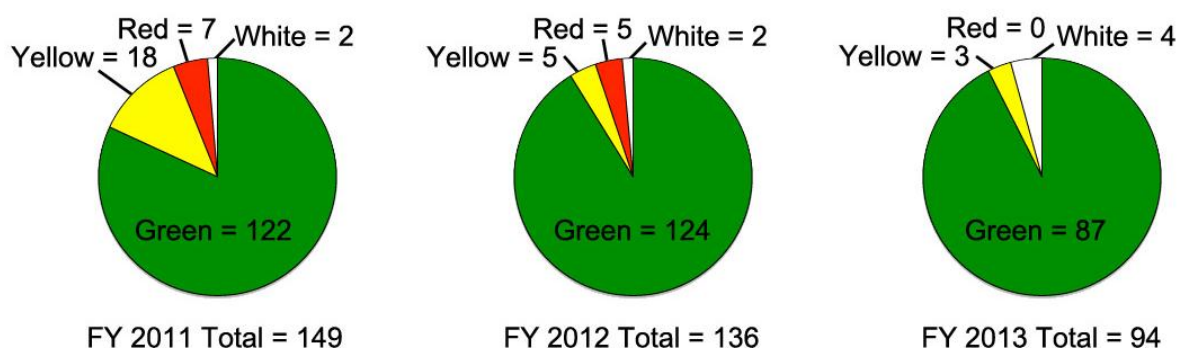
- Four percent of NASA's performance goals in FY 2011 and FY 2012 fell below expectations. Seventeen and seven percent of the annual performance indicators fell below expectations in FY 2011 and FY 2012, respectively.

**Figure 7: Trends in Annual Performance, FY 2011-FY2013**

### Performance Goals



### Annual Performance Indicators



NASA rated one of its performance goals Yellow in FY 2013. The Space Network Ground Segment Sustainment (SGSS) project planned to replace or upgrade obsolete systems at the White Sands Complex. SGSS has not completed the cost and schedule portion of the Critical Design Review (CDR) for this activity; due to performance issues, this project is currently under review.

NASA rated three of its annual performance indicators Yellow in FY 2013. They are related to ISS, SGSS, and the Ice, Cloud, and Land Elevation Satellite (ICESat-2) activities. NASA rated ISS utilization Yellow, as it is currently at 60 percent utilization, below the 75 percent threshold set for FY 2013. (Utilization includes participation from three classes of participants: NASA research among different NASA programs; ISS National Laboratory operations that include other U.S. agencies and commercial research; and ISS International Partners like the European Space Agency, the Canadian Space Agency, Agenzia Spaziale Italiana, or Italian Space Agency, and Japan Aerospace Exploration Agency.) The SGSS project, which includes updates to the Tracking and Data Relay Satellites (TDRS) and ground segments in New Mexico and Guam, received a Yellow rating due to slower than planned progress

## **NASA'S APPROACH TO PERFORMANCE MANAGEMENT**

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towards its 2014 CDR (see the Yellow performance goal described above). ICESat-2 is designed to measure ice sheets, clouds and aerosols, and land topography and vegetation. Due to erosion in cost and schedule performance, the program replaced the instrument management team. The new team will present an achievable plan at CDR, which is now in FY 2014. Based on this revised schedule, NASA rated the FY 2013 annual performance indicator Yellow. This is in accordance with the measure's success criteria for a Yellow rating, which states that it must be completed within the following fiscal year. In three of the last four years, NASA rated the ICESat-2 annual performance indicator Yellow.

NASA rated four performance goals and four annual performance indicators White, as canceled or postponed. FY 2013 budget levels were reduced for two information technology (IT) programs, which affected IT enterprise service commitments for FY 2014, and data center energy consumption commitments for FY 2015. NASA's Office of Education rated one performance goal and one annual performance indicator White, because continuing resolutions in FY 2012 and FY 2013 resulted in the untimely allocation of funds, hindering Education's ability to implement planned programmatic changes within the calendar year. The Office of Education also rated another performance goal and annual performance indicator White, because the measurement strategy was inadequate and did not have an accurate baseline. NASA will re-evaluate these measures in future Annual Performance Plans.

## **COST AND SCHEDULE PERFORMANCE SUMMARY**

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### **FY 2014 COST AND SCHEDULE PERFORMANCE DETAILS AND TRENDS**

#### **2014 Major Program Annual Report Summary**

The 2014 MPAR is provided to meet the requirements of section 103 of the NASA Authorization Act of 2005 (P.L. 109-155; 42 U.S.C. 16613). The 2014 MPAR consists of this summary and FY 2015 Congressional Justification pages designated as “Projects in Development,” for the projects outlined below. These project pages constitute each project’s annual report, or if this is the first year for which it is in reporting, the baseline report. The MPAR summary also includes the confidence level of achieving the commitments as requested in the Conference Report accompanying the FY 2010 Consolidated Appropriations Act (P.L. 111-117). As required by section 1203 of NASA 2010 Authorization Act (P.L. 111-267; 42 U.S.C. 18301), the corrective action plans for GPM, OCO-2, JWST, and SOFIA can be found in the respective project pages in the FY 2015 Congressional Justification.

#### **Changes in MPAR Composition since the FY 2014 NASA Budget Estimates**

Four new projects with estimated lifecycle costs greater than \$250 million received authority to proceed into the development phase since NASA submitted its 2013 MPAR in the FY 2014 NASA Congressional Justification:

- Origins, Spectral Interpretation, Resource Identification, and Security - Regolith Explorer (OSIRIS-REx), with a baseline development cost of \$778.6 million at a joint confidence level of 70 percent;
- Space Network Ground System Segment Sustainment (SGSS), with a baseline development cost of \$368.1 million and 70 percent joint confidence level.
- Solar Orbiter Collector (SOC) with a baseline development cost of \$376.9 million and a 70 percent confidence level for both cost and schedule;
- Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), with a baseline development cost of \$541.8M at a joint confidence level of 70 percent.

The 2013 MPAR in the FY 2014 NASA Congressional Justification included three projects that are no longer in MPAR reporting. NASA successfully launched the LADEE spacecraft on September 6, 2013, and the MAVEN spacecraft on November 18, 2013. NASA launched the MAVEN spacecraft within days of the project baseline launch date and approximately 14% below the baseline development cost. NASA launched LADEE two months before the project baseline launch date and approximately 14% above the baseline development cost. TDRS K/L was also removed from MPAR reporting in this budget with the launch of the TDRS L spacecraft.

#### **Changes in Cost and Schedule Estimates from the 2013 MPAR**

Four projects had no or minor changes in their cost or schedule estimates over the last year.

Two projects ICESat-2 and SGSS are experiencing cost and schedule growth and are under review:

- The ICESat-2 project experienced significant cost growth since the 2013 MPAR as a result of technical difficulties associated with developing the project’s primary instrument. NASA completed the threshold reporting notification requirements under section 103(c) of P.L. 109-155 of the NASA Authorization Act of 2005 and submitted these reports to appropriate Congressional committees.

## COST AND SCHEDULE PERFORMANCE SUMMARY

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- The SGSS project is experiencing contractor performance issues and preparing the notification required under the NASA Authorization Act.

### MPAR Summary Table

Figure 2 provides cost, schedule, and confidence level information for NASA projects currently in development with lifecycle cost estimates of \$250 million or more. NASA records the estimated development cost and a key schedule milestone and then measures changes from them. NASA tracks one of several key milestones, listed below, for reporting purposes:

- Launch readiness date (LRD);
- Full operational capability (FOC); or
- Initial operating capability (IOC).

As a note for clarification, LRD schedule milestones, as reported here, are not typically the launch dates on the NASA launch manifest, but are the desired launch dates as determined by the payload mission and approved by the NASA Flight Planning Board (FPB). A launch manifest is a dynamic schedule that is affected by real world operational activities conducted by NASA and multiple other entities. It reflects the results of a complex process that requires the coordination and cooperation by multiple users for the use of launch range and launch contractor assets. The launch dates shown on the NASA FPB launch manifest are a mixture of confirmed range dates for missions launching within approximately six months and contractual/planning dates for the missions beyond six months from launch. The NASA FPB launch manifest date is typically earlier than the reported schedule dates reported here, thereby allowing for the operationally driven fluctuations to the launch schedule that may be outside of the Project's control. The NASA FPB launch manifest is updated on a periodic basis throughout the year.

The confidence level (CL) estimates reflect an evolving process as NASA improves its probabilistic estimation techniques and processes. Each estimate reflects the practices and policies at the time it was developed. Estimates that include combined cost and schedule risks are denoted as Joint Confidence Level (JCL) estimates; all other CLs reflect cost confidence without necessarily factoring the potential impacts of schedule changes on cost.

Additional explanations for the data in the summary table are provided here:

- JWST: Cost Estimate includes Construction of Facilities funds.
- MMS: the confidence level estimates include the partners' contributions, while the development cost reflects only the NASA portion of project costs.
- OCO-2: Pursuant to sec. 103(e) of PL 109-155, this budget request establishes a new baseline. Details concerning OCO-2 purpose, cost estimate, schedule, and risks are provided in the OCO-2 project pages of this budget.
- SOC: Two instruments are below the \$250M LCC threshold for JCL. Independent cost and schedule estimates completed by Aerospace and GSFC RAO with each instrument had confidence levels for cost and schedule that were 70 percent when the start of development was approved (at KCP-C).
- GPM: GPM successfully launched February 27, 2014, eight months after its baseline schedule. The launch delay was due to development issues and schedule challenges encountered by both NASA and its partner, JAXA.

## COST AND SCHEDULE PERFORMANCE SUMMARY

Additional information on the projects shown in the table below can be found in their individual program and project pages in the main body of the Congressional Justification.

**Figure 2: MPAR Summary and Confidence Levels**

Project	Base Year	JCL (%)	Development Cost Estimate (\$M)		Cost Change (%)	Key Milestone	Key Milestone		Schedule Change (months)
			Base	2014			Base	2014	
GPM	2010	70	555.2	519.3	-6	LRD	Jul 2013	Feb 2014	8
ICESat-2	2013	70	558.9	Under Review	N/A	LRD	May 2017	Under Review	N/A
InSight	2014	70	541.8	541.8	0	LRD	Mar 2016	Mar 2016	0
JWST	2012	66	6,197.9	6,190.4	0	LRD	Oct 2018	Oct 2018	0
MMS	2010	70	857.3	856.7	0	LRD	Mar 2015	Mar 2015	0
OCO-2	2014	>70	371.8	371.6	0	LRD	Feb 2015	Feb 2015	0
OSIRIS-REx	2014	70	778.6	721.7	-7	LRD	Oct 2016	Oct 2016	0
SGSS	2013	70	368.1	Under Review	N/A	FAR	Jun 2017	Under Review	N/A
SMAP	2013	>70	485.7	490.0	1	LRD	Mar 2015	Mar 2015	0
SOC	2014	N/A	376.9	376.6	0	LRD	Oct 2018	Oct 2018	0
SOFIA*	2007	70	919.5	1,106.3	20	FOC	Dec 2013	Mar 2014	3

*Note: Pursuant to sec. 103(e) of PL 109-156, this budget request establishes a new baseline for OCO-2. The original OCO-2 baseline in 2011 had a 49% cost increase.*

*\*SOFIA: The Budget proposes to greatly reduce funding for SOFIA. Please refer to the Science Mission Directorate section of the Congressional Justification for more detail*



# BASIC RESEARCH

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## BACKGROUND

Section 1008(c) of the American COMPETES Act (P.L. 110-69) directs that each Executive agency shall submit to the Congress each year, together with documents in support of the budget of the President, a report outlining agency funding for “high-risk, high-reward” basic research projects. Specifically, the report shall describe whether a funding goal has been established that: (1) meets fundamental technological or scientific challenges; (2) involves multidisciplinary work; and (3) involves a high degree of novelty. The Act further stipulates that basic research shall be defined in accordance with OMB Circular A-11.

The information requested in section 1008(c) is provided herein.

OMB Circular A-11 defines basic research as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific application towards processes or products in mind. Basic research, however, may include activities with broad applications in mind.

## REPORT

The total fiscal year (FY) 2015 President’s budget request is \$17.5 billion. The NASA Research and Development (R&D) budget consists of 18% basic research, 13% applied research, and 34% development as defined by OMB circular A-11.

Because much of NASA’s work revolves around the creation of one-of-a-kind missions, a relatively large portion of our research and development activities involve *high-risk, high-reward* research and development—from basic research through applications and technology development. Additionally, NASA is a leader in using innovative research approaches, such as science competitions and prizes, as well as multidisciplinary approaches. However, since the majority of these activities do not fall within the OMB definition of basic research, they are excluded from this report.

NASA conducts basic research under two accounts: (1) Science and (2) Human Exploration Operations.

NASA expects that of its basic research for FY 2015, 32% will be for high-risk, high-reward fundamental technical and scientific challenges that are novel and multidisciplinary. NASA is budgeting \$989M for high-risk, high-reward basic research.

### Description of activities:

1) Science: NASA conducts basic research in four theme areas:

- a) Astrophysics: Study of the origin, evolution and fate of the universe, and to search for exoplanets;
- b) Earth Science: Study of the Earth, its interior, oceans, atmosphere and fundamental processes within and interactions among those areas, including long-term climate change;
- c) Heliophysics: Study of the sun, its interior, corona, solar wind, and the heliosphere, specifically including interactions with planetary magnetospheres; and

## BASIC RESEARCH

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(d) Planetary Science: Study of the planets, moons, comets, asteroids and other bodies within our own solar system, including their interiors, surfaces, atmospheres, magnetospheres, etc. and their interactions.

Many of NASA's missions are inherently risky when they are launched on rockets into space and performing missions in the air-less, weightless, high-radiation environment of space or near or on the surface of other planets. In addition, like other high-risk research, the outcomes of the research are often far from clear. However, the rewards can also be great. The following are examples of *high-risk, high-reward* science projects:

Mars Science Lab (<http://www.jpl.nasa.gov/missions/details.php?id=5918>): The Mars Science Laboratory mission's Curiosity rover, the most technologically advanced rover ever built, landed in Mars' Gale Crater the evening of August 5, 2012 PDT (morning of August 6 EDT) using a series of complicated landing maneuvers never before attempted. The specialized landing sequence, which employed a giant parachute, a jet-controlled descent vehicle, and a bungee-like apparatus called a "sky crane," was necessary because landing techniques used during previous rover missions could not safely accommodate the much larger and heavier Curiosity. The rover, which is about the size of a MINI Cooper, is equipped with 17 cameras and a robotic arm containing a suite of specialized laboratory-like tools and instruments.

Curiosity's mission is to determine whether the Red Planet ever was, or is, habitable to microbial life. If we eventually discover life on Mars, it could revolutionize our understanding of some aspects of biology. Over a year since landing, the rewards so far have met or exceeded all expectations. The rover has already traveled more than 2.5 miles since landing. Key discoveries include:

- Water once flowed on Mars' surface, was relatively neutral and low salinity ("you could have drank it"), and contained the ingredients for life, demonstrating Mars could have supported microbial life.
- Approximately two percent of the weight of the examined soil samples is composed of water ice.
- Analysis of the isotope ratio of argon in the atmosphere of Mars has confirmed that some meteorites that have fallen to Earth originated on Mars. The isotope ratios also confirm that the Martian atmosphere was once much thicker.
- A lack of detectable methane in the Mars atmosphere was a surprise, as prior observations by an orbital instrument and Earth-based observations had led to the expectation that methane would be present.
- The radiation dose that a human crew might receive during a 30-month round trip mission to Mars could be 0.6 Sievert, or 60 REM, which could affect mission design.

Curiosity is now traversing from the landing site to the base of Mt. Sharp, about five miles away. Should Curiosity continue to survive the harsh Martian environment, it will study thick layers of exposed rock at Mt. Sharp, which hold more clues to Mars' past.

Orbiting Carbon Observatory 2 (OCO-2) (<http://oco.jpl.nasa.gov>) will be NASA's first dedicated satellite to study atmospheric carbon dioxide (CO<sub>2</sub>). CO<sub>2</sub> is one of several gases, known as greenhouse gases, which trap heat near the surface of the Earth. Substantial increases in the abundance of CO<sub>2</sub> will generate an increase in the Earth's surface temperature.

Understanding where atmospheric CO<sub>2</sub> originates (sources), and how quickly it is reabsorbed by the oceans, plants and land (sinks), is key to predicting future global temperatures. OCO-2 will collect global

## BASIC RESEARCH

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measurements of atmospheric CO<sub>2</sub> with the precision, resolution, and coverage needed to characterize sources and sinks on regional scales. OCO-2 will also be able to quantify CO<sub>2</sub> variability over the seasonal cycles, year after year.

OCO-2 thus demonstrates the high potential return of space missions – as well as the high risks. OCO-2 is based on the original OCO mission that was launched from Vandenberg Air Force Base on February 24, 2009. Before spacecraft separation, a launch vehicle failure prevented the OCO spacecraft from reaching orbit, and it was destroyed during re-entry. The scientific importance of the mission drives our second attempt in late 2014.

(2) Human Exploration Operations: NASA conducts basic research on the International Space Station (ISS) in several areas including human health and exploration, technology development and demonstration, physical sciences research, biology and biotechnology research, earth and space science research. In addition, ISS basic research enables education and the development of market driven commercial research and applications in low earth orbit. The following are examples of high-risk, high-reward human exploration projects and programs:

Biological and Physical Sciences ([http://www.nasa.gov/mission\\_pages/station/research/index.html](http://www.nasa.gov/mission_pages/station/research/index.html)) will soon fly their first group of rodents on ISS dedicated entirely to long-duration research. They study of rodents onboard the ISS is high-risk, high-reward basic research because it allows NASA to conduct and enable research which could not be conducted on humans. A new rodent research habitat validation flight will take place with a small amount of science in 2014, and then in 2015 approximately 40 rodents will be flown to the ISS for 30 days. Upon return to Earth, they will be utilized in a variety of studies on the musculoskeletal system, and the reproduction and immune functions. Prior rodent research studies only lasted eight- twelve days with 10 - 20 rodents. Longer duration and greater numbers of subjects are key, given the life span and development of mice. Approximately one month of a mouse's life is equivalent to two-and-a-half human years. This, along with genetic and developmental similarities to humans, makes mice a model organism for human research.

Vaccine development for osteoporosis countermeasures, microbial virulence and infection and wound healing studies may also become possible with the increased amount of rodent research and newly developed hardware which supports it.

Human Research Program (<http://www.nasa.gov/exploration/humanresearch/>) is dedicated to discovering the best methods and technologies to support safe, productive human space exploration. The major areas of HRP's physiological research include bone health, muscle function, cardiovascular response, sensorimotor systems, immunology, behavioral health, and space radiation effects. One example of this *high-risk, high-reward* research is in the area of ocular health.

A significant number of the astronauts on long-duration missions to the International Space Station experience changes to their vision including blurring, optic disc swelling, and choroidal folds. Although the cause of these visual changes has not been determined, researchers believe that fluid shifts within the body from the microgravity environment of space produce increases to the astronaut's intracranial pressure. Current research is producing information that can be used to assess the risk of microgravity-induced visual impairment and guide future understanding of how to manage this problem and mitigate the impact to future exploration missions.

In order for NASA to systematically measure visual, vascular, and intracranial changes over the course of time, new research and technology is being developed to better define the risk to astronauts and enable

## BASIC RESEARCH

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countermeasure testing. The research and technology development obtained to address this spaceflight medical risk may also be relevant to patients suffering from eye diseases such as glaucoma, elevated intracranial pressure, or neurological disorders, such as water on the brain.

### SUMMARY

The NASA 2015 budget supports an extensive program of high-risk, high-reward basic research that is novel, multidisciplinary and of fundamental scientific or technological interest. NASA expects that 32% of its basic research to be *high-risk, high-reward*.

# FY 2015 PROPOSED APPROPRIATIONS LANGUAGE

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## SCIENCE

For necessary expenses, not otherwise provided for, in the conduct and support of science research and development activities, including research, development, operations, support, and services; maintenance and repair, facility planning and design; space flight, spacecraft control, and communications activities; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$5,151,200,000]\$4,972,000,000, to remain available until September 30, [2015: *Provided*, That the formulation and development costs (with development cost as defined under section 30104 of title 51, United States Code) for the James Webb Space Telescope shall not exceed \$8,000,000,000: *Provided further*, That should the individual identified under subsection (c)(2)(E) of section 30104 of title 51, United States Code, as responsible for the James Webb Space Telescope determine that the development cost of the program is likely to exceed that limitation, the individual shall immediately notify the Administrator and the increase shall be treated as if it meets the 30 percent threshold described in subsection (f) of section 30104: *Provided further*, That \$80,000,000 shall be for pre-formulation and/or formulation activities for a mission that meets the science goals outlined for the Jupiter Europa mission in the most recent planetary science decadal survey]2016. (*Science Appropriations Act, 2014.*)

## AERONAUTICS

For necessary expenses, not otherwise provided for, in the conduct and support of aeronautics research and development activities, including research, development, operations, support, and services; maintenance and repair, facility planning and design; space flight, spacecraft control, and communications activities; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$566,000,000]\$551,100,000, to remain available until September 30, [2015]2016. (*Science Appropriations Act, 2014.*)

## SPACE TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of space research and technology development activities, including research, development, operations, support, and services; maintenance and repair, facility planning and design; space flight, spacecraft control, and communications activities; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$576,000,000]\$705,500,000, to remain available until September 30, [2015]2016. (*Science Appropriations Act, 2014.*)

# FY 2015 PROPOSED APPROPRIATIONS LANGUAGE

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## EXPLORATION

For necessary expenses, not otherwise provided for, in the conduct and support of exploration research and development activities, including research, development, operations, support, and services; maintenance and repair, facility planning and design; space flight, spacecraft control, and communications activities; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$4,113,200,000]\$3,976,000,000, to remain available until September 30, [2015: *Provided*, That not less than \$1,197,000,000 shall be for the Orion Multi-Purpose Crew Vehicle: *Provided further*, That not less than \$1,918,200,000 shall be for the Space Launch System, which shall have a lift capability not less than 130 metric tons and which shall have an upper stage and other core elements developed simultaneously: *Provided further*, That of the funds made available for the Space Launch System, \$1,600,000,000 shall be for launch vehicle development and \$318,200,000 shall be for exploration ground systems: *Provided further*, That funds made available for the Orion Multi-Purpose Crew Vehicle and Space Launch System are in addition to funds provided for these programs under the "Construction and Environmental Compliance and Restoration" heading: *Provided further*, That \$696,000,000 shall be for commercial spaceflight activities, of which \$171,000,000 shall be made available after the Administrator of the National Aeronautics and Space Administration has certified that the commercial crew program has undergone an independent benefit-cost analysis that takes into consideration the total Federal investment in the commercial crew program and the expected operational life of the International Space Station as described in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated Act): *Provided further*, That \$302,000,000 shall be for exploration research and development]2016. (*Science Appropriations Act, 2014.*)

## SPACE OPERATIONS

For necessary expenses, not otherwise provided for, in the conduct and support of space operations research and development activities, including research, development, operations, support and services; space flight, spacecraft control and communications activities, including operations, production, and services; maintenance and repair, facility planning and design; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance and operation of mission and administrative aircraft, [\$3,778,000,000]\$3,905,400,000, to remain available until September 30, [2015]2016. (*Science Appropriations Act, 2014.*)

# FY 2015 PROPOSED APPROPRIATIONS LANGUAGE

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## EDUCATION

For necessary expenses, not otherwise provided for, in carrying out aerospace and aeronautical education research and development activities, including research, development, operations, support, and services; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$116,600,000]\$88,900,000, to remain available until September 30, [2015, of which \$18,000,000 shall be for the Experimental Program to Stimulate Competitive Research and \$40,000,000 shall be for the National Space Grant College program]2016. (*Science Appropriations Act, 2014.*)

## CROSS AGENCY SUPPORT

For necessary expenses, not otherwise provided for, in the conduct and support of science, aeronautics, *space technology*, exploration, space operations and education research and development activities, including research, development, operations, support, and services; maintenance and repair, facility planning and design; space flight, spacecraft control, and communications activities; program management; personnel and related costs, including uniforms or allowances therefor, as authorized by sections 5901 and 5902 of title 5, United States Code; travel expenses; purchase and hire of passenger motor vehicles; not to exceed \$63,000 for official reception and representation expenses; and purchase, lease, charter, maintenance, and operation of mission and administrative aircraft, [\$2,793,000,000]\$2,778,600,000, to remain available until September 30, [2015: *Provided*, That not less than \$39,100,000 shall be available for independent verification and validation activities]2016. (*Science Appropriations Act, 2014.*)

## CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

For necessary expenses for construction of facilities including repair, rehabilitation, revitalization, and modification of facilities, construction of new facilities and additions to existing facilities, facility planning and design, and restoration, and acquisition or condemnation of real property, as authorized by law, and environmental compliance and restoration, [\$515,000,000]\$446,100,000, to remain available until September 30, [2019]2020: *Provided*, That, *notwithstanding section 20145(b)(2)(A) of title 51, United States Code*, proceeds from leases deposited into this account shall be available for a period of 5 years [to the extent and in amounts as provided in annual appropriations Acts: *Provided further*, That such proceeds referred to in the preceding proviso shall be available for obligation for fiscal year 2014 in an amount not to exceed \$9,584,100]: *Provided further*, That each annual budget request shall include an annual estimate of gross receipts and collections and proposed use of all funds collected pursuant to section [315 of the National Aeronautics and Space Act of 1958 (51 U.S.C. 20145)]20145 of title 51, *United States Code*. (*Science Appropriations Act, 2014.*)

# FY 2015 PROPOSED APPROPRIATIONS LANGUAGE

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## INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, [~~\$37,500,000~~]~~\$37,000,000~~, of which \$500,000 shall remain available until September 30, [2015]2016. (*Science Appropriations Act, 2014.*)

## ADMINISTRATIVE PROVISIONS

Funds for announced prizes otherwise authorized shall remain available, without fiscal year limitation, until [the] a prize is claimed or the offer is withdrawn.

Not to exceed 5 percent of any appropriation made available for the current fiscal year for the National Aeronautics and Space Administration in this Act may be transferred between such appropriations, but no such appropriation, except as otherwise specifically provided, shall be increased by more than 10 percent by any such transfers. *Any funds transferred to "Construction and Environmental Compliance and Restoration" for construction activities shall not increase that account by more than 20 percent.* Balances so transferred shall be merged with and available for the same purposes and the same time period as the appropriations to which transferred. Any transfer pursuant to this provision shall be treated as a reprogramming of funds under section [505]504 of this Act and shall not be available for obligation except in compliance with the procedures set forth in that section.

The spending plan required by this Act shall be provided by NASA at the theme, program, project and activity level. The spending plan, as well as any subsequent change of an amount established in that spending plan that meets the notification requirements of section [505]504 of this Act, shall be treated as a reprogramming under section [505]504 of this Act and shall not be available for obligation or expenditure except in compliance with the procedures set forth in that section. (*Science Appropriations Act, 2014.*)



## ACRONYMS AND ABBREVIATIONS

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\$K	Dollars in thousands
\$M	Dollars in millions
21CSLC	21st Century Space Launch Complex
AANAPISI	Asian American Native American Pacific Islander Serving Institutions
AAV	Advanced Air Vehicles
ACCESS	Achieving Competence in Computing, Engineering, and Space Science
ACE	Advanced Composition Explorer
ADA	Americans with Disabilities
ADAP	Astrophysics Data Analysis Program
ADCAR	Astrophysics Data Curation and Archival Research
ADEPT	Adaptive Deployable Entry and Placement Technology
ADS-B	Automatic Dependent Surveillance-Broadcast
ADSI	Affordable Destination Systems and Instruments
ADSM	Astrophysics Decadal Strategic Mission
AEDL	Advanced Entry, Descent, and Landing
AES	Advanced Exploration Systems
AFRC	Armstrong Flight Research Center
AFTA	Astrophysics Focused Telescope Assets
AGI	Active Galactic Nuclei
AIM	Aeronomy of Ice in the Mesosphere
AIMS	Agency Information Technology Services
AMMOS	Advanced Multi-Mission Operations System
AMO	Agency Management and Operations
AO	Announcement of Opportunity
AOC	Airspace Operations Challenge
AOSP	Airspace Operations and Safety Program
APL	Applied Physics Laboratory
APMC	Agency Program Management Council
ARC	Ames Research Center
ARCD	Aerospace Research and Career Development Program
ARM	Asteroid Redirect Mission
ARMED	Aeronautics Research Mission Directorate
ARTEMIS	Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun
ASF	Alaska Satellite Facility
ASRG	Advanced Stirling Radioisotope Generator
ASI	Agenzia Spaziale Italiana
ASPERA	Analyzer of Space Plasma and Energetic Atoms
ATD	Airspace Technology Demonstration
ATFM	Applied Traffic Flow Management

## ACRONYMS AND ABBREVIATIONS

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ATK	Alliant Techsystems
ATLAS	Asteroid Terrestrial-impact Last Alert System
ATLO	Assembly, Text, Launch, and Operations
AU	Astronomical Units
BARREL	Balloon Array for RBSP Relativistic Electron Losses
BB	Building-Block
BBEDCA	Budget and Emergency Deficit Control Act
BFF	Booster Fabrication Facility
BLAST	Balloon-borne Large-Aperture Sub-millimeter Telescope
BWG	Beam Wave Guide
C3F	Commercial Crew and Cargo Processing Facility
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CAMMEE	Committee on Aerospace Medicine and the Medicine of Extreme Environments
CAP	Cross-Agency Priority
CAS	Cross Agency Support
CAS	Convergent Aeronautics Solutions
CASIS	Center for the Advancement in Space
CCAFS	Cape Canaveral Air Force Station
CCD	Charge-Coupled Devices
CCDev	Commercial Crew Development
CCDev2	Commercial Crew Development Round 2
CCiCap	Commercial Crew integrated Capability
CCLC	Century Community Learning Center
CCM	Camera Control Module
CCtCap	Commercial Crew transportation Capability
CDM	Continuous Diagnostic Mitigation
CDR	Critical Design Review
CDSCC	Canberra Deep Space Communications Complex
CECR	Construction and Environmental Compliance and Restoration
CHAMPS	Charge and Mass of Meteoric Smoke Particles
CHS	Crew Health and Safety
CIBER	Cosmic Infrared Background ExpeRiment
CINDI	Coupled Ion Neutral Dynamic Investigation
CIPAIR	Curriculum Improvements Partnership Award for the Integration of Research
CL	Confidence Level
CME	Coronal Mass Ejection
CMO	Center Management and Operations
CNES	Centre National d'Etudes Spatiales
CO <sub>2</sub>	Carbon Dioxide
CoF	Construction of Facilities

## ACRONYMS AND ABBREVIATIONS

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COMPETES	Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science
COR SAT	Cosmic Origins Strategic Astrophysics Technology
CoSTEM	Committee on Science Technology Engineering and Mathematics
CPC	Certification Products Contact
CPOD	Cubesat Proximity Operations Demonstration
CRADA	Cooperative Research and Development Agreement
CREAM	Cosmic Ray Energetics and Mass
CRF	Canister Rotation Facility
CSA	Canadian Space Agency
CSO	Communications Services Office
CSTD	Crosscutting Space Technology Development
CT	Crawler Transporter
CYGNSS	Cyclone Global Navigation Satellite System
DAEP	DSN Aperture Enhancement Project
DAR	Data at Rest
DHS	Department of Homeland Security
DLR	German Aerospace Center
DNA	Deoxyribonucleic Acid
DoD	Department of Defense
DoE	Department of Energy
DPMC	Directorate Program Management Council
DRIVE	Diversify, Realize, Integrate, Venture, Educate
DSI	Deutsches SOFIA Institut
DSN	Deep Space Network
DSS	Deep Space Station
DWR	Dynamic Weather Rerouting
EBEX	E and B Experiment
ECC	Education Coordinating Council
ECR	Environmental Compliance and Restoration
ED	Department of Education
EDL	Entry, Descent, and Landing
EDUC	Education Mission Directorate
EFB	Earth Flyby
EGS	Exploration Ground Systems
EHRS	Electronic Health Records System
EICC	EPSCoR Interagency Coordinating Committee
EMCS	Energy Management Control System
EONS	Educational Opportunities in NASA STEM
EPA	Environmental Protection Agency

## ACRONYMS AND ABBREVIATIONS

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EPF	Eastern Processing Facility
EPSCoR	Experimental Program to Stimulate Competitive Research
ESPC	Energy Savings Performance
ERA	Environmentally Responsible Aviation
ESA	European Space Agency
ESD	Exploration Systems Development
ESDN	Edison Demonstration of Smallsat Networks
ET	External Tank
ETD	Exploration Technology Development
EUV	Extreme Ultraviolet
EVA	Extravehicular Activities
EVI	Earth Venture Instrument
EX	Explorers
EXES	Echellon-Cross-Echelle Spectrograph
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FDC	Flight Demonstrations and Capabilities Project
FGS	Fine Guidance Sensor
FIFI-LS	Field Imaging Far-Infrared Line Spectrometer
FIRST	For Inspiration and Recognition of Science and Technology
FLITECAM	First Light Infrared Test Experiment Camera
FOC	Full Operational Capability
FORCAST	Faint Object InfraRed CAmera for the SOFIA Telescope
FORTIS	Far-ultraviolet Off Rowland-circle Telescope for Imaging and Spectroscopy
FRR	Flight Readiness Review
FT	Fast Traverse
FTE	Full Time Equivalent
FUV	Far Ultraviolet
FY	Fiscal Year
GALEX	Galaxy Evolution Explorer
GAO	Government Accountability Office
GEO	Geosynchronous Orbit
GEMS	Gravity and Extreme Magnetism
GIOP	Ground Integration and Operations Program
GLOBE	Global Learning and Observations to Benefit the Environment
GNC	Guidance, Navigation, and Control
GO	Guest Observer
GOES	Geostationary Operational Environmental Satellites
GOLD	Global-scale Observations of the Lamb Disk
GPM	Global Precipitation Measurement

## ACRONYMS AND ABBREVIATIONS

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GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	Gravity Recovery and Climate Experiment Follow-On
GRAIL	Gravity Recovery and Interior Laboratory
GRB	Gamma-Ray Burst
GRC	Glenn Research Center
GREAT	German Receiver for Astronomy at Terahertz Frequencies
GSDO	Ground Systems Development and Operations
GSFC	Goddard Space Flight Center
GSRT	GSFC System Review Team
GTA	Ground Test Article
HAWC	High-resolution Airborne Wideband Camera
HB	High Bay
HBCU	Historically Black Colleges and Universities
HEO	Human Exploration and Operations
HERO	Human Exploration Research Opportunities
Hi-C	High Resolution Coronal Imager
HIPO	High-speed Photometer for Occultations
HICO	Hyperspectral Imager for the Coastal Ocean
HIS	Heavy Ion Sensor
HMF	Hypergol Maintenance Facility
HMTA	Health and Medical Technical Authority
HP3	Heat Flow and Physical Properties Package
HQ	NASA Headquarters
HRP	Human Research Program
HS3	Hurricane and Severe Storm Sentinel
HSFO	Human Space Flight Operations
HSI	Hispanic-Serving Institutions
HST	Hubble Space Telescope
HVAC	Heating, Ventilation, and Air Conditioning
HWB	Hybrid Wing Body
I3P	Information Technology Infrastructure Integration Program
I&T	Integration & Test
IADS	Integrated Arrival/Departure/Surface
IASP	Integrated Aviation Systems Program
IBEX	Interstellar Boundary Explorer
ICESat-II	Ice, Cloud, and land Elevation Satellite-II
ICON	Ionospheric Connection Explorer
ICRP	Independent Comprehensive Review Panel
IL	Ionic Liquid

## ACRONYMS AND ABBREVIATIONS

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IMAGER	Interstellar Medium Absorption Gradient Experiment Rocket
IMC	International Mission Contributions
InSight	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport
IOM	Institute of Medicine
IPAC	Infrared Processing and Analysis Center
IPAO	Independent Program Assessment Office
IRB	Institutional Review Board
IRIS	Interface Region Imaging Spectrograph
ISARA	Integrated Solar Array and Reflectarray Antenna
ISAS	Institute of Space and Astronautical Science
ISIM	Integrated Science Instrument Module
ISCM	Information Security Continuous Monitoring
ISO	Infrared Space Observatory
ISRU	In-Situ Resource Utilization
ISS	International Space Station
IT	Information Technology
IV&V	Independent Verification and Validation
IVM	Ion Velocity Meter
JAXA	Japanese Aerospace Exploration Agency
JCL	Joint Confidence Level
JHU	Johns Hopkins University
JPPF	Jenkins Pre-Doctoral Fellowship Project
JRPE	Joint Robotics Program for Exploration
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
JUICE	JUpter ICy moons Explorer
JWST	James Webb Space Telescope
KDP	Key Decision Point
LADEE	Lunar Atmosphere and Dust Environment Explorer
LAN	Local Area Network
LaRC	Langley Research Center
LASF	Launch Abort System Facility
LB	Low Bay
LBTI	Large Binocular Telescope Interferometer
LC	Launch Complex
LCC	Launch Control Center
LCRD	Laser Communications Relay Demonstration
LEARN	Leading Edge Aeronautics Research for NASA
LEED	Leadership in Energy and Environmental Design
LEO	Low Earth Orbit

## ACRONYMS AND ABBREVIATIONS

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LIDAR	Light Detection and Ranging
LLCD	Lunar Laser Communication Demonstration
LMMSC	Lockheed Martin Space Systems Company
LOX	Liquid Oxygen
LRD	Launch Readiness Date
LRO	Lunar Reconnaissance Orbiter
LRR	Launch Readiness Review
LSP	Launch Services Program
LVS	Lander Vision System
LWS	Living with a Star
MAF	Michoud Assembly Facility
MARSIS	Mars Advanced Radar for Subsurface and Ionospheric Sounding
MAVEN	Mars Atmosphere and Volatile Evolution
MD	Mission Directorate
MDA	MacDonald, Dettwiler and Associates Ltd.
MDR	Mission Definition Review
MDSCC	Madrid Deep Space Communications Complex
MER	Mars Exploration Rover
MESSENGER	MErcury Surface, Space ENvironment, GEochemistry, and Ranging
MFR	Mission Formulation Review
MFRP	Mars Fundamental Research Program
MIGHTI	Michelson Interferometer for Global High-resolution Thermospheric Imaging
MIRI	Mid Infrared Instrument
MIT	Massachusetts Institute of Technology
ML	Mobile Launcher
MLP	Mobile Launch Platform
MLTI	Mesosphere-Lower Thermosphere-Ionosphere
MMPB	Multilateral Medical Policy Board
MMS	Magnetospheric Multiscale
MO	Missions of Opportunity
MOMA	Mars Organic Molecule Analyzer
MOMA-MS	Mars Organics Molecule Analyzer-Mass Spectrometer
MPAR	Major Program Annual Report
MPCV	Multi-Purpose Crew Vehicle
MPPF	Multi-Payload Processing Facility
MRO	Mars Reconnaissance Orbiter
MRR	Manufacturing Readiness Review
MSFC	Marshall Space Flight Center
MSI	Minority Serving Institutions
MSL	Mars Science Laboratory

## ACRONYMS AND ABBREVIATIONS

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MSP	MUREP Small Projects
MUREP	Minority University Research and Education Project
MUSS	Multi-User Systems Support
MUST	Motivating Undergraduates in Science and Technology
NAC	Network Access Control
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NEO	Near Earth Object
NEOO	Near Earth Object Observations
NESC	NASA Engineering and Safety Center
NextGen	Next Generation Air Traffic Management
NIAC	NASA Innovative Advanced Concepts
NICE	NASA Innovations in Climate Education
NICER	Neutron Star Interior Composition Explorer
NIRCam	Near Infrared Camera
NIRISS	Near Infrared Imager and Slitless Spectrograph
NIRSpec	Near Infrared Spectrograph
NISN	NASA Integrated Services Network
NOAA	National Oceanic and Atmospheric Administration
NOC	Network Management and Operations Center
NPP	National Polar-orbiting Partnership
NRA	NASA Research Announcement
NRC	National Research Council
NRO	National Reconnaissance Office
NRPTA	National Rocket Propulsion Test Alliance
NSC	NASA Safety Center
NuSTAR	Nuclear Spectroscopic Telescope Array
NSBRI	National Space Biomedical Research Institute
NSF	National Science Foundation
NSSDC	National Space Science Data Center
NSTC	National Science Technology Council
NSTI-MI	NASA Science and Technology Institute for Minority Institutions
OA	Office of Audits
O&C	Operation & Checkout
OCAMS	OSIRIS-REx Camera Suite
OCE	Office of the Chief Engineer
OCHMO	Office of Chief Health Medical Officer
OCO	Orbiting Carbon Observatory
OCSD	Optical Communications and Sensor Demonstration
OCT	Office of the Chief Technologist



## ACRONYMS AND ABBREVIATIONS

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OE	Office of Education
OGSI	Opportunity, Growth, and Security Initiative
OI	Office of Investigation
OIG	Office of Inspector General
OLA	OSIRIS-REx Laser Altimeter
OORT	Operations Optimization Review Team
OPF	Orbiter Processing Facility
ORR	Operational Readiness Review
OSHA	Occupational Safety and Health Administration
OSIRIS-Rex	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
OSMA	Office of Safety and Mission Assurance
OSTM	Ocean Surface Topography Mission
OTES	OSIRIS-REx Thermal Emission Spectrometer
OTE	Optical Telescope Element
OVIRS	OSIRIS-REx Visible and Infrared Spectrometer
PACE	Pre-Aerosol, Clouds, and ocean Ecosystem
Pan-STARRS	Panoramic Survey Telescope and Rapid Reporting System
PBN	Performance Based Navigation
PCAST	President's Council of Advisors on Science and Technology
PCC	Processing Control Center
PCOS	Physics of the Cosmos
PDR	Preliminary Design Review
PDRC	Precision Departure Release Capability
PDS	Planetary Data System
PDSI	Partnership Development and Strategic Integration
PHSF	Payload Hazardous Servicing Facility
PI	Principal Investigator
PIR	Program Implementation Review
PIV	Personal Identification Verification
PMC	Polar Mesospheric Cloud
PMDAP	Planetary Mission Data Analysis Program
PRF	Parachute Refurbishment Facility
QCL	Quantum Cascade Laser
QuikSCAT	Quick Scatterometer
R&A	Research and Analysis
R&D	Research and Development
R&T	Research and Technology
RAP	Robotics Alliance Project
REXIS	Regolith X-ray Imaging Spectrometer
RFD	Research Flight Deck

## ACRONYMS AND ABBREVIATIONS

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RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Imager
RID	Research Infrastructure Development
RINGS	Resonant Inductive Near-field Generation System
RISE	Rotation and Interior Structure Experiment
ROSES	Research Opportunities in Space and Earth Science
RPS	Radioisotope Power Systems
RPSF	Rotation, Processing, and Surge Facility
RPT	Rocket Propulsion Test
RRS	Research Range Services
RTM	Revolutionary Tools and Methods
SAA	Space Act Agreement
SAGE	Stratospheric Aerosol and Gas Experiment
SAM	Sample Analysis at Mars
SAO	Smithsonian Astrophysical Observatory
SASO	Safe Autonomous Systems Operations
SEMAA	Science Engineering Mathematics and Aerospace Academy
SBIR	Small Business Innovation Research
SCaN	Space Communication and Navigation
SCAP	Strategic Capabilities Assets Program
SDO	Solar Dynamics Observatory
SEIS	Seismic Experiment for Interior Structure
SERENA	Search for Exospheric Refilling and Emitted Natural Abundances
SMD	Science Mission Directorate
SEA	STEM Education and Accountability
SEAP	STEM Education and Accountability Projects
SEMAA	Science, Engineering, Math and Aerospace Academy
SEO	Science Enhancement Option
SEP	Solar Electric Propulsion
SES	Senior Executive Service
SET	Space Environment Testbeds
SFCO	Space Flight Crew Operations
SFS	Space and Flight Support
SGSS	Space Network Ground Segment Sustainment
SIR	Systems Integration Review
SLC	Space Launch Complex
SLF	Shuttle Landing Facility
SLICE	Sub-orbital Local Interstellar Cloud Experiment
SLPSRAD	Space Life and Physical Sciences Research and Applications Division
SLS	Space Launch System
SMA	Safety and Mission Assurance

## ACRONYMS AND ABBREVIATIONS

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SMAP	Soil Moisture Active and Passive
SMART-NAS	Shadow Mode Assessment Using Realistic Technologies for the National Air Space System
SMD	Science Mission Directorate
SMEX	Small Explorers
SMS	Safety and Mission Success
SN	Space Network
SNC	Sierra Nevada Corporation
SoA	State of the Art
SOC	Solar Orbiter Collaboration
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOHO	Solar & Heliospheric Observatory
SoI	Summer of Innovation
SoloHi	Solar Orbiter Heliospheric Imager
SORCE	Solar Radiation and Climate Experiment
Space Grant	National Space Grant College and Fellowship Program
SPB	Super Pressure Balloon
SPDF	Space Physics Data Facility
SPO	Science Processing and Operations Center
SPP	Solar Probe Plus
SR&T	Supporting Research & Technology
SRB	Standing Review Board
SRC	Sample Return Capsule
SRR	System Requirements Review
SSC	Stennis Space Center
SSERVI	Solar System Exploration Research Virtual Institute
SSFL	Santa Susana Field Laboratory
SSMLI	Self Supporting High Performance Multi-Layer Insulation
SSPF	Space Station Processing Facility
SST	Spitzer Space Telescope
STDT	Science and Technology Definition Team
STEM	Science, Technology, Engineering, and Mathematics
STEREO	Solar TERrestrial RELations Observatory
STMD	Space Technology Mission Directorate
STP	Solar Terrestrial Probe
STS	Space Transportation System
STScI	Space Telescope Science Institute
STTR	Small Business Technology Transfer
Super-TIGER	Super Trans-Iron Galactic Element Recorder
SWOT	Surface Water Ocean Topography

## ACRONYMS AND ABBREVIATIONS

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SXS	Soft X-Ray Spectrometer
TAC	Transformative Aeronautics Concepts
TAGSAM	Touch and Go Sample Acquisition Mechanism
TASEAS	Technologies for Assuring Safe Energy and Attitude State
TBD	To Be Determined
TCU	Tribal Colleges and Universities
TDM	Technology Demonstration Mission
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TES	Thermal Emission Spectrometer
TESS	Transiting Exoplanet Survey Satellite
THEMIS	Time History of Events and Macroscale Interactions during Substorms
TIC	Trusted Internet Connections
TCU	Tribal Colleges and Universities
TCUP	Tribal Colleges and Universities Project
TESS	Transiting Exoplanet Survey Satellite
TIMED	Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics
TIRS	Thermal Infrared Sensor
TPS	Thermal Protection System
TPSF	Thermal Protection System Facility
TRMM	Tropical Rainfall Measuring Mission
TWINS	Two Wide-angle Imaging Neutral-atom Spectrometers
TRL	Technology Readiness Level
UA	Utility Annex
UAS	Unmanned Aircraft Systems
UAV	Unmanned Air Vehicle
UESC	Utility Energy Service Contracts
UHB	Ultra High Bypass
UHF	Ultra-High Frequency
ULA	United Launch Alliance
UPWT	Unitary Plan Wind Tunnel
URC	University Research Centers
USAF	United States Air Force
USRA	Universities Space Research Association
UTM	UAS Traffic Management
VAB	Vehicle Assembly Building
VAC	Vertical Assembly Center
VIIP	Visual Impairment/Intra-cranial Pressure
VPN	Virtual Private Network
VSO	Virtual Solar Observatory

## **ACRONYMS AND ABBREVIATIONS**

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VWC	Vertical Weld Center
WAN	Wide Area Network
WISE	Wide-field Infrared Survey Explorer
WFC3	Wide Field Camera 3
WFF	Wallops Flight Facility
WMAP	Wilkinson Microwave Anisotropy Probe
WSTF	White Sands Test Facility
WYE	Work Year Equivalent
XMM	X-ray Multi-Mirror