FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
Budget Authority ($ in millions)	2014	2015	2016	2017	2018	2019	2020
NASA Total	**17,646.5**	**18,010.2**	**18,529.1**	**18,807.0**	**19,089.2**	**19,375.5**	**19,666.1**
Science	**5,148.2**	**5,244.7**	**5,288.6**	**5,367.9**	**5,488.4**	**5,530.2**	**5,613.1**
Earth Science	**1,824.9**	**--**	**1,947.3**	**1,966.7**	**1,988.0**	**2,009.3**	**2,027.4**
Planetary Science	**1,345.7**	**--**	**1,361.2**	**1,420.2**	**1,458.1**	**1,502.4**	**1,527.8**
Astrophysics	**678.3**	**--**	**709.1**	**726.5**	**769.5**	**1,005.5**	**1,138.3**
James Webb Space Telescope	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**	**197.5**
Heliophysics	**641.0**	**--**	**651.0**	**685.2**	**697.9**	**708.1**	**722.1**
Aeronautics	**566.0**	**651.0**	**571.4**	**580.0**	**588.7**	**597.5**	**606.4**
Space Technology	**576.0**	**596.0**	**724.8**	**735.7**	**746.7**	**757.9**	**769.3**
Exploration	**4,113.2**	**4,356.7**	**4,505.9**	**4,482.2**	**4,298.7**	**4,264.7**	**4,205.4**
Exploration Systems Development	**3,115.2**	**3,245.3**	**2,862.9**	**2,895.7**	**2,971.7**	**3,096.2**	**3,127.1**
Commercial Spaceflight	**696.0**	**805.0**	**1,243.8**	**1,184.8**	**731.9**	**173.1**	**1.1**
Exploration Research and Development	**302.0**	**306.4**	**399.2**	**401.7**	**595.1**	**995.4**	**1,077.2**
Space Operations	**3,774.0**	**3,827.8**	**4,003.7**	**4,191.2**	**4,504.9**	**4,670.8**	**4,864.3**
International Space Station	**2,964.1**	**--**	**3,105.6**	**3,273.9**	**3,641.0**	**3,826.0**	**4,038.3**
Space and Flight Support	**809.9**	**--**	**898.1**	**917.3**	**863.8**	**844.8**	**826.1**
Education	**116.6**	**119.0**	**88.9**	**90.2**	**91.6**	**93.0**	**94.4**
Safety, Security, and Mission Services	**2,793.0**	**2,758.9**	**2,843.1**	**2,885.7**	**2,929.1**	**2,973.0**	**3,017.5**
Center Management and Operations	**2,041.5**	**--**	**2,075.2**	**2,105.0**	**2,136.6**	**2,168.6**	**2,201.0**
Agency Management and Operations	**751.5**	**--**	**767.9**	**780.7**	**792.5**	**804.4**	**816.5**
Construction and Environmental Compliance and Restoration	**522.0**	**419.1**	**465.3**	**436.1**	**442.6**	**449.3**	**456.0**
Construction of Facilities	**455.9**	**--**	**374.8**	**344.3**	**349.3**	**354.6**	**359.9**
Environmental Compliance and Restoration	**66.1**	**--**	**90.5**	**91.8**	**93.3**	**94.7**	**96.1**
Inspector General	**37.5**	**37.0**	**37.4**	**38.0**	**38.5**	**39.1**	**39.7**
NASA Total	**17,646.5**	**18,010.2**	**18,529.1**	**18,807.0**	**19,089.2**	**19,375.5**	**19,666.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2014	2015	2016	2017	2018	2019	2020
NASA Total	**17,646.5**	**18,010.2**	**18,529.1**	**18,807.0**	**19,089.2**	**19,375.5**	**19,666.1**
Science	**5,148.2**	**5,244.7**	**5,288.6**	**5,367.9**	**5,448.4**	**5,530.2**	**5,613.1**
Earth Science	**1,824.9**	**--**	**1,947.3**	**1,966.7**	**1,988.0**	**2,009.3**	**2,027.4**
Earth Science Research	**456.7**	**--**	**485.3**	**471.0**	**480.4**	**475.2**	**470.6**
Earth Science Research and Analysis	334.6	--	348.4	329.8	329.8	323.4	322.5
Computing and Management	122.1	--	136.9	141.2	150.5	151.9	148.1
Earth Systematic Missions	**837.2**	**--**	**895.2**	**919.7**	**948.6**	**994.1**	**1,004.8**
Ice, Cloud, and land Elevation Satellite-2	182.2	126.5	127.4	102.4	66.6	14.2	14.2
Soil Moisture Active and Passive	65.4	74.9	15.9	11.3	11.3	11.3	11.5
GRACE Follow-On	87.8	73.4	66.3	38.7	21.1	11.1	12.1
Surface Water and Ocean Topography	59.2	--	78.3	96.9	131.4	126.3	80.5
Other Missions and Data Analysis	442.6	--	607.4	670.5	718.3	831.2	886.5
Earth System Science Pathfinder	**257.4**	**--**	**267.7**	**272.8**	**255.4**	**238.7**	**244.8**
Venture Class Missions	163.1	--	185.2	200.1	200.6	190.0	192.6
Other Missions and Data Analysis	94.3	--	82.5	72.7	54.8	48.7	52.1
Earth Science Multi-Mission Operations	**179.0**	**--**	**190.7**	**192.5**	**193.7**	**192.4**	**195.8**
Earth Science Technology	**59.6**	**--**	**60.7**	**62.1**	**61.5**	**61.2**	**62.7**
Applied Sciences	**35.0**	**--**	**47.6**	**48.7**	**48.4**	**47.6**	**48.8**

FY 2016 President's Budget Request Summary

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Planetary Science	**1,345.7**	**--**	**1,361.2**	**1,420.2**	**1,458.1**	**1,502.4**	**1,527.8**
Planetary Science Research	**221.8**	**--**	**276.3**	**282.0**	**292.0**	**291.7**	**285.7**
Planetary Science Research and Analysis	130.0	--	162.5	164.0	166.7	170.6	170.6
Directorate Management	4.0	--	7.1	7.4	7.4	7.4	7.4
Near Earth Object Observations	40.5	--	50.0	50.0	50.0	50.0	50.0
Other Missions and Data Analysis	47.3	--	56.7	60.6	67.9	63.7	57.7
Lunar Quest Program	**11.4**	**--**	**--**	**--**	**--**	**--**	**--**
Discovery	**297.4**	**--**	**156.1**	**201.6**	**277.2**	**337.4**	**344.9**
InSight	203.3	170.0	92.1	13.3	8.7	9.0	9.0
Other Missions and Data Analysis	94.1	--	64.0	188.4	268.5	328.4	335.9
New Frontiers	**231.6**	**--**	**259.0**	**124.0**	**81.5**	**85.7**	**137.8**
Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer	207.3	216.8	189.7	44.0	38.1	43.1	27.7
Other Missions and Data Analysis	24.3	--	69.3	80.0	43.4	42.6	110.1
Mars Exploration	**288.0**	**--**	**411.9**	**539.3**	**561.3**	**531.5**	**464.2**
Outer Planets	**152.4**	**--**	**116.2**	**117.7**	**81.6**	**87.6**	**110.5**
Jupiter Europa	80.0	100.0	30.0	30.0	50.0	75.0	100.0
Technology	**143.1**	**--**	**141.7**	**155.5**	**164.4**	**168.5**	**184.7**
Astrophysics	**678.3**	**--**	**709.1**	**726.5**	**769.5**	**1,005.5**	**1,138.3**
Astrophysics Research	**145.2**	**--**	**187.7**	**228.1**	**226.9**	**229.1**	**253.2**
Astrophysics Research and Analysis	63.3	--	72.3	73.7	73.0	73.0	73.0
Balloon Project	32.9	--	34.2	34.3	37.3	37.4	37.4
Other Missions and Data Analysis	49.1	--	81.1	120.1	116.6	118.7	142.8
Cosmic Origins	**224.2**	**--**	**199.3**	**200.4**	**199.1**	**207.9**	**244.5**
Hubble Space Telescope	98.3	--	97.1	93.5	97.7	89.3	89.3
Stratospheric Observatory for Infrared Astronomy	84.4	--	85.2	85.1	86.2	89.1	91.0
Other Missions and Data Analysis	41.5	--	17.0	21.7	15.3	29.5	64.2
Physics of the Cosmos	**112.6**	**--**	**107.6**	**81.9**	**86.9**	**96.0**	**106.6**
Exoplanet Exploration	**106.7**	**--**	**64.2**	**67.8**	**148.4**	**302.2**	**365.7**
Astrophysics Explorer	**89.6**	**--**	**150.3**	**148.2**	**108.1**	**170.4**	**168.3**
Transiting Exoplanet Survey Satellite	35.9	80.1	88.0	82.6	17.8	9.1	2.5
Other Missions and Data Analysis	53.7	--	62.4	65.6	90.3	161.3	165.8

FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2014	2015	2016	2017	2018	2019	2020
James Webb Space Telescope	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**	**197.5**
Heliophysics	**641.0**	**--**	**651.0**	**685.2**	**697.9**	**708.1**	**722.1**
Heliophysics Research	**185.1**	**--**	**158.5**	**168.5**	**202.1**	**207.6**	**208.4**
Heliophysics Research and Analysis	33.5	--	34.0	33.9	48.9	53.9	53.9
Sounding Rockets	53.4	--	48.3	53.3	59.0	61.1	63.1
Research Range	21.8	--	21.6	21.7	21.7	21.7	21.7
Other Missions and Data Analysis	76.4	--	54.6	59.6	72.5	71.0	69.7
Living with a Star	**212.5**	**--**	**343.0**	**387.3**	**399.9**	**212.6**	**103.3**
Solar Probe Plus	121.4	179.2	230.4	226.5	323.7	100.4	25.2
Solar Orbiter Collaboration	39.4	31.5	62.9	112.2	19.3	42.8	2.3
Other Missions and Data Analysis	51.7	--	49.7	48.7	56.9	69.4	75.9
Solar Terrestrial Probes	**143.3**	**--**	**50.5**	**37.6**	**41.8**	**133.3**	**189.2**
Magnetospheric Multiscale	120.9	52.4	30.1	17.5	10.8	-	-
Other Missions and Data Analysis	22.4	--	20.4	20.1	31.0	133.3	189.2
Heliophysics Explorer Program	**100.2**	**--**	**98.9**	**91.9**	**54.1**	**154.5**	**221.3**
ICON	59.8	61.0	49.8	48.0	9.0	4.5	1.3
Other Missions and Data Analysis	40.4	--	49.2	43.9	45.1	150.1	220.0
Aeronautics	**566.0**	**651.0**	**571.4**	**580.0**	**588.7**	**597.5**	**606.4**
Aeronautics	**566.0**	**651.0**	**571.4**	**580.0**	**588.7**	**597.5**	**606.4**
Airspace Operations and Safety Program	**--**	**--**	**142.4**	**153.2**	**159.6**	**160.0**	**163.0**
Advanced Air Vehicles Program	**--**	**--**	**240.9**	**243.2**	**241.2**	**231.0**	**232.8**
Integrated Aviation Systems Program	**--**	**--**	**96.0**	**85.6**	**89.0**	**101.6**	**104.8**
Transformative Aeronautics Concepts Program	**--**	**--**	**92.1**	**98.0**	**98.9**	**104.9**	**105.8**
Aviation Safety	**80.0**	**--**	**--**	**--**	**--**	**--**	**--**
Airspace Systems	**91.8**	**--**	**--**	**--**	**--**	**--**	**--**
Fundamental Aeronautics	**168.0**	**--**	**--**	**--**	**--**	**--**	**--**
Aeronautics Test	**77.0**	**--**	**--**	**--**	**--**	**--**	**--**
Integrated Systems Research	**126.5**	**--**	**--**	**--**	**--**	**--**	**--**
Aeronautics Strategy and Management	**22.7**	**--**	**--**	**--**	**--**	**--**	**--**
Space Technology	**576.0**	**596.0**	**724.8**	**735.7**	**746.7**	**757.9**	**769.3**
Space Technology	**576.0**	**596.0**	**724.8**	**735.7**	**746.7**	**757.9**	**769.3**
Agency Technology and Innovation	**30.6**	**--**	**33.0**	**33.0**	**33.2**	**33.2**	**33.2**
SBIR and STTR	**175.0**	**--**	**200.9**	**213.0**	**213.2**	**213.5**	**213.8**
Space Technology Research and Development	**370.4**	**--**	**491.0**	**489.7**	**500.3**	**511.2**	**522.4**

FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2014	2015	2016	2017	2018	2019	2020
Exploration	**4,113.2**	**4,356.7**	**4,505.9**	**4,482.2**	**4,298.7**	**4,264.7**	**4,205.4**
Exploration Systems Development	**3,115.2**	**3,245.3**	**2,862.9**	**2,895.7**	**2,971.7**	**3,096.2**	**3,127.1**
Orion Program	**1,197.0**	**1,194.0**	**1,096.3**	**1,119.8**	**1,122.9**	**1,126.7**	**1,138.0**
Crew Vehicle	1,165.8	--	1,085.8	1,109.3	1,112.4	1,116.2	1,127.5
Orion Program Integration and Support	31.2	--	10.5	10.5	10.5	10.5	10.5
Space Launch System	**1,600.0**	**1700.0**	**1,356.5**	**1,343.6**	**1,407.6**	**1,516.5**	**1,531.6**
Launch Vehicle Development	1,557.7	--	1,303.5	1,247.1	1,313.9	1,424.4	1,436.4
SLS Program Integration and Support	42.3	--	53.0	96.5	93.7	92.1	95.2
Exploration Ground Systems	**318.2**	**351.3**	**410.1**	**432.3**	**441.2**	**453.0**	**457.5**
Exploration Ground Systems Development	315.8	--	390.9	417.1	425.9	437.7	442.1
EGS Program Integration and Support	2.4	--	19.1	15.3	15.3	15.3	15.4
Commercial Spaceflight	**696.0**	**805.0**	**1,243.8**	**1,184.8**	**731.9**	**173.1**	**1.1**
Exploration Research and Development	**302.0**	**306.4**	**399.2**	**401.7**	**595.1**	**995.4**	**1,077.2**
Human Research Program	149.4	--	167.8	170.3	178.2	178.2	180.0
Advanced Exploration Systems	152.7	--	231.4	231.4	416.9	817.2	897.2
Space Operations	**3,774.0**	**3,827.8**	**4,003.7**	**4,191.2**	**4,504.9**	**4,670.8**	**4,864.3**
International Space Station	**2,964.1**	**--**	**3,105.6**	**3,273.9**	**3,641.0**	**3,826.0**	**4,038.3**
International Space Station Program	**2,964.1**	**--**	**3,105.6**	**3,273.9**	**3,641.0**	**3,826.0**	**4,038.3**
ISS Systems Operations and Maintenance	1,236.1	--	1,106.1	1,194.5	1,327.7	1,321.3	1,327.6
ISS Research	330.7	--	394.0	362.3	364.2	370.6	376.8
ISS Crew and Cargo Transportation	1,397.3	--	1,605.5	1,717.1	1,949.1	2,134.1	2,333.9
Space and Flight Support	**809.9**	**--**	**898.1**	**917.3**	**863.8**	**844.8**	**826.1**
21st Century Space Launch Complex	**39.6**	**--**	**23.3**	**11.8**	**--**	**--**	**--**
Space Communications and Navigation	**538.5**	**--**	**632.4**	**659.7**	**616.6**	**597.6**	**576.4**
Space Communications Networks	477.0	--	539.7	543.8	504.7	463.4	425.9
Space Communications Support	61.5	--	92.7	115.9	111.9	134.2	150.5
Human Space Flight Operations	**106.5**	**--**	**108.5**	**110.2**	**110.5**	**110.5**	**111.6**
Launch Services	**80.9**	**--**	**86.7**	**88.0**	**89.1**	**89.1**	**90.0**
Rocket Propulsion Test	**44.4**	**--**	**47.2**	**47.6**	**47.6**	**47.6**	**48.0**

FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Fiscal Year						
	Actual	Enacted	Request	Notional			
	2014	2015	2016	2017	2018	2019	2020
Education	**116.6**	**119.0**	**88.9**	**90.2**	**91.6**	**93.0**	**94.4**
Education	**116.6**	**119.0**	**88.9**	**90.2**	**91.6**	**93.0**	**94.4**
Aerospace Research and Career Development	**58.0**	**58.0**	**33.0**	**33.0**	**33.0**	**33.0**	**33.0**
National Space Grant College and Fellowship Project	40.0	40.0	24.0	24.0	24.0	24.0	24.0
Experimental Project to Stimulate Competitive Research	18.0	18.0	9.0	9.0	9.0	9.0	9.0
STEM Education and Accountability	**58.6**	**--**	**55.9**	**57.2**	**58.6**	**60.0**	**61.4**
Minority University Research Education Project	30.0	--	30.0	30.0	30.0	30.9	30.0
STEM Education and Accountability	28.6	--	25.9	27.2	28.6	29.1	31.4
Cross Agency Support	**2,793.0**	**2,758.9**	**2,843.1**	**2,885.7**	**2,929.1**	**2,973.0**	**3,017.5**
Center Management and Operations	**2,041.5**	**--**	**2,075.2**	**2,105.0**	**2,136.6**	**2,168.6**	**2,201.0**
Center Management and Operations	**2,041.5**	**--**	**2,075.2**	**2,105.0**	**2,136.6**	**2,168.6**	**2,201.0**
Center Institutional Capabilities	1,591.9	--	1,627.4	1,644.1	1,667.5	1,692.0	1,714.4
Center Programmatic Capabilities	449.6	--	447.8	460.9	469.1	476.6	486.6
Agency Management and Operations	**751.5**	**--**	**767.9**	**780.7**	**792.5**	**804.4**	**816.5**
Agency Management	**384.0**	**--**	**395.4**	**402.6**	**408.7**	**414.8**	**421.0**
Safety and Mission Success	**179.0**	**--**	**166.6**	**169.1**	**171.7**	**174.3**	**177.0**
Safety and Mission Assurance	48.7	--	50.1	50.8	51.6	52.4	53.2
Chief Engineer	87.0	--	83.4	84.7	86.0	87.3	88.6
Chief Health and Medical Officer	4.2	--	4.2	4.3	4.3	4.4	4.5
Independent Verification and Validation	39.1	--	28.9	29.3	29.8	30.2	30.7
Agency IT Services	**161.5**	**--**	**179.0**	**181.7**	**184.4**	**187.2**	**190.0**
IT Management	14.9	--	13.2	18.2	19.2	20.3	21.4
Applications	55.5	--	60.6	59.4	61.7	64.1	66.1
Infrastructure	91.1	--	105.2	104.1	103.5	102.8	102.5
Strategic Capabilities Assets Program	**27.0**	**--**	**26.9**	**27.3**	**27.7**	**28.1**	**28.5**

FY 2016 PRESIDENT'S BUDGET REQUEST SUMMARY

	Actual	Enacted	Request	Notional			
	2014	2015	2016	2017	2018	2019	2020
Construction and Environmental Compliance and Restoration	522.0	419.1	465.3	436.1	442.6	449.3	456.0
Construction of Facilities	455.9	--	374.8	344.3	349.3	354.6	359.9
Institutional CoF	283.4	--	338.6	344.3	349.3	354.6	359.9
Science CoF	3.0	--	--	--	--	--	--
Exploration CoF	139.3	--	10.0	--	--	--	--
Space Operations CoF	30.2	--	26.2	--	--	--	--
Environmental Compliance and Restoration	66.1	--	90.5	91.8	93.3	94.7	96.1
Inspector General	37.5	37.0	37.4	38.0	38.5	39.1	39.7
NASA Total	17,646.5	18,010.2	18,529.1	18,807.0	19,089.2	19,375.5	19,666.1

Fiscal Year

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FY 2016 BUDGET REQUEST EXECUTIVE SUMMARY

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MESSAGE FROM THE ADMINISTRATOR

I am delighted to present President Obama's FY2016 budget request for NASA.

NASA innovation helps drive our journey to reach new heights, reveal the unknown, and benefit all of humanity and our nation's space program is well positioned to continue the United States' world leadership in exploration.

President Obama's strong investment in NASA has spurred innovation and economic growth and enabled breakthroughs in science and technology. Space is good for the economy. It's good for our future and it helps unify the entire world.

Our ambitious journey out into the Solar System, this time to stay, drives much of what we do. Robotic explorers are visiting asteroids and planets, and rovers are roaming the surface of Mars – paving the way for human explorers to arrive there in the coming decades. Technology drives exploration and right now NASA is working on the challenge of sending humans to Mars by working on breakthroughs in propulsion, radiation shielding and landing large payloads among many other cutting-edge technologies. At the same time, NASA is working on technologies such as advanced solar arrays, laser communication, and green propellant that will benefit US industry and other government agencies, as well as NASA.

The Orion spacecraft in which humans will travel deeper into the solar system has achieved a major milestone with its first flight to deep space. It will fly again on the Space Launch System (SLS), the world's most powerful rocket, which has moved from concept to development. Our mission to redirect an asteroid to cis-lunar space will test new capabilities in the proving ground of deep space and bring us closer to a mission to the Red Planet using Orion and the SLS.

The future is unfolding right now in low Earth orbit aboard the International Space Station, where astronauts are helping us learn how to live and work in space for the long term and demonstrating new technologies in the unique environment of microgravity.

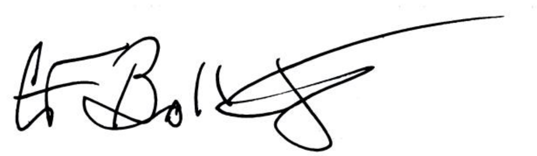
Commercial partners are proving our faith in this investment and after successfully beginning cargo transport to the station are now hard at work on the capabilities to once again launch astronauts from American soil in the coming years. Their innovation creates good jobs, lowers the cost of access to space, and frees up NASA to focus on farther destinations. NASA is working to identify additional opportunities to work with the private sector to achieve low-cost results and catalyze innovation and risk-sharing.

Our impressive fleet of science missions is taking us on a journey of discovery to help understand our solar system and its sun, search for life beyond and explore the origins and future of the universe. The most important planet is the one on which we live, and NASA's constantly expanding view of our planet from space is helping us understand Earth and its changes. We are uniquely qualified to take on the challenge of documenting and understanding these changes, predicting the ramifications and sharing information across the globe.

All of our work has an impact on people worldwide every day. One of the most visible aspects of this work is in aviation. NASA is with you when you fly and we are transforming air travel by dramatically reducing its environmental impact, maintaining safety in more crowded skies, and paving the way toward revolutionary aircraft shapes and propulsion.

MESSAGE FROM THE ADMINISTRATOR

This budget supports all of these activities. Our work is part of a vital strategy to equip our nation with the technologies for the future and inspire a new generation of explorers to make the next giant leaps in human experience. At NASA, we're creating a bright future today.



Charles F. Bolden, Jr.

NASA Administrator

BUDGET HIGHLIGHTS

The National Aeronautics and Space Act of 1958 challenged our Nation to grow our technical and scientific abilities in air and space. Since the 1970s, numerous economic reports and articles have demonstrated that NASA investments helped grow the US economy. Perhaps most importantly NASA-funded R&D helped stimulate our long-term capacity for innovation and economic growth within the government, at universities, and at industrial companies. The disciplines advanced were many – including materials, computing and electronics, fuels, radio communications, safety, and even human health.

In the FY 2016 President's Budget Request, NASA addresses the challenge of advancing US 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 return on the dollar. 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 held steady or slowed. 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 US 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, among other things, 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 2016 budget aims to create jobs and support the growing US economy.

In FY 2016, NASA continues to plan and refine the requirements for its first-of-a-kind mission to capture and redirect a near-Earth asteroid into a stable orbit around the Moon, where astronauts will explore the asteroid. 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 we learn to operate and live safely beyond the Earth for extended periods of time and drive towards future human missions to Mars, and will improve the ability of our Nation and others to protect the planet from asteroid impacts.

Today's technology 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 rendezvous with a small, non-threatening asteroid and move it into a stable lunar orbit. Designers of the mission spacecraft will also incorporate anticipated technological advances in lightweight materials, communication, data storage and transfer, and space navigation. Many of these technologies will also be useful for other NASA missions, as well as for commercial space activities. In the third segment of the mission, NASA will employ the Orion crew vehicle 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 2016 budget request fully supports the plan for crewed exploration of deep space. NASA has identified our Agency Baseline Commitment for the Space Launch System (SLS) and Exploration Ground Systems (EGS) which supports a launch capability readiness date of November 2018 at 70% and

80% JCL respectively. The Agency will determine the Exploration Mission 1 (EM-1) integrated launch date after Orion, SLS, and EGS have completed their respective Critical Design Reviews.

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 US 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 future deep space missions, including to Mars. 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 to study the Earth, Sun, solar system, and deep space. Earth observations continue to allow unprecedented study of climate change, weather, and natural hazards. 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 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 continue formulating a mission to Europa, Jupiter's icy moon that, data suggests, may have organic material on its surface.

NASA continues to reduce 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 2016 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 areas in 2016 include solar electric propulsion, which is necessary for a deep space asteroid mission; 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 2016 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 delivery of science, technology, engineering, and mathematics (STEM) education programs. 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 Federal STEM Education Five-Year Strategic Plan. 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 2016 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 launching humans to another planet or moving an 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 has always done. It serves as a stimulus to US creativity and innovation, our competitiveness on the global stage, and economic growth that benefits all Americans.

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 2016 budget request for Science is $5,288.6 million.

The Webb telescope, a successor to the Hubble telescope, is on schedule for a 2018 launch. Webb 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 Webb. Other astrophysics missions in formulation and development include the Astro-H Soft X-Ray Spectrometer, and the TESS and NICER Explorer missions. The request also includes full funding for SOFIA.

NASA continues to learn more about Earth. The launch and operation of Soil Moisture Active-Passive (SMAP) will enable global mapping of soil moisture with unprecedented accuracy, resolution, and coverage. The request also fully funds Ice, Cloud, and land Elevation Satellite (ICESat-II); Gravity Recovery and Climate Experiment (GRACE-FO); and many other future Earth Science missions. The Sustainable Land Imaging (SLI) program will provide US users with high-quality, global, land imaging measurements that are compatible with the existing 42-year record; that will address near- and longer-term issues of continuity risk; and that will evolve flexibly and responsibly through investment in, and introduction of, new sensor and system technologies. SLI is initiating the Landsat-9 mission in FY 2015.

The OSIRIS-REx spacecraft will launch in 2016, travel to a near-Earth asteroid in 2018, and be the first US mission to carry samples from an asteroid back to Earth. InSight (launching in 2016) and Mars 2020 are future Mars lander missions. The request also supports a potential future mission to Jupiter's moon Europa, providing double the amount of funding as last year's request to proceed with pre-formulation activities.

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.

AERONAUTICS RESEARCH TO ADDRESS AVIATION'S CHALLENGES

The air transportation system of today is a vital part of the US and Global economies. It is the primary mechanism for connecting major population centers in the US and countries across the world for people and cargo. 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 2016 budget request for the Aeronautics account is $571.4 million.

The request funds cutting-edge research programs aligned with a new and compelling strategic vision that addresses global challenges of growing demand for mobility; sustainability of energy and environment; and application of rapid advances in information, communication, and automation technologies.

NASA is developing new methods of validating and verifying complex flight systems to improve safety and reduce development costs. A system-wide safety management system is being developed in partnership with FAA to ensure that aviation's enviable current safety record is maintained and improved into the future with growing traffic and increased system complexity. NASA, in partnership with FAA and industry, is demonstrating an effective and harmonious integrated suite of air traffic management tools, which 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.

Through research into next generation aircraft configurations, efficient engines, and low carbon propulsion systems, NASA is developing concepts and technologies that enable revolutionary new vehicles to dramatically reduce fuel consumption, emissions, and noise, and assure safety levels. NASA is also developing technologies that will integrate Unmanned Aircraft Systems (UAS) into the National Airspace System and enable small UAS operations at low altitude. The request will initiate fundamental research in autonomous systems for aviation applications.

BUDGET HIGHLIGHTS

SPACE TECHNOLOGY GROWS CAPABILITIES, REDUCES COSTS, AND DRIVES EXPLORATION

Space Technology conducts rapid development and incorporation of transformative space technologies that enable and reduce the cost of NASA's missions and reduce the cost and increase the capabilities of other US agencies and the US space industry. Technology drives exploration by improving our ability to access and travel through space; land more mass more accurately in more locations throughout the solar system; live and work in deep space and on planetary bodies; transform the ability to observe the universe to answer profound questions in earth and space sciences including the outer planets; and improve the US aerospace industry technological capability to continue the Nation's economic leadership. The FY 2016 budget request for Space Technology is $724.8 million.

In FY 2014, Space Technology completed the world's largest, out-of-autoclave composite cryogenic propellant tank ever manufactured. The 18-foot (5.5-meter) diameter tank successfully endured a rigorous series of tests over the course of five months to replicate the physical stresses launch vehicles experience during flight. The development effort validated the ability to manufacture large-scale composite structures for aerospace applications that will significantly reduce the structural mass of future launch vehicles and consequently dramatically increase their payload mass to orbit. In addition, Space Technology successfully flew a rocket-powered, saucer-shaped test vehicle into near-space in late June from the US Navy's Pacific Missile Range Facility on Kauai, Hawaii. This first flight successfully demonstrated that the experimental vehicle could reach the altitudes and airspeeds needed to test two new breakthrough technologies for landing large payloads on the surface of Mars.

Informed by the results of FY 2014 testing of solar array and thruster designs, Space Technology continues 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, over the next two years, Space Technology will execute several in-space demonstrations including: a deep space atomic clock for advanced navigation- particularly applicable to understanding Europa's under-ice liquid water oceans, green propellant and four small spacecraft demonstrations of pioneering new technologies. Space Technology will continue maturation of enabling technologies incentivized in the Science Discovery 2014 solicitation: advanced thermal protection system materials, solar arrays, green propellant, deep space optical communications, and an advanced atomic clock. Space Technology will also initiate development of foundational technologies to support future outer planets icy moons missions with emphasis on landing and mobility, navigation and communications, radiation protection and accommodating power requirements.

In addition, Space Technology has developed a wide and diverse portfolio of early-stage research and technology that is primed to solve the Agency and Nation's most difficult exploration challenges. Space Technology will continue to prioritize "tipping point" technologies and early-stage innovation with over 600 awards to small businesses, private innovators, and academia to spark new ideas for the benefit of US aerospace and high tech industries. 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.

BUDGET HIGHLIGHTS

EXPANDING HUMAN EXPLORATION OF THE SOLAR SYSTEM

The work of NASA ensures the United States remains both a leader and international partner in the human exploration of space. NASA's exploration goal is to develop the capability for people to live and work safely beyond the Earth for extended periods of time. The Agency is working to incrementally and progressively develop systems and capabilities, and leverage near-term mission opportunities, which will allow the expansion of the human presence into the solar system and to the surface of Mars.

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 US commercial providers. The FY 2016 budget request for Exploration is $4,505.9 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 2016, 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, the Agency transitioned industry partners from Space Act Agreements to fixed-price, milestone based contracts to support the next phase of commercial crew transportation systems. NASA's commercial partners will continue development efforts towards flights in 2017 by performing risk reduction and technical readiness testing.

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 2016 budget request for Space Operations is $4,003.7 million.

In the Space Operations account, NASA will complete the year-long US and Russian crew expedition to ISS that will help scientists better understand the impacts of long-duration spaceflight on the human body and aid in the development of effective countermeasures. The Agency will fly Raven to the ISS in FY 2016, demonstrating a common rendezvous sensor suite for satellite servicing, Orion and the Asteroid Redirect Mission. NASA will leverage satellite servicing technologies such as dexterous robotic capture mechanisms for future missions. Space Operations 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.

BUDGET HIGHLIGHTS

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

NASA's education programs share the excitement of the Agency's science and engineering missions with learners, educators, and the public. Investments in the NASA education programmatic accounts maintain the advancement of high-quality STEM education using NASA's unique capabilities and resources. NASA's unique capabilities, resources, and expertise will play a crucial role in the contribution towards shaping the Nation's STEM education portfolio in support of the Administration's Five-Year Federal Strategic Plan on STEM Education. Hands-on challenges with NASA experts generate interest in undergraduate STEM study, fostering student participation in aerospace or related STEM fields. NASA's STEM education programs provide opportunities for educators and learners of all ages. Planned activities serve middle school audiences; offer pre- and in-service educator professional development; and provide experiential opportunities for high school and undergraduate students.

NASA's education programs inspire learners to pursue STEM study and careers by engaging them in the Agency's missions, fostering collaborative relationships between learners and the current NASA workforce, and offering experiential learning opportunities at Agency facilities. NASA education will continue to coordinate closely with other Federal agencies in pursuit of the Administration's STEM education goals. The FY 2016 budget request for Education is $88.9 million.

MANAGING NASA'S PEOPLE AND CAPABILITIES TO SAFELY ACCOMPLISH OUR MISSION

NASA's Safety, Security, and Mission Services 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 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 personnel 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 2016 NASA will continue to provide strategic and operational planning and management over a wide range of functions and services to help NASA operate in a more efficient and sustainable manner. The FY 2016 budget request for Safety, Security, and Mission Services is $2,843.1 million.

The Construction and Environmental Compliance and Restoration account enables NASA 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 2016, NASA continues to consolidate facilities to achieve greater operational efficiency, replacing old, obsolete, costly facilities with fewer, high performance facilities. Institutional construction projects replace deficient and obsolete facilities and correct deficiencies to support core capabilities within a smaller, more efficient footprint. Programmatic construction of facilities projects provide the specialized technical facilities required by the missions. NASA will decommission and continue preparations to dispose of property and equipment no longer needed. To protect human health and the environment, and to preserve natural resources for future missions, environmental compliance and restoration projects will clean up pollutants released into the environment during past NASA activities. The FY 2016 request for Construction and Environmental Compliance and Restoration is $465.3 million.

NOTES ON THE 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 2016 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, and transferring work in-house from on and near site support contracts. As NASA works toward he 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 200 full-time equivalents from FY 2015 to FY 2016, bringing the civil service workforce to approximately 17,200 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*.

AGENCY DIGITAL SERVICE TEAMS

The success rate of government digital services is improved when agencies have digital service experts on staff with modern design, software engineering, and product management skills. To ensure the agency can effectively build and deliver important digital services, the FY 2016 Budget includes funding for staffing costs to build a Digital Service team that will focus on transforming the agency's digital services with the greatest impact to citizens and businesses so they are easier to use and more cost-effective to build and maintain.

These digital service experts will bring private sector best practices in the disciplines of design, software engineering, and product management to bear on the agency's most important services. The positions will be term-limited, to encourage a continuous influx of up-to-date design and technology skills into the agency. The digital service experts will be recruited from among America's leading technology enterprises and startups, and will join with the agency's top technical and policy leaders to deliver meaningful and lasting improvements to the services the agency provides to citizens and businesses.

NOTES ON THE BUDGET

This digital service team will build on the success of the United States Digital Service team inside of OMB, created in 2014. This team has worked in collaboration with Federal agencies to implement cutting edge digital and technology practices on the nation's highest impact programs, including the successful re-launch of HealthCare.gov in its second year, which led to millions of Americans receiving health coverage; the Veterans Benefits Management System; online visa applications, green card replacements and renewals; among others. In addition to their work on these high priority projects, this small team of tech experts has worked to establish best practices (as published in the US Digital Services Playbook at http://playbook.cio.gov) and to recruit more highly skilled digital service experts and engineers into government.

EXPLANATION OF BUDGET TABLES AND SCHEDULES

NASA presents the FY 2016 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 2016 should be considered notional.

EXPLANATION OF FY 2014 AND FY 2015 BUDGET COLUMNS

FY 2014 Column

The FY 2014 Actual column in budget tables is consistent with the approved 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 2016 request. See note below.

All FY 2014 budget figures represent appropriations reflect funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

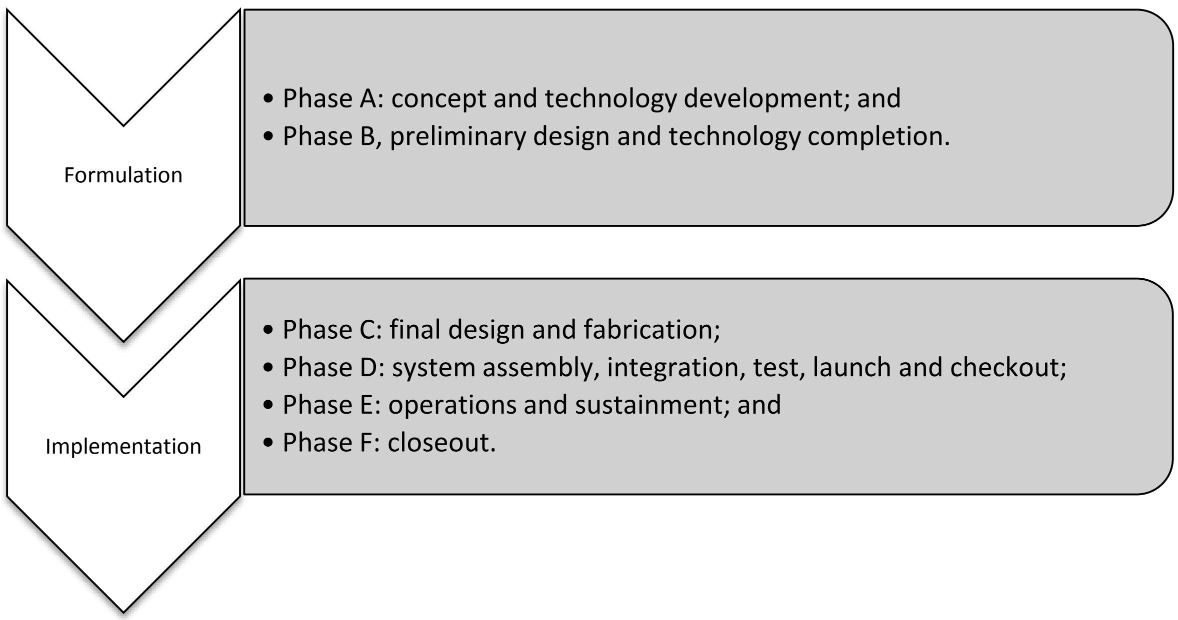
FY 2015 Column

The FY 2015 Enacted column in budget tables displays appropriations enacted in the Consolidated and Further Continuing Appropriations Act, 2015 (P.L. 113-235). As of budget release, an initial FY 2015 operating plan has not been approved by Congress. As a result, budget tables show only accounts, themes, or programs where appropriations are called out in P.L. 113-235. Tables also show tentatively planned FY 2015 funding for projects in development (subject to change pending finalization of the FY 2015 initial operating plan). Budget structures and figures are adjusted for comparability to the FY 2016 budget structure. See note below.

EXPLANATION OF BUDGET TABLES AND SCHEDULES

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.

EXPLANATION OF BUDGET TABLES AND SCHEDULES

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 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.

Formulation Milestone	Explanation
KDP-A	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: • The project addresses a critical NASA need; • The proposed mission concept(s) is feasible; • The associated planning is sufficiently mature to begin activities defined for formulation; and • The mission can likely be achieved as conceived.
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	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: • The proposed mission/system architecture is credible and responsive to program requirements and constraints, including resources; • The maturity of the project's mission/system definition and associated plans is sufficient to begin Phase B; and • The mission can likely be achieved within available resources with acceptable risk.
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.

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	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: • The project's planning, technical, cost, and schedule baselines developed during Formulation are complete and consistent; • The preliminary design complies with mission requirements; • The project is sufficiently mature to begin Phase C; and • The cost and schedule are adequate to enable mission success with acceptable risk.
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	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: • The project is still on plan; • The risk is commensurate with the project's payload classification; and • The project is ready for assembly, integration and test with acceptable risk within its Agency baseline commitment.
Launch Readiness Date (LRD)	The date at which the project and its ground, hardware, and software systems are ready for launch.

EXPLANATION OF BUDGET TABLES AND SCHEDULES

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).
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.

EXPLANATION OF BUDGET TABLES AND SCHEDULES

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
- NASA Launch Services Web site: http://www.nasa.gov/directorates/heo/launch_services/index.html

SCIENCE

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Earth Science	1824.9	--	**1947.3**	1966.7	1988.0	2009.3	2027.4
Planetary Science	1345.7	--	**1361.2**	1420.2	1458.1	1502.4	1527.8
Astrophysics	678.3	--	**709.1**	726.5	769.5	1005.5	1138.3
James Webb Space Telescope	658.2	645.4	**620.0**	569.4	534.9	305.0	197.5
Heliophysics	641.0	--	**651.0**	685.2	697.9	708.1	722.1
Total Budget	**5148.2**	**5244.7**	**5288.6**	**5367.9**	**5448.4**	**5530.2**	**5613.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

SCIENCE

SCIENCE

Heliophysics

SCIENCE

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Earth Science	1824.9	--	**1947.3**	1966.7	1988.0	2009.3	2027.4
Planetary Science	1345.7	--	**1361.2**	1420.2	1458.1	1502.4	1527.8
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Heliophysics	641.0	--	**651.0**	685.2	697.9	708.1	722.1
Total Budget	**5148.2**	**5244.7**	**5288.6**	**5367.9**	**5448.4**	**5530.2**	**5613.1**
Change from FY 2015			**43.9**				
Percentage change from FY 2015			**0.8%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

From the vantage point of space, NASA captures breath-taking images of our world and the universe. These images advance our scientific understanding in a multitude of disciplines. They also have the power to inform policy, influence action, and inspire learning.

NASA's Science Mission Directorate (SMD) 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.

NASA uses the recommendations of the National Academies' decadal surveys as an important input in planning the future of its science programs. For over 30 years, decadal surveys have proven vital 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. Assessments of how this budget request supports the recommendations of the most recent decadal surveys are included below.

EXPLANATION OF MAJOR CHANGES IN FY 2016

Building on NASA's successful launch of the NASA/USGS Landsat Data Continuity Mission (LDCM)/Landsat-8 mission in February 2013, the Administration's new Sustainable Land Imaging (SLI) program will provide US users with high-quality, global, land imaging measurements that are compatible with the existing 42-year record. The proposed program will address near- and longer-term issues of continuity risk; and will evolve flexibly and responsibly through investment in, and introduction of, new sensor and system technologies. The multi-decadal SLI system involves three NASA mission/development activities, including initiation of Landsat 9 immediately in FY 2015, along with a fourth activity combining technology investments and detailed system engineering to design and build a full-capability Landsat 10 satellite.

Also in Earth Science, NASA has assigned the Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) mission to the Goddard Space Flight Center (GSFC), and the mission is preparing to begin formulation activities.

The budget request for Planetary Science now supports formulation of a new mission to explore Jupiter's moon, Europa, the destination within the solar system most likely to harbor current life. The Europa mission will investigate the science questions established in the most recent decadal survey.

In Astrophysics, the budget restores funding for the Stratospheric Observatory for Infrared Astronomy (SOFIA) mission. The 2016 Senior Review panel will evaluate SOFIA's scientific productivity.

The Education budget within Science receives an increase relative to the FY 2015 request. This funding will support multi-year cooperative agreements that NASA will award in late FY 2015. SMD's restructured education program will allow for more streamlined and effective implementation of STEM education activities in support of the goals of the Federal STEM Education 5-Year Strategic Plan.

ACHIEVEMENTS IN FY 2014

Science missions have continued a recent string of excellent technical, cost and schedule performance. The Magnetospheric MultiScale (MMS) mission, scheduled for launch in March 2015, has had a cost overrun of about three percent. Other than MMS, there has been no cost growth or schedule delay on any NASA Science spacecraft in development in the last year. The Global Precipitation Measurement (GPM) and Orbiting Carbon Observatory-2 (OCO-2) missions launched in 2014; both were ahead of schedule and under budget, and are already making important scientific contributions. Seven other Science missions under development are holding closely to their original cost and schedule baseline estimates: Soil Moisture Active/Passive (SMAP), InSight, Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx), Cyclone Global Navigation Satellite System (CYGNSS), Gravity Recovery and Climate Experiment Follow-On (GRACE-FO), Solar Probe Plus (SPP), and the Solar Orbiter Collaboration (SOC). James Webb Space Telescope (Webb) and Ice, Cloud, and land

Elevation Satellite (ICESat)-2 experienced past cost and schedule growth, but are still holding closely to their revised cost and schedule commitments.

A steady pace of important science results continued in FY 2014. In Earth Science, some of the most notable findings related to global ice melting. Mass loss from the Greenland ice sheet contributes significantly to present sea level rise. Surface melt has been spreading and intensifying in Greenland, with the highest surface area melt and runoff recorded in 2012. A recent analysis detected widespread ice-covered valleys that extend significantly deeper below sea level and farther inland than previously thought. The findings imply that the outlet glaciers of Greenland, and the ice sheet as a whole, are probably more vulnerable to heating from warm ocean waters and peripheral thinning than inferred previously from existing numerical ice-sheet models. For the first time, Operation IceBridge conducted a deployment in the Arctic to collect altimetry data over sea ice and the Greenland ice sheet during the annual melt season. For three weeks, between October and November 2013, NASA's C-130 aircraft flew nine science missions with the Land, Vegetation, and Ice Sensor and its smaller version designed for the unpiloted Global Hawk platform.

In Planetary Science, the Mars Science Laboratory Curiosity rover has been exploring the surface of Mars with the objective of determining if the weather and environmental conditions could have supported microbial life, past or present. The rover has traveled outside its landing ellipse, more than 9.5 kilometers, and reached its prime destination: the base of Mt. Sharp. During the journey, scientists determined that the area of Yellowknife Bay once had water flowing on its surface, and the water was relatively neutral pH, low salinity, and contained the ingredients for life, showing that Mars could have supported microbial life. For the first time on another planet, Curiosity has dated a rock in Gale Crater to be 4.2 billion years old and yet the rock has only been exposed for about 80 million years. Atmospheric measurements indicate that Mars lost over 85 percent of its atmosphere. Radiation measurements in cruise and on the surface of Mars have shown that a nominal mission to Mars would expose an astronaut to radiation equivalent to one Sievert, which represents an approximate 5 percent increase in the risk of developing fatal cancer.

Astronomers used Hubble's Wide Field Camera 3 and a technique called transmission spectroscopy to find evidence for clear skies and water vapor in a Neptune-sized planet around the star HAT-P-11. As a planet passes in front of its star, starlight filters thru the rim of the planet's atmosphere and this transmission provides information about the contents of that atmosphere. If molecules like water vapor are present, the molecules absorb some of the starlight, leaving distinct signatures in the light that reaches Earth. Closer to home, NASA's Hubble Space Telescope has uncovered three Kuiper Belt objects the Agency's New Horizons spacecraft could potentially visit after it flies by Pluto in July 2015. Meanwhile, astronomers have confirmed more than 1,000 exoplanets, with more than an additional 3,500+ candidates discovered 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.

Using an instrument on NASA's Solar Dynamics Observatory (SDO), called the Helioseismic and Magnetic Imager (HMI), researchers finally found elusive giant convective cells in the solar interior. Scientists theorized their existence over 40 years ago, but data was not available to prove their existence until scientists were able to get continuous observations that are only available from space and specifically from the HMI instrument with its high resolution. Giant convective cells are 30 times the size of the Earth, transport heat from the Sun's core, and play a role in originating the cycles of sunspot activity. The HMI observations may also help answer a question asked since the time of Galileo: why does the Sun rotate faster at the equator than at the pole? The motion of giant cells can explain this rotation, which is a key part of how the solar cycle works, with implications to every star, not just the Sun.

WORK IN PROGRESS IN FY 2015

NASA continues to support 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. 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.

NASA released a competitive Astrophysics Explorer Announcement of Opportunity (AO) on September 17, 2014. NASA will select missions for further study in the summer of 2015, leading to final selection in early FY 2017.

NASA has received proposals for flight instruments for a potential mission to Europa, and has issued an AO for a new Discovery mission. NASA plans to evaluate proposals from both of these announcements and make selections in FY 2015. The Dawn spacecraft will arrive at Ceres around March 2015, New Horizons will encounter Pluto in July, and MESSENGER will complete its mission at Mercury.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA plans to launch two planetary missions in 2016. InSight will launch in March, landing on Mars in September, and OSIRIS-REx launches in September, to begin its journey to the asteroid Bennu. Juno will arrive at Jupiter, after five years in cruise, to begin its mapping of the gravity field at the solar system's largest planet. NASA plans to make the final mission selection from the Discovery 2014 AO by September 2016.

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

The primary recommendations of the National Academies' 2007 Decadal Survey for Earth Science and Applications from Space (ESAS), which informed the 2010 Climate-Centric Architecture plan, were:

- Complete the ongoing program. All legacy Earth Science missions identified in the 2007 ESAS Decadal [Jason-2 (2008), OCO (2009, 2014), Glory (2011), Aquarius (2011), Suomi-National Polar-orbiting Partnership (Suomi-NPP) (2011), LDCM (2013)] have been developed and launched. OCO-1 and Glory suffered launch vehicle failures. OCO-2 was then developed and successfully launched. The FY 2016 budget fully funds operations and science exploitation of these on-orbit missions. Additionally, the budget supports completion of OCO-3, which will provide precise measurements of carbon dioxide from the vantage point of the International Space Station.
- Continue the balance between flight and non-flight activities. The FY 2016 request fully supports this recommendation.
- Increase the scope and fraction of the Earth Science Technology program. The FY 2016 request fully supports this recommendation, in part through funding for the In-Space Validation of Earth Science Technologies (InVEST) CubeSat-based program.
- Establish a robust program of competed Venture-class missions. The FY 2016 budget request fully supports this recommendation. It funds all Earth Venture (EV) missions selected under the three previous solicitations, including CYGNSS, Tropospheric Emissions: Monitoring of Pollution (TEMPO), Global Ecosystem Dynamics Investigation (GEDI), and ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS). It also fully funds the planned future solicitations in all three strands on schedule (4-year cadence for EV-Suborbital and EV-Mission, 18-month cadence for EV-Instrument).
- Aggressively develop a number of future strategic missions. The 2007 ESAS Decadal identified 4 systematic Tier-1 missions [SMAP, ICESAT-2, Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI), Climate Absolute Radiance and Refractivity Observatory (CLARREO)] to be developed and launched by NASA by 2013, along with 5 Tier-2 missions [Hyperspectral Infrared Image (HyspIRI), Surface Water Ocean Topography (SWOT), GEOstationary Coastal and Air Pollution Events (GEO-CAPE), Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS), and Aerosol-Cloud-Ecosystem (ACE)] by 2016. Those Decadal recommendations assumed unrealistically low mission costs and overly optimistic appropriation estimates, rendering the target launch dates unachievable. NASA launched SMAP in January 2015. The FY 2016 budget request fully funds ICESAT-2 (2018), the radar portion of DESDynI (NISAR – 2021), and technology demonstration instruments for risk reduction for CLARREO (for launch to the International Space Station (ISS) in 2019). The FY 2016 budget request also funds completion of high-priority, Decadal-identified, continuity missions: Stratospheric Aerosol and Gas Experiment (SAGE)-III (2016), Landsat-9 (2023, assigned to USGS in the Decadal), GRACE-FO (2017, deferred to Tier-3 in the Decadal), and SWOT (2020). The FY 2016 budget request supports launch dates that are consistent with the latest (2014 or earlier) mission gate review decision memoranda and Agency commitments.

SCIENCE

NASA asks the Earth Science Subcommittee of the NASA Advisory Committee for input regarding budget priorities, to ensure that our proposed programs maximize scientific productivity, within the general framework established by the National Academies.

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 is in formulation 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 a mission that will return to Earth samples from a near-Earth asteroid.

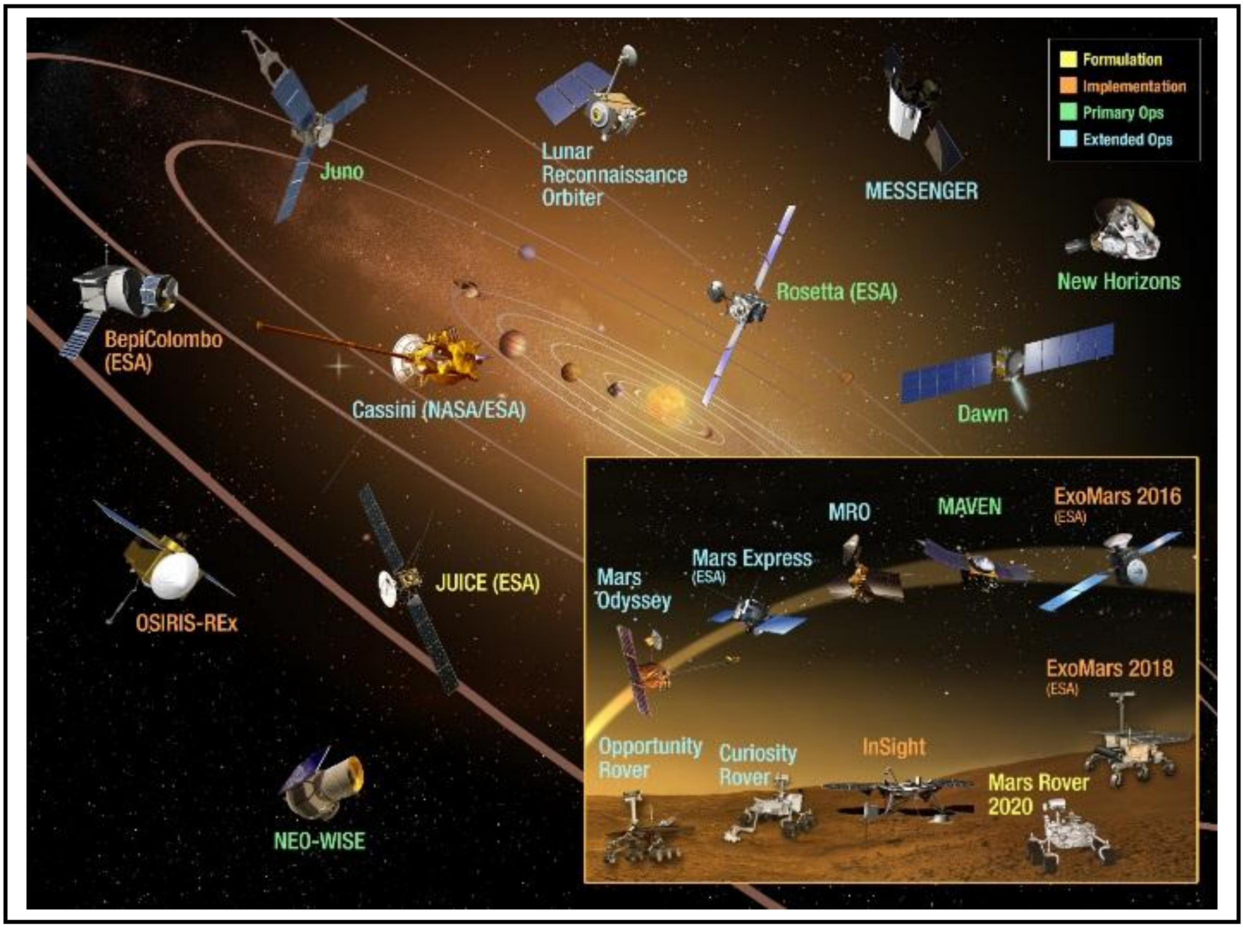
The primary recommendations of the National Academies' 2012 Decadal Survey for Planetary Science were:

1. Continue Discovery solicitations, with the cost cap adjusted for inflation and a 24-month cadence. NASA adjusted the cost cap of the latest AO per the Decadal recommendation. The out-year budget supports a 36-month cadence for new mission competitions.
2. Continue New Frontiers with a $1 billion cost cap, and select two new missions by 2022. This budget supports a new AO in 2016 with selection by the end of 2017, and would notionally support the next AO by 2021 for selection in 2022.
3. Two highest priority flagships are a Mars Astrobiology Explorer-Cacher and a Europa mission. This budget supports a Mars 2020 rover mission that will address the highest priority Mars science objectives recommended by the Planetary Decadal Survey and initiates a Europa mission project.
4. Continue missions in development and flight, subject to senior review. This budget fully supports all missions selected for development, all missions in prime operations, and all but two extended missions (Lunar Reconnaissance Orbiter and Mars Exploration Rover/Opportunity) ranked highly in the latest senior review.
5. Increase research and analysis (R&A) spending by 5 percent above the FY 2011 budget level, and then 1.5 percent above inflation thereafter. The total R&A budget in FY 2011 was $208 million. This budget funds R&A programs at $203 million in FY 2016.
6. Planetary Technology spending should be 6 to 8 percent of the total division budget, including completion of the advanced Stirling radioisotope generators. This budget funds technology at roughly 3 percent, and delays Stirling systems development into later years.

The proposed budget deviates from Decadal Survey recommendations due to overly optimistic Decadal assumptions regarding future budgets, and adjustments are made across the portfolio to ensure balance accordingly.

SCIENCE

NASA asks the Planetary Science Subcommittee of the NASA Advisory Committee for input regarding budget priorities, to ensure that our proposed programs maximize scientific productivity, within the general framework established by the National Academies.



ASTROPHYSICS

The theories of the past century about the physical universe related to the Big Bang, black holes, and dark matter and dark energy 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 further 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 2010 Decadal Survey in Astronomy and Astrophysics, New Worlds, New Horizons (Astro2010) in Astronomy and Astrophysics, recommended a coordinated program of research, technology development, ground-based facilities, and space-based missions for implementation during 2012–2021. The primary recommendations were:

- Complete the ongoing program. The Astro2010 Decadal Survey assumed launch of Webb in 2014; full operations of the SOFIA airborne observatory in 2012; and completion of three Explorer missions: the Nuclear Spectroscopic Telescope Array (NuSTAR) in 2012, the Gravity and Extreme Magnetism (GEMS) Explorer in 2014, and the US contribution to the Japanese ASTRO-H mission in 2014. This budget fully supports launch of Webb in 2018, delivery of the ASTRO-H instrument to Japan in 2014 for launch in 2015, and continued operations by SOFIA (fully operational in 2014) and NuSTAR (launched in 2012). NASA halted development of GEMS in 2012 due to cost overruns.
- Support the ongoing core research program to ensure a balanced program that optimizes overall scientific return. This budget fully supports the ongoing core research program and maintains a balanced program of large missions, small missions, research and analysis, suborbital projects, and technology development addressing the highest priorities in cosmic origins, exoplanet exploration, and physics of the cosmos.
- Launch the Wide-Field Infrared Survey Telescope (WFIRST) by 2020. This budget supports pre-formulation and focused technology development for a 2.4-meter version of WFIRST, incorporating the Astrophysics Focused Telescope Assets (AFTA) and potentially a coronagraph to enable the potential start of Phase A formulation activities no earlier than FY 2017.
- Augment the Astrophysics Explorers Program to support the selection of four missions and four smaller missions of opportunity each decade. This budget fully supports the recommended cadence of new Astrophysics Explorers missions, with AOs in 2014, 2016/2017, and 2019.
- Launch the Laser Interferometer Space Antenna (LISA) by 2025. This budget supports studies leading toward a potential contribution to a European Space Agency (ESA) led gravitational wave observatory for launch in 2034.
- Invest in Technology leading toward an international X-ray observatory in the 2020s. This budget supports a US contribution to the ESA-led Athena advanced X-ray observatory for launch in 2028.
- Invest in a New Worlds technology development and precursor science program for a 2020s mission to image habitable rocky planets. This budget supports the development of technology and conduct of precursor science required for a future mission to directly image and characterize habitable rocky exoplanets.
- Invest in technology development and precursor science for a 2020s mission to probe the epoch of inflation. This budget supports the development of technology and conduct of precursor science required for a future mission to probe the epoch of inflation.
- Increase funding for several targeted areas of supporting research and technology. This budget supports increased funding for research and analysis including recommended investments in intermediate technology development, theoretical and computational networks, suborbital programs, laboratory astrophysics, and technology for future ultraviolet/visible space telescopes.

NASA has and is continuing to address many of the Decadal Survey recommendations, though in some cases at a slower pace. Adjustments to the Decadal Survey recommendations are primarily due to overly optimistic Decadal assumptions regarding future budgets and challenges and delays to programs such as Webb. Other factors that could not be anticipated by the Decadal Survey include the availability of the AFTA, changing international partnership opportunities, emerging technologies that have changed what can be accomplished, and advances in our scientific understanding of the universe.

SCIENCE

NASA asks the Astrophysics Subcommittee of the NASA Advisory Council for input regarding budget priorities, to ensure that our proposed programs maximize scientific productivity, within the general framework established by the National Academies.

JAMES WEBB SPACE TELESCOPE (WEBB)

Webb 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. Webb is progressing well towards its scheduled launch in October 2018, within the cost and schedule baseline NASA established in 2011.

SCIENCE

HELIOPHYSICS

The Sun, a typical small star midway through its life, governs the solar system. 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.

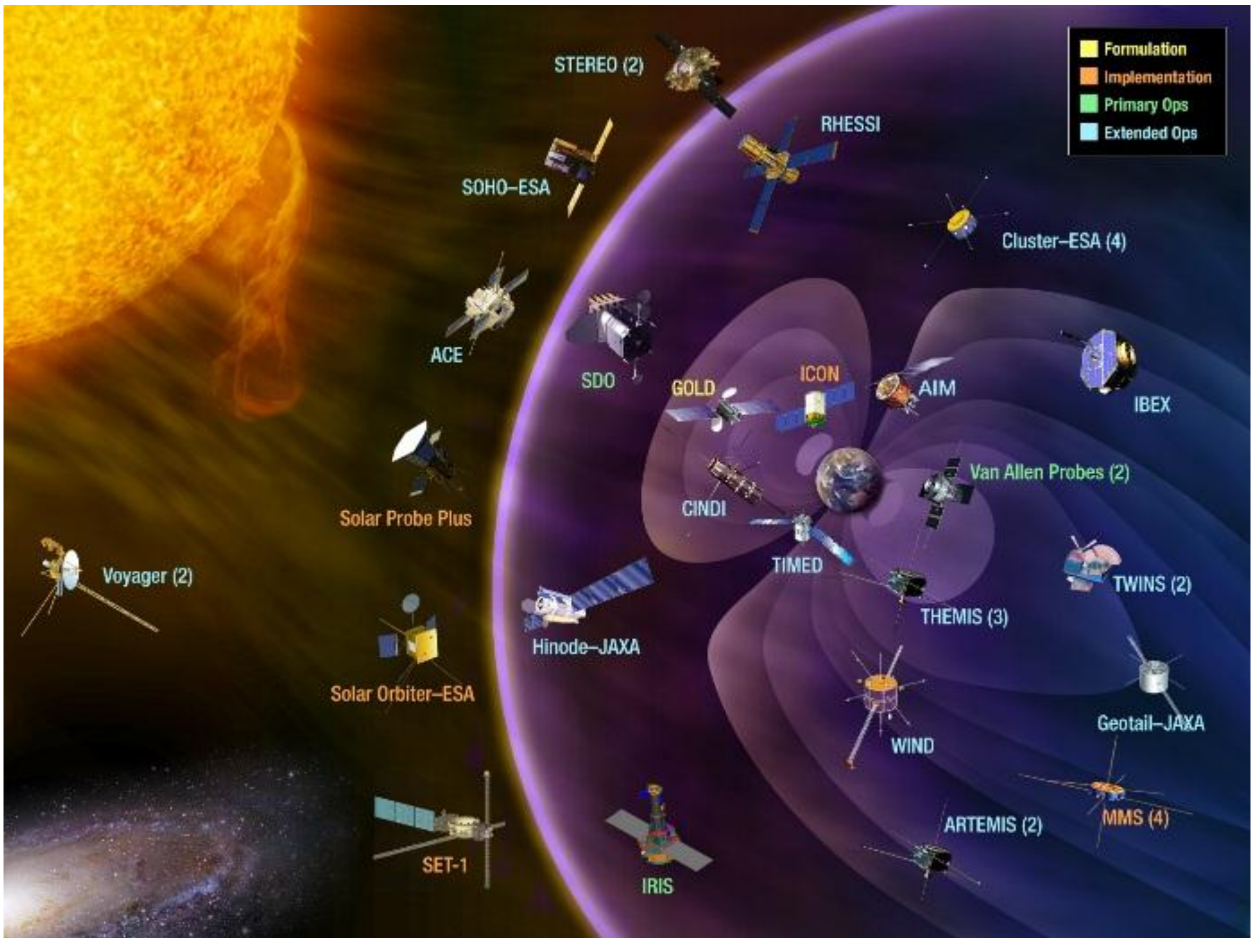
The primary recommendations of the National Academies' 2013 Decadal Survey for Heliophysics were:

1. Maintain and complete the current program. The Decadal assumed launch of Van Allen Probes by 2012, Interface Region Imaging Spectrograph (IRIS) by 2013, MMS by 2014, SOC by 2017, SPP by 2018, and continued current funding of the Research program. Van Allen and IRIS have launched on schedule, MMS is working toward launch in 2015, and SOC and SPP are currently on schedule. The FY 2016 budget fully supports those missions.
2. Implement the DRIVE (Diversify, Realize, Integrate, Venture, Educate) initiative, resulting in an increase of the competed research program from 10 percent to about 15 percent of the budget request. The FY 2016 budget supports a gradual increase with a goal of fully implementing DRIVE by the end of the decade.
3. Accelerate and expand the Heliophysics Explorer Program, resulting in an increase to the cadence of competed missions to one launch every 2-3 years, starting in roughly 2018. This budget supports the launch of an Explorer and a Mission of Opportunity in 2017, six years after the previous Explorer launch. The notional out-year budgets, if realized, would support the next launch around 2021-2022.
4. Restructure Solar Terrestrial Probes (STP) as a moderate scale principal investigator-led flight program, and implement three mid-scale missions with an eventual recommended 4-year cadence. This budget assumes an Announcement of Opportunity no earlier than 2017 for a launch in about 2023. The procurement strategy (principle investigator-led versus Center led) for future STP strategic missions is not budget dependent.
5. Implement a large Living with a Star (LWS) mission to study Global Dynamic Coupling with a launch in 2024. The FY16 budget does not support this mission as described in the Decadal Survey.

The FY 2016 budget deviations from Decadal Survey recommendations are due to overly optimistic Decadal assumptions regarding future budgets. The Heliophysics Decadal Survey provided specific decision rules for prioritizing the recommendations if the enacted budgets did not meet assumptions. The projects supported within this budget request follow those decision rules. NASA asks the Heliophysics Subcommittee of the NASA Advisory Committee for input regarding budget priorities, to ensure that our proposed programs maximize scientific productivity, within the general framework established by the National Academies.

SCIENCE

The decadal survey went beyond its Heliophysics science recommendations and made recommendations related to space weather applications, addressed collectively to the relevant government agencies. NASA will continue collaborating with other agencies to improve space weather observation and forecasting capabilities.



EARTH SCIENCE

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Earth Science Research	456.7	--	**485.3**	471.0	480.4	475.2	470.6
Earth Systematic Missions	837.2	--	**895.2**	919.7	948.6	994.1	1004.8
Earth System Science Pathfinder	257.4	--	**267.7**	272.8	255.4	238.7	244.8
Earth Science Multi-Mission Operations	179.0	--	**190.7**	192.5	193.7	192.4	195.8
Earth Science Technology	59.6	--	**60.7**	62.1	61.5	61.2	62.7
Applied Sciences	35.0	--	**47.6**	48.7	48.4	47.6	48.8
Total Budget	**1824.9**	**--**	**1947.3**	**1966.7**	**1988.0**	**2009.3**	**2027.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Earth Science

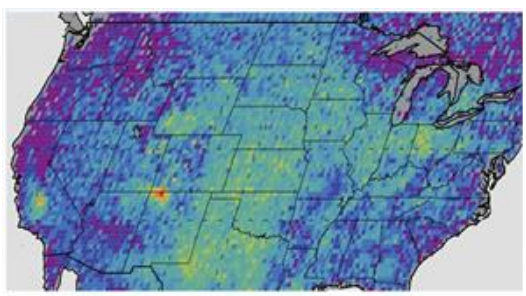
EARTH SCIENCE RESEARCH

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Earth Science Research and Analysis	334.6	--	**348.4**	329.8	329.8	323.4	322.5
Computing and Management	122.1	--	**136.9**	141.2	150.5	151.9	148.1
Total Budget	**456.7**	--	**485.3**	**471.0**	**480.4**	**475.2**	**470.6**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



A recent study entitled "Four corners: The largest US methane anomaly viewed from space," space observations identified that one small "hot spot" in the Southwest is responsible for producing the largest concentration of the greenhouse gas methane observed over the entire country. The area is roughly half the size of Connecticut or 6,500 square kilometers.

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.

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 US 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 2016

NASA extended Operation IceBridge through FY 2019 to ensure overlap with the Ice, Cloud, and land Elevation Satellite (ICESat)-2 mission.

ACHIEVEMENTS IN FY 2014

In 2014, NASA scientists developed a prototype online extreme precipitation monitoring system from 15 years of Tropical Rainfall Measurement Mission (TRMM) Multi-satellite Precipitation Analysis data. This system demonstrated a strong relationship between changes in global rainfall pattern and atmospheric circulation, known as Hadley circulation. The system also characterized the precipitation features and annual rainfall patterns during the TRMM era in the Central Andes. In addition, the Journal of Climate presented and evaluated an article on an updated 15-year TRMM composite climatology, based on a combination of individual rainfall estimates made with data from the primary TRMM instruments: the TRMM Microwave Imager and the precipitation radar.

The NASA Global Precipitation Measurement (GPM) Mission Integrated Precipitation and Hydrology Experiment took place in the Appalachian Mountains of southwestern North Carolina from May 1, 2014 to June 15, 2014. Overarching campaign objectives included the improvement of satellite-based remote sensing algorithms of clouds and precipitation over mountainous terrain, and evaluation and further development of associated data products for use in hydrologic applications, such as flood prediction. To achieve these objectives, researchers deployed and operated an extensive set of airborne and ground-based instruments under occasional overpasses of GPM constellation satellite platforms.

Mass loss from the Greenland ice sheet contributes significantly to present sea level rise. Surface melt has been spreading and intensifying in Greenland, with the highest surface area melt and runoff recorded in 2012. A recent analysis detected widespread ice-covered valleys that extend significantly deeper below sea level and farther inland than previously thought. The findings imply that the outlet glaciers of Greenland, and the ice sheet as a whole, are probably more vulnerable to heating from warm ocean waters and peripheral thinning than inferred previously from existing numerical ice-sheet models. For the first time, Operation IceBridge conducted a deployment in the Arctic to collect altimetry data over sea ice and the Greenland ice sheet during the annual melt season. For three weeks, between October and November 2013, NASA's C-130 aircraft flew nine science missions with the Land, Vegetation, and Ice Sensor and its smaller version designed for the unpiloted Global Hawk platform.

One of the largest Earth Science earthquake response activities in the last year was for the magnitude 6.0 South Napa earthquake on August 24, 2014 (http://photojournal.jpl.nasa.gov/catalog/PIA18798). The Advanced Rapid Imaging and Analysis project at Jet Propulsion Laboratory (JPL) provided Global Positioning System (GPS) measurements of the coseismic deformation, connecting points at which earthquake waves arrive at the same time, within two days and a coseismic interferogram within four days after the earthquake. An interferogram is a photographic record of light interference patterns produced with an interferometer, used for recording shock waves and fluid flow patterns. NASA called the Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) project to aid rapid response efforts shortly after the South Napa earthquake in determining faulting and assessing levee/aqueduct damage.

The project initiated the data processing rapidly, delivered images of all flown flight lines within 48 hours post-flight, and began delivering refined interferometric products within four days post-flight. The project provided information to the California Department of Water Resources about crustal deformation along the San Pablo Bay shoreline quickly in support of their levee response activities and to the US Geological Survey (USGS) to direct their ground survey crews. In FY 2014, the NASA Center for Climate Simulations (NCCS) upgraded its capability by adding 480 compute-nodes and over 5 petabytes of usable storage capacity for the Discover cluster to support the large-scale climate simulations of the Global Modeling and Assimilation Office (GMAO). NCCS integrated and upgraded tape drives and tapes to the mass storage environment to upkeep with the science requirements. The resulting mass storage grew to just over 45 petabytes. For data services, NCCS supported the download of over 200 terabytes of Intergovernmental Panel on Climate Change (IPCC) data and created a prototype Climate Analytics as a Service using Hadoop big data technology. NCCS is beginning to support the creation of the Level 4 soil moisture analysis for the Soil Moisture Active/Passive (SMAP) mission.

The High End Computing Capability (HECC) project expanded the compute capability available to the NASA science and engineering communities by over 50 percent in FY 2014. Multiple expansions to Pleiades and the addition of Merope caused the increase. Merope is a cluster of repurposed processors that were once part of the Pleiades supercomputer and NASA uses this system for running real-world computational jobs and for testing purposes. The online storage doubled to greater than 20 petabytes in multiple file systems, and the project upgraded the primary data analysis and visualization system with new compute nodes and fully integrated it into Pleiades' network. NASA, Google, and Universities Space Research Association (USRA) formed an innovative partnership to explore the potential for quantum computers to tackle optimization problems that are difficult or impossible for traditional supercomputers to handle.

WORK IN PROGRESS IN FY 2015

NASA's Earth Science program will continue funding investigations in competitively selected projects.

Key field campaigns planned for FY 2015 are:

- The Polar Winds mission is conducting two campaigns to Greenland to investigate polar warming, ice loss and calibration/validation measurements for the European Space Agency (ESA) Atmospheric Dynamics Mission using measurements from the Langley Research Center (LaRC) Doppler Aerosol Wind Light Detection and Ranging (LIDAR) system.
- The Plains Elevated Convection at Night campaign aims to advance the understanding of continental, nocturnal, warm-season precipitation. The campaign will focus on nocturnal convection in conditions located above the Southern Great Plains. Thunderstorms are most common after sunset across this region in summer and much of the resulting precipitation falls from mesoscale convective systems. Nocturnal systems may produce heavy rainfall and their intensity correlates with the nocturnal low-level jet. To date, an accurate prediction and an in-depth understanding of elevated convection in this environment remains an elusive goal. NASA will conduct the campaign across northern Oklahoma, central Kansas and into south-central Nebraska from June 1, 2015 to July 15, 2015.

Research under NASA's Carbon Monitoring System (CMS) program will continue to focus on using satellite and airborne remote sensing capabilities to prototype key data products to meet US carbon monitoring, reporting, and verification needs. Ongoing CMS studies that use commercial off-the-shelf airborne measurement methodologies in support of international Reducing Emissions from Deforestation and forest Degradation (REDD); REDD+ projects in Indonesia, Mexico, Peru, and Brazil; as well as carbon sequestration, management, and state-level mapping projects within the United States will continue. Work will proceed with the newly selected CMS investigations to improve the CMS biomass and flux products, and conduct new monitoring, reporting, and verification relevant projects at local to regional scales.

Earth Venture Suborbital missions and Operation IceBridge continue to collect data. Hyperspectral Infrared Imager (HyspIRI) continues to develop, calibrate, and validate airborne campaigns. Earth Surface and Interior focus area continues volcano, earthquake, and levee monitoring.

The compute environment for Scientific Computing will decommission 1,200 nodes (14,400 cores) and integrate 1,680 nodes (over 45,000 cores). This will roughly triple the peak compute capability of the NCCS. In addition, the NCCS will integrate approximately 15 petabytes of raw storage capability throughout the NCCS and upgrade its networking infrastructure and firewall capabilities to 40 gigabit Ethernet (an increase of four times the performance). The NCCS will have a new production capability to enable NCCS to better measure the carbon uptake and its effect on climate through high-resolution imagery, models, and remote sensing measurements.

HECC continues incremental growth to the Pleiades supercomputer and storage environment, focusing on integrating additional Intel's latest Haswell-based nodes, which are equipped with higher speed memory to provide higher memory bandwidth. Storage increases of approximately 10 petabytes will expand current capacity by 50 percent.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, in response to solicitations in Research Opportunities in Space and Earth Sciences 2015 (ROSES-15) and ROSES-14, NASA anticipates awarding over 200 new three-year research awards. The new research includes work selected in response to new elements solicited in ROSES-14 and ROSES-15, namely Remote Sensing Theory, Climate Indicators and Data Products for Future National Climate Assessments, and Satellite Calibration and Inter-consistency studies. NASA is increasing focus on improving understanding of the coupled North Atlantic-Arctic system in conjunction with other agencies, and improving understanding and quantifying linkages between the global oceans and regional/global climate change, including air-sea moisture and chemical fluxes and impacts on oceanic ecosystems.

NASA's GPM mission plans an intensive precipitation field campaign for the beginning of FY 2016 in the Olympic mountain range in Washington State. The DC-8 aircraft campaign will be coordinated with ground-based observations and with cloud in-situ measurements conducted with the University of North Dakota Cessna Citation aircraft. The aircraft will collect microwave radiometer and radar remote sensing data that simulate the observations planned for NASA's GPM spaceflight mission.

Operation IceBridge continues as the largest airborne survey of the Earth's polar ice ever flown to provide data continuity between the loss of the ICESat-1 satellite and the launch of ICESat-2. It is yielding a three-dimensional view of the Arctic and Antarctic ice sheets, ice shelves, and sea ice. These flights provide a yearly, multi-instrument look at the behavior of the polar ice sheets to determine their contributions to current and future global sea level rise, and to help understand the changes in sea ice cover and the Earth system.

The planned FY 2016 activities for Scientific Computing include operating and management of NCCS, deferred facility maintenance cost, continued compute and storage upgrades and continued support of Earth and space science and field experiment campaigns.

HECC plans a procurement to assess new technologies planned for release in 2016. Based on the findings, HECC will determine whether any new technologies are more productive for NASA's computational workload, or if augmentation of the current technologies should continue.

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 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 competitively selected under the suborbital portion of Earth Venture.
- 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.

EARTH SCIENCE RESEARCH

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

GLOBAL LEARNING AND OBSERVATIONS TO BENEFIT THE ENVIRONMENT

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 National Oceanographic and Atmospheric Administration (NOAA) and National Science Foundation (NSF) Earth System Science Projects to 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 (SGP) 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 SGP manages the operations and development of NASA's Space Geodetic Network that is comprised of the following major space geodetic observing systems: Very Long Baseline Interferometry. Satellite Laser Ranging, Global Navigation Satellite System. It currently develops the next generation Space Geodetic Stations. The Space Geodesy project began in 2011. It is a Goddard Space Flight Center (GSFC) and JPL partnership, with participation from the Smithsonian Astrophysical Observatory and the University of Maryland.

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 RESEARCH

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 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)

HECC 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. These 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 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 (SMD) 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 2015	ROSES-2015 solicitation
Q1 FY 2016	ROSES-2015 selection within six to nine months of receipt of proposals
Q2 FY 2016	ROSES-2016 solicitation
Q1 FY 2017	ROSES-2016 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), GRC, JSC, LaRC 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
Scientific Computing	Provider: GSFC Lead Center: HQ Performing Center(s): GSFC Cost Share Partner(s): N/A
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: 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): N/A

EARTH SCIENCE RESEARCH

Program Element	Provider
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): US Forest Service, DOE, NOAA
Global Learning and Observations to Benefit the Environment	Provider: University Corporation for Atmospheric Research Lead Center: HQ Performing Center(s): GSFC Cost Share Partner(s): N/A

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.

EARTH SCIENCE RESEARCH

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Relevance	NASA Advisory Council Earth Science Subcommittee	2014	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 2014 Performance and Accountability Report	2015; annually thereafter

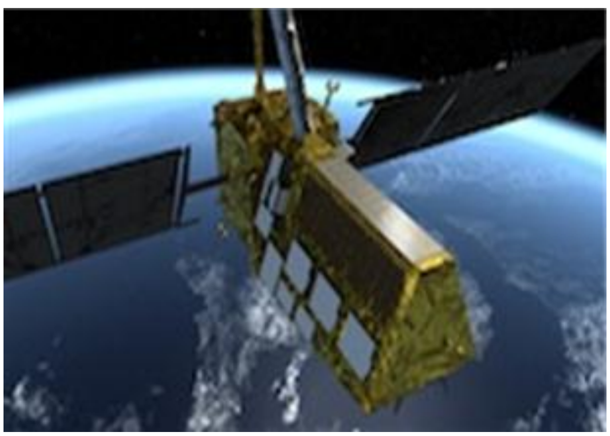
EARTH SYSTEMATIC MISSIONS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Ice, Cloud, and land Elevation Satellite (ICESat-2)	182.2	126.5	**127.4**	102.4	66.6	14.2	14.2
Soil Moisture Active and Passive (SMAP)	65.4	74.9	**15.9**	11.3	11.3	11.3	11.5
GRACE FO	87.8	73.4	**66.3**	38.7	21.1	11.1	12.1
Surface Water and Ocean Topography	59.2	--	**78.3**	96.9	131.4	126.3	80.5
Other Missions and Data Analysis	442.6	--	**607.4**	670.5	718.3	831.2	886.5
Total Budget	**837.2**	**--**	**895.2**	**919.7**	**948.6**	**994.1**	**1004.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



An artist's conception shows the NASA-ISRO Synthetic Aperture Radar (NISAR) mission, currently in formulation. The NISAR mission would make global integrated measurements of the causes and consequences of land surface changes. NISAR would provide a means of understanding complex processes ranging from ecosystem disturbances, to ice sheet collapse and natural hazards including earthquakes, tsunamis, volcanoes, and landslides.

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 US and international meteorological agencies and disaster responders. Five of the 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 USGS. The GPM mission, now operating on orbit, 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 Surface Water Ocean Topography (SWOT) mission includes significant collaborations with the Centre National d'Etudes' Spatiales (CNES), the Canadian Space Agency (CSA) and the United Kingdom Space Agency (UKSA). The NASA-ISRO Synthetic Aperture Radar (NISAR) mission is a major collaboration between NASA and the Indian Space Research Organisation (ISRO.

EARTH SYSTEMATIC MISSIONS

EXPLANATION OF MAJOR CHANGES IN FY 2016

NASA submitted a new estimate of the ICESat-2 mission budget and schedule in the project cost and scheduled analysis report pursuant to Section 103 (d)(2) of the NASA Authorization Act of 2005 (P.L. 109-155). The Agency submitted the report to Congress in July 2014. This submission reflects the ICESat-2 new baseline. NASA increased the Sustainable Land Imaging project budget to support the Administration's implementation strategy for sustained land imaging (described in detail within the ESM Other Missions & Data Analysis [OM&DA] section). NASA will begin formulation activities for the TSIS-1 instrument, and will implement an ocean altimetry strategy (described in detail within the ESM OM&DA section).

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	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	171.7	182.2	126.5	**127.4**	100.8	55.2	0.0	0.0	0.0	763.7
Operations/Close-out	0.0	0.0	0.0	**0.0**	1.6	11.4	14.2	14.2	9.4	50.7
2015 MPAR LCC Estimate	**420.8**	**182.2**	**126.5**	**127.4**	**102.4**	**66.6**	**14.2**	**14.2**	**9.4**	**1063.5**
Total Budget	**420.8**	**182.2**	**126.5**	**127.4**	**102.4**	**66.6**	**14.2**	**14.2**	**9.4**	**1063.6**
Change from FY 2015				**0.9**						
Percentage change from FY 2015				**0.7%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

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.

PROJECT PURPOSE

The 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.

The ICESat-2 mission is a Tier 1 mission recommended by the National Academies. It entered formulation in FY 2010 and confirmed to proceed into implementation in FY 2013.

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

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	Development	Operations

EXPLANATION OF MAJOR CHANGES IN FY 2016

NASA informed Congress by letters dated December 2, 2013, January 29, 2014, and July 28, 2014, that ICESat-2 experienced a significant cost overrun and schedule delay. NASA addressed the root causes of the overrun and delays, and subsequently established a new estimate for the project with a revised budget and schedule. On July 28, 2014, NASA transmitted the final ICESat-2 Project Cost and Schedule Analysis Report pursuant to Section 103(d)(2) of the NASA Authorization Act of 2005 (P.L. 109-155). NASA's detailed report included a project overview and scope, discussion on development cost and schedule growth, an analysis of alternatives, and a new cost and schedule estimate.

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. NASA replaced the ATLAS instrument management team, added new technical expertise, realigned the instrument organizational structure, and reassessed instrument development risks. NASA also reviewed and revamped their engineering review processes to improve execution.

Pursuant to Section 103 (e) of P.L. 109-155, this budget request establishes a new baseline for ICESat-2. The detailed discussion of ICESat-2 included in this budget request constitutes NASA's response to the requirements of Section 103 (e) of P.L. 109-155 for a New Baseline Report for ICESat-2. This new baseline is consistent with NASA's prior notifications and reflects a revised life cycle cost estimate of $1,063.5 million. The new baseline plan also includes a revised development schedule, with launch in June 2018.

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 2014

The ATLAS instrument and the overall mission both successfully completed their Critical Design Reviews (CDR) in FY 2014. Mission readiness testing for the ground system began in June 2014. In parallel with the Mission CDR, the Agency approved the new baseline cost and schedule for the project.

WORK IN PROGRESS IN FY 2015

The team will complete the spacecraft and commence testing activities during FY 2015. The team will complete and deliver all ATLAS instrument subsystems, and begin integrated and overall instrument testing.

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	Development	Operations

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The team will complete ATLAS instrument testing and delivery of the instrument during FY 2016. The project will mate the instrument with the spacecraft; begin testing on the resultant observatory; and hold the Mission Operations Review in FY 2016.

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
Key Decision Point-C (KDP-C)	Dec 2012	Dec 2012
CDR	Feb 2014	Feb 2014
New Baseline*	Feb 2015	Feb 2015
Launch	Jun 2018	Jun 2018
End of Prime Mission	Sep 2021	Sep 2021

Pursuant to sec. 103(e) of P.L. 109-155, this budget request establishes a new baseline for ICESat-2. The original ICESat-2 baseline in 2013 had a 37% development cost increase.

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2015	763.7	>70	2015	763.7	0	Launch	Jun 2018	Jun 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

Pursuant to sec. 103(e) of PL 109-155, this budget request establishes a new baseline for ICESat-2. The original ICESat-2 baseline in 2013 had a 37% development cost increase.

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	**Development**	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**763.7**	**763.7**	**0.0**
Aircraft/Spacecraft	106.0	106.0	0.0
Payloads	239.1	239.1	0.0
Systems Integration and Test (I&T)	21.6	21.6	0.0
Launch Vehicle	118.8	118.8	0.0
Ground Systems	55.4	55.4	0.0
Science/Technology	31.0	31.0	0.0
Other Direct Project Costs	191.9	191.9	0.0

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
Launch Vehicle	Provides launch service and entry into proper Earth orbit	Provider: United Launch Alliance (ULA) Lead Center: GSFC Performing Center(s): KSC Cost Share Partner(s): N/A	N/A
Ground System	Provides control of observatory operations, science data processing and distribution	Provider: OSC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A	N/A

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	Development	Operations

Project Risks

Risk Statement	Mitigation
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 (OSC), which will provide the ground system element via a contract option. NASA competitively selected United Launch Alliance (ULA) as the launch services vendor.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Ground System	OSC	Dulles, VA
Spacecraft	OSC	Gilbert, AZ
Launch Service	ULA	Decatur, AL

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	Standing Review Board (SRB)	Dec 2012	KDP-C	Mission was approved to enter development	Feb 2014
Perform-ance	SRB	Feb 2014	Mission CDR	Mission CDR was successfully completed	Oct 2016
Perform-ance	SRB	Oct 2016	KDP-D	TBD	Jul 2017
Perform-ance	SRB	Jul 2017	Operational Readiness Review (ORR)	TBD	N/A

ICE, CLOUD, AND LAND ELEVATION SATELLITE (ICESAT-2)

Formulation	Development	Operations

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

NASA informed Congress by letters dated December 2, 2013, January 29, 2014, and July 28, 2014, that ICESat-2 experienced a significant cost overrun and schedule delay. NASA addressed the root causes of the overrun and delays, and subsequently established a new estimate for the project with a revised budget and schedule. On July 28, 2014, NASA transmitted the final ICESat-2 Project Cost and Schedule Analysis Report pursuant to Section 103(d)(2) of the NASA Authorization Act of 2005 (P.L. 109-155). NASA's detailed report included a project overview and scope, discussion on development cost and schedule growth, an analysis of alternatives, and a new cost and schedule estimate.

The current projected ICESat-2 launch readiness date is June 2018, the development cost estimate is $763.7 million, and the life cycle cost estimate is $1,063.5 million. The revised ICESat-2 cost and schedule incorporates 18 months of schedule reserve within the planned funding for development.

The following table describes the issues that NASA addressed during the new estimate of ICESat-2 in 2014.

Issues	Corrective Action Plan
Issue 1: Cost and schedule overrun Current Status: The Agency approved the revised cost and schedule baseline and submitted it to Congress.	Programmatic: NASA replaced the ATLAS instrument management team, added new technical expertise, realigned the instrument organizational structure, and recalculated required reserves based on a reassessment of instrument development risks. NASA also reviewed and revamped their engineering review processes to improve execution. Technical: No action required. Cost: The revised baseline plan submitted to Congress resulted in a revised life cycle cost estimate of $1,063.5 million. Schedule: The revised baseline plan submitted to Congress also resulted in a revised development schedule, with launch in June 2018. The revised schedule incorporates 18 months of funded schedule reserve.

SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

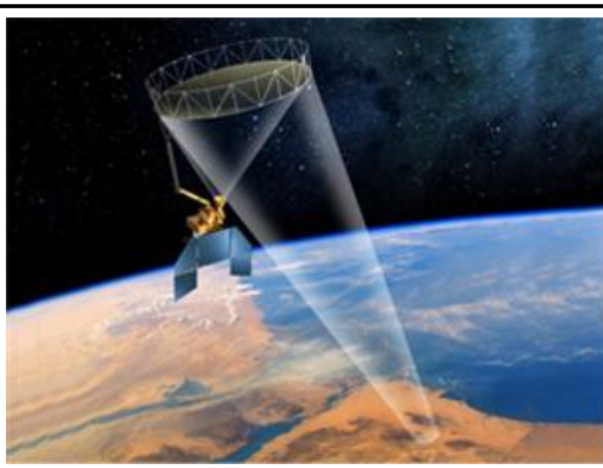
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	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	357.2	65.4	56.4	**0.0**	0.0	0.0	0.0	0.0	0.0	479.0
Operations/Close-out	0.0	0.0	18.5	**15.9**	11.3	1.7	0.0	0.0	0.0	47.4
2015 MPAR LCC Estimate	**745.4**	**65.4**	**74.9**	**15.9**	**11.3**	**1.7**	**0.0**	**0.0**	**0.0**	**914.6**
Total Budget	**745.4**	**65.4**	**74.9**	**15.9**	**11.3**	**11.3**	**11.3**	**11.5**	**0.0**	**947.1**
Change from FY 2015				**-59.0**						
Percentage change from FY 2015				**-78.8%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



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.

PROJECT PURPOSE

The SMAP mission will provide a capability for global mapping of soil moisture with unprecedented accuracy, resolution, and coverage.

Scientific understanding of how climate 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 bring climate models 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:

- Understand processes that link the terrestrial water, energy and carbon cycles;
- Estimate global water and energy fluxes at the land surface;

SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations

- 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 2016

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 2014

The SMAP project completed the manufacture and assembly of the observatory, and all environmental testing.

WORK IN PROGRESS IN FY 2015

NASA delivered the SMAP observatory to the launch site in October 2014, for launch by March 2015. The SMAP observatory will then undergo check out and commissioning, as well as the initiation of calibration and validation activities.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The SMAP Project should meet the Mission Success Criteria in the first quarter of the fiscal year. Initial versions of data products will be available for all required data products.

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 2016 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 Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	485.7	>70	2015	479.0	1.4	Launch	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.

SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations

Development Cost Details

The project performed an Estimate at Completion, which is a standard review practice. Baseline changes were limited to those areas requiring an update to scope, schedule, and/or cost. As a result, increases in 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 to cover additional requirements associated with increased understanding of science and operational implementation. The offsetting reductions were in the Other Direct Project Costs and the Systems Integration and Test lines.

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**485.7**	**479.0**	**-6.7**
Aircraft/Spacecraft	80.1	96.7	16.6
Payloads	59.7	114.0	54.3
Systems I&T	22.3	24.1	1.8
Launch Vehicle	123.6	120.1	-3.5
Ground Systems	24.2	31.9	7.7
Science/Technology	8.9	11.6	2.7
Other Direct Project Costs	166.9	80.6	-86.3

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

SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations

Element	Description	Provider Details	Change from Baseline
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: ULA Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A	N/A

Project Risks

Risk Statement	Mitigation
If: The project cannot achieve launch prior to March 10, 2015, Then: There will be a delay of launch for not less than 5 months, potentially causing a breach for both cost and schedule.	The Observatory and the Launch Vehicle are on schedule to be prepared for final processing and launch prior to March 10, 2015.

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	Carpentaria, CA

SOIL MOISTURE ACTIVE AND PASSIVE (SMAP)

Formulation	Development	Operations

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jun 2012	KDP-C Milestone Review	Project approved to enter development	May 2013
Perform-ance	SRB	May 2013	KDP-D Milestone Review	Project approved to enter integration and test	Aug 2014
Perform-ance	Independent Review Team	Nov 2014	Operational Readiness Review	Project was considered ready for Launch and entry into operations	Dec 2014
Perform-ance	SRB	Dec 2014	KDP-E Milestone Review	Project approved for launch and entry into operations	N/A

GRACE FOLLOW-ON

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	95.2	13.4	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	108.5
Development/Implementation	0.0	74.4	73.4	**66.3**	38.7	10.1	0.0	0.0	0.0	262.8
Operations/Close-out	0.0	0.0	0.0	**0.0**	0.0	11.0	11.1	12.1	26.3	60.5
2015 MPAR LCC Estimate	**95.2**	**87.8**	**73.4**	**66.3**	**38.7**	**21.1**	**11.1**	**12.1**	**26.3**	**431.9**
Total Budget	**95.2**	**87.8**	**73.4**	**66.3**	**38.7**	**21.1**	**11.1**	**12.1**	**26.3**	**431.9**
Change from FY 2015				**-7.1**						
Percentage change from FY 2015				**-9.7%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

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, and 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 a minimal gap in gravitational field measurements following the decommissioning of the currently operating GRACE mission. GRACE-FO includes a partnership with Germany.

EXPLANATION OF MAJOR CHANGES IN FY 2016

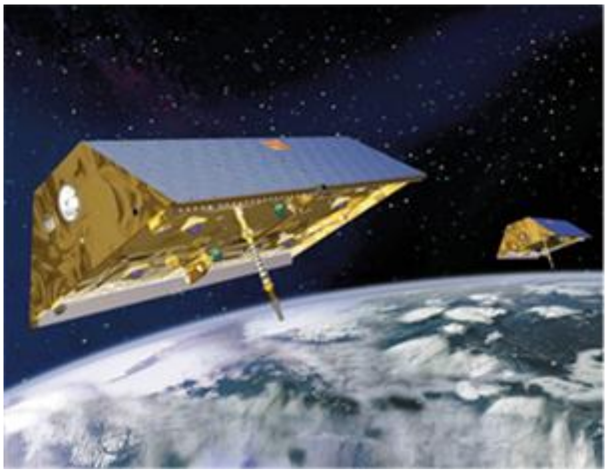
NASA confirmed the GRACE-FO project to proceed into implementation and this budget represents the Agency commitment.

PROJECT PARAMETERS

The GRACE-FO observatory employs two dedicated spacecraft launched into a near-circular polar orbit. As the two spacecraft orbit Earth, slight variations in gravity will alter the spacecraft speed and distance relative to each other. Scientists use the speed and distance changes to extrapolate and map Earth's gravitational field.

GRACE FOLLOW-ON

Formulation	Development	Operations



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.

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 United States 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 2014

The GRACE-FO Project successfully completed its Preliminary Design Review (PDR) in January 2014 and its (KDP-C) in February 2014 where NASA confirmed the project to enter into implementation.

WORK IN PROGRESS IN FY 2015

In FY 2015, the GRACE-FO project will conduct its Critical Design Review (CDR) and Systems Integration Review (SIR), followed by a KDP-D. The team will deliver spacecraft flight hardware and assembly, test, and integration activities will begin.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the three GRACE-FO instruments (the Microwave Instrument, the Laser Ranging Interferometer, and the Accelerometer) will be delivered for integration and testing.

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-C	Feb 2014	Feb 2014
CDR	Feb 2015	Feb 2015
KDP-D	Aug 2015	Aug 2015

GRACE FOLLOW-ON

Formulation	Development	Operations

Milestone	Confirmation Baseline Date	FY 2016 PB Request
Launch (or equivalent)	Feb 2018	Feb 2018
Start Phase E	May 2018	May 2018
End of Prime Mission	Feb 2023	Feb 2023

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2015	264	70	2015	262.8	0.5	Launch	Feb 2018	Feb 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

NASA confirmed GRACE FO to proceed into implementation in February 2014. 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)
TOTAL:	**264.0**	**262.8**	**-1.2**
Aircraft/Spacecraft	118.7	121.4	2.7
Payloads	32.1	33.6	1.5
Systems I&T	0.0	0.0	0.0
Launch Vehicle	0.0	0.0	0.0
Ground Systems	0.0	0.0	0.0
Science/Technology	12.3	13.8	1.5

GRACE FOLLOW-ON

Formulation	Development	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
Other Direct Project Costs	100.9	94.0	-6.9

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 Baseline
Spacecraft	Provides platform for the instruments	Provider: Airbus GmbH (Germany) Lead Center: N/A Performing Center(s): JPL Cost Share Partner(s): 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
Accelerometers	Measures all non-gravitational accelerations of the satellite(s)	Provider: French Office National d'Etudes et Recherches Aérospatiales (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

GRACE FOLLOW-ON

Formulation	Development	Operations

Project Risks

Risk Statement	Mitigation
If: The contributions from the international partner for the GRACE-FO mission are delayed or cannot be provided as planned, Then: The GRACE-FO mission could be delayed, as well.	NASA and JPL will work diligently with its international partners to assess status of their deliverables on a routine basis and assist them with mitigating any technical or programmatic issues if they arise, as ITAR and other international regulations allow. NASA would determine the best course of action for the project, based on the given circumstances at that time.

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.

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
Perform-ance	SRB	Feb 2014	KDP-C Milestone Review	Project approved to development	Aug 2015
Perform-ance	SRB	Aug 2015	KDP-D Milestone Review	Project was considered ready for Launch and entry into operations	Jul 2017
Perform-ance	SRB	Jul 2017	Flight Readiness Review	TBD	N/A

SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

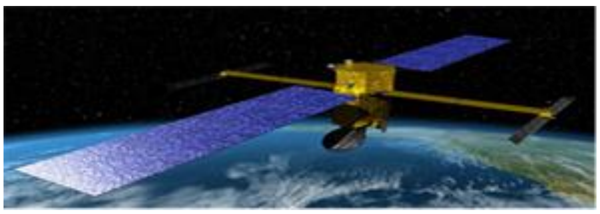
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	59.2	--	78.3	96.9	131.4	126.3	80.5

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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.

PROJECT PURPOSE

The Surface Water and Ocean Topography (SWOT) 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 operation and development to measure the global water cycle (GPM, SMAP, and GRACE-FO). NASA will collaborate with CNES, CSA, and UKSA to accomplish this mission.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

PROJECT PRELIMINARY PARAMETERS

SWOT will provide broad-swath sea surface heights and terrestrial water heights for at least 90 percent of the globe using a dual-antenna Ka-band Radar Interferometer (KaRIn). The SWOT payload will also include a precision orbit determination system consisting of Global Positioning System-Payload (GPSP), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) receivers, and a Laser Retro-

SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

Formulation	Development	Operations

reflector Assembly (LRA). In addition, SWOT carries a Nadir Altimeter, and a radiometer for tropospheric path delay corrections. The mission will operate for 3 years.

ACHIEVEMENTS IN FY 2014

The SWOT project successfully completed the Systems Requirement Review (SRR)/Mission Design Review (MDR) and the KDP-B review, entering Phase B, preliminary design and technology completion. NASA and CNES signed the Implementing Arrangement for cooperation. NASA and CSA signed the Implementing Arrangement for cooperation.

WORK IN PROGRESS IN FY 2015

In FY 2015, the SWOT Project will complete the KaRIn Nadir Channel and KaRIn Antenna PDRs and technology development of the KaRIn High Power Amplifier, KaRIn Mechanical and Thermal Subsystem, KaRIn Digital Electronics Subsystem, and KaRIn Antenna Subsystem.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the SWOT project will complete preliminary design, remaining KaRIn technology development, the KDP-C review, and will enter into implementation.

ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2016 PB Request
Formulation Authorization	Nov 2012	Nov 2012
KDP-B	Jun 2014	Jun 2014
PDR	Jan 2016	Jan 2016
KDP-C	Mar 2016	Mar 2016
CDR	Jun 2017	Jun 2017
KDP-D	Aug 2019	Aug 2019
Launch	Oct 2020	Oct 2020

SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

Formulation	Development	Operations

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 PDR.

KDP-B Date	Estimated Life Cycle Cost Range ($M)	Key Milestone	Key Milestone Estimated Date Range
Jun 2014	647- 757	Launch	Oct 2020

Project Management & Commitments

Element	Description	Provider Details	Change from Formulation Agreement
Ka-band Radar Interferometer (KaRIn)	Makes swath measurements of sea surface topography and lake and river heights	Provider: NASA, CNES, CSA, UKSA Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): CNES (RFU), CSA (EIK), UKSA (Duplexer)	N/A
Advanced Microwave Radiometer (AMR)	Provides wet tropospheric delay correction of KaRIn	Provider: NASA Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
GPS Payload (GPSP)	Provides orbit determination	Provider: NASA Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N /A	N/A
Laser Retroreflector Assembly (LRA)	Provides orbit determination	Provider: NASA Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A
X-band Telecom	Provides downlink of science data	Provider: NASA Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A	N/A

SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

Formulation	Development	Operations

Element	Description	Provider Details	Change from Formulation Agreement
Nadir Altimeter	Measures Jason-heritage ocean surface topography at nadir	Provider: CNES Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):CNES	N/A
DORIS	Provides orbit determination	Provider: CNES Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):CNES	N/A
Spacecraft Bus	Provides instrument platform	Provider: CNES Lead Center: N/A Performing Center(s): N/A Cost Share Partner(s):CNES	N/A
Launch Vehicle	Delivers spacecraft to orbit	Provider: NASA Lead Center: JPL Performing Center(s): KSC Cost Share Partner(s):N/A	N/A

Project Risks

Risk Statement	Mitigation
If: KaRIn critical path contributions from the multiple partners are not timely, Then: It will delay delivery of the KaRIn instrument.	Project worked with CNES to define interfaces, requirements, test plans, and hardware exchanges early. NASA, CSA, and CNES synchronized the development schedules for KaRIn and Radio Frequency Unit (RFU). SRR was successfully completed. NASA signed Implementing Arrangements with CNES and CSA.

Acquisition Strategy

The acquisition strategy for SWOT leveraged Jason heritage by using JPL legacy instrument designs (AMR, GPSP, LRA) and in-house build with a combination of sole source and competitive procurements. The KaRIn leverages Earth Science Technology Office investments and is an in-house development. The X-band Telecom will be a competitive procurement.

SURFACE WATER AND OCEAN TOPOGRAPHY MISSION

Formulation	Development	Operations

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
X-band Telecom	TBD	TBD

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	May 2014	SRR/MDR	Project met all review success criteria	Jan 2016
Perform-ance	SRB	Jan 2016	PDR	TBD	Jun 2017
Perform-ance	SRB	Jun 2017	CDR	TBD	Jan 2019
Perform-ance	SRB	Jan 2019	SIR	TBD	Aug 2020
Perform-ance	SRB	Aug 2020	ORR	TBD	N/A

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Earth Systematic Missions (ESM) Research	12.1	--	**16.6**	18.8	18.8	24.0	24.2
Ocean Surface Topography Science Team (OSTST)	6.0	--	**6.2**	5.8	5.8	5.8	5.9
Earth Observations Systems (EOS) Research	33.1	--	**24.1**	22.9	20.9	18.7	18.8
Deep Space Climate Observatory	4.5	--	**2.9**	0.5	0.0	0.0	0.0
Stratospheric Aerosol and Gas Experiment III (Sage III)	22.6	--	**21.1**	4.8	3.9	4.6	4.6
Sustainable Land Imaging	30.0	--	**78.9**	134.6	174.4	179.9	147.3
Radiation Budget Instrument (RBI)	18.6	--	**45.3**	38.6	28.7	12.2	6.3
NASA-ISRO SAR	57.3	--	**74.0**	64.4	85.0	150.0	145.0
Earth from ISS	0.0	--	**2.3**	2.8	3.1	3.1	3.1
Total Solar Irradiance Sensor-2 (TSIS-2)	0.0	--	**1.0**	9.6	25.9	42.9	31.5
Earth Radiation Budget Science	0.0	--	**12.8**	14.0	13.7	13.6	13.8
Ozone Mapping and Profiler Suite Limb Sounder (OMPS-L)	7.4	--	**5.7**	2.2	0.3	0.0	0.0
Total Solar Irradiance Sensor-1 (TSIS-1)	0.0	--	**16.0**	21.0	13.5	4.0	3.0
Altimetry Follow-On (AFO)	0.0	--	**35.9**	31.2	36.4	53.0	61.4
Pre-Aerosol, Clouds, and Ocean Ecosystem	0.0	--	**53.0**	99.0	91.5	144.4	196.0
CLARREO Pathfinder	0.0	--	**15.0**	17.3	31.0	12.5	0.9
Decadal Survey Missions	21.7	--	**24.1**	24.5	14.4	15.5	75.3
Earth Science Program Management	48.3	--	**32.4**	32.9	33.0	33.3	33.7
Precipitation Science Team	7.2	--	**7.5**	7.0	7.0	7.0	7.1
Ocean Winds Science Team	4.4	--	**4.6**	4.3	4.3	4.3	4.3
Land Cover Project Science Office	1.5	--	**1.6**	1.5	1.5	2.8	2.8
Quick Scatterometer	3.5	--	**0.0**	0.0	0.0	0.0	0.0
Tropical Rainfall Measuring Mission	10.2	--	**10.6**	5.0	0.0	0.0	0.0
Global Precipitation Measurement (GPM)	40.3	--	**21.1**	15.7	18.8	15.3	15.6
Landsat Data Continuity Mission (LDCM)	2.2	--	**2.3**	2.4	2.4	0.0	0.0
Ocean Surface Topography Mission	1.2	--	**2.3**	2.3	2.3	2.3	2.3
Suomi National Polar-Orbiting Partnership (NPP)	7.9	--	**3.4**	3.4	3.4	3.5	3.6
Terra	30.9	--	**25.8**	26.1	25.3	25.3	25.9
Aqua	32.0	--	**27.8**	28.1	27.3	27.3	27.8
Aura	25.8	--	**26.6**	26.9	25.9	25.9	26.4
Solar Radiation and Climate Experiment (SORCE)	5.4	--	**5.3**	2.8	0.0	0.0	0.0
Earth Observing-1	2.5	--	**1.3**	0.0	0.0	0.0	0.0
Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSat)	1.3	--	**0.0**	0.0	0.0	0.0	0.0
Jason	4.6	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**442.6**	**--**	**607.4**	**670.5**	**718.3**	**831.2**	**886.5**

OTHER MISSIONS AND DATA ANALYSIS

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Earth Systematic Missions Other Missions and Data Analysis includes 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 2016 Budget redefines NASA and NOAA Earth-observing satellite responsibilities to leverage NASA Earth Science's expertise in developing Earth-observing satellites while allowing NOAA to focus its development efforts on its weather satellites and weather forecasting mission. Under the new framework, NOAA will be responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts and warnings to protect life and property. NASA will be responsible for other nondefense Earth-observing satellite missions. The near-term impact of this revised framework is the transfer of responsibility for TSIS-1 and future ocean altimetry missions (following Jason-3, which remains a NOAA mission) to NASA beginning in FY 2016. Geostationary and polar-orbiting weather satellites, radio occultation satellites, and space weather satellites remain within the NOAA budget.

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

In 2013, the NASA Suomi National Polar-orbiting Partnership (NPP) Science Team completed its evaluation of the quality and suitability for Earth system science and applications of the raw data records, sensor data records and environmental data records produced by the JPSS Program. The science team recommended specific modifications, improvements, and/or new products that would yield science-quality standard data products to ensure the continuity of essential data records for the land, ocean, and atmosphere. In 2014, NASA re-competed the Suomi NPP Science Team and focused the call for proposals on the needed research to develop and implement these modifications, improvements, and new products. Specifically, NASA called for proposals to develop the scientific algorithms and software necessary to create science-quality NASA Suomi NPP standard data products and other new data products. NASA also called for proposals to continue applications-relevant Suomi NPP research.

The peer review and selection was completed and the new Suomi-NPP Science Team announced in August 2014. The new science team consists of 40 investigations. These investigations are now getting underway, and some of the new NASA standard products will become available in the first year while others will take longer to develop.

OTHER MISSIONS AND DATA ANALYSIS

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 OSTM mission science team made 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 resulted from combining precision altimetry, tide gauges, and sea surface temperature data with a novel mathematical technique. This has enabled estimation of trends in sea level from natural and anthropogenic forcing. The global mean sea level curve completely recovered from the two-year dip (2011 to 2012) caused by El Niño-Southern Oscillation and is now back to an upward trend.

EARTH OBSERVATION SYSTEMS (EOS) RESEARCH

Earth Observation Systems (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

The Terra mission continues to increase our understanding of volcanic processes through the imaging of more than 1,500 active volcanoes, allowing chemical analysis of ash plumes from those that are erupting, improving disaster response, and using the measurement results as inputs to understand the volcanic impacts on our climate. The impacts of wildfires, including their gaseous and particulate emissions, has been extensively studied by Terra scientists leading to the implementation of fire monitoring approaches by recently launched NOAA sensors. Coupling of earth radiation data from Terra's instruments has shown that the Earth has been steadily accumulating energy despite a reduction in the rate of global mean temperature rise.

Similarly, the Aqua mission continues to be extremely successful, with its products widely used by scientists, government agencies, and operational groups. In 2014, analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) aerosol observations has determined decreasing aerosol loading (improved air quality) over the United States and Western Europe but continued degradation of air quality in eastern Asia. Scientists have also used MODIS and Atmospheric Infrared Sounder (AIRS) data in the analysis of sources, sinks, and transatlantic transport of dust aerosols coming from North Africa.

The Aura science team was re-competed in FY 2014. The new selected investigations will focus on tropospheric and stratospheric photochemical processes, air quality, aerosol processes, atmospheric transport, cloud formation, and the coupling between atmospheric composition and climate.

The studies with ICESat and ESA's CryoSat-2 mission continue research on the global ice cover using the time series begun with NASA's ICESat satellite and continuing through the operational periods of NASA's IceBridge aircraft mission and CryoSat-2. The studies create long-term, integrated records of change in the polar ice sheets. Most importantly, they help us understand the physical processes that improve predictive models, especially for sea level rise estimates.

DEEP SPACE OBSERVATORY (DSCOVR)

The Deep Space Climate Observatory (DSCOVR) mission is a multi-agency (NOAA, United States Air Force [USAF], and NASA) mission 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 warming for adverse space weather events. NASA has delivered 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 has supported their integration. NASA will collect, archive, and disseminate the data from EPIC and NISTAR, and will 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 Space Exploration Technologies Corporation (SpaceX) Falcon 9 launch vehicle out of Cape Canaveral, FL.

Recent Achievements

The project successfully integrated the EPIC and NISTAR instruments onto the DSCOVR satellite. The DSCOVR satellite and all of its instruments have successfully undergone the full suite of environmental testing and comprehensive performance testing.

STRATOSPHERIC AEROSOL AND GAS EXPERIMENT III (SAGE-III)

Stratospheric Aerosol and Gas Experiment 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 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 ISS aboard one of NASA's first commercial SpaceX flights in 2016.

SAGE III experienced cost growth of more than 10 percent and is providing the following information pursuant to Section 521 of P.L. 113-235. In 2014, the SAGE III project began experiencing technical difficulties with the Interface Adaptor Module (IAM) and the Hexapod hardware development. The Hexapod, a European Space Agency (ESA) contribution, experienced a reboot anomaly during testing, and ESA took extensive time to conduct detailed fault tree analysis to seek root cause. During the same period, the IAM also experienced performance issues with the spacecraft bus communications, and the Ethernet data ISS interface for science data transfer. The bus anomaly required a complete re-design, development and qualification of a new board, and the Ethernet anomaly assessment is on-going at this time. Because of these technical problems, the SAGE III on ISS mission was de-manifested from SpaceX-6 (March 2015) and subsequently re-manifested on SpaceX-10 for a February 2016 launch. Such an extensive delay could not be accommodated within the previously planned budget. An additional

$12M has been added to the project budget to ensure all technical issues are resolved, and to accommodate the resulting launch delay. The SAGE III total life cycle cost is now $133M.

The ESM Program Office has increased monitoring of the project's performance against the revised cost and schedule plan, and has arranged support from technical experts from other NASA centers to assist the project in resolving the remaining technical difficulties. The SAGE III project will present a revised project plan, including plans to resolve all outstanding technical issues, and updated cost and schedule estimates, to SMD management in March 2015.

Recent Achievements

The project completed refurbishment of the SAGE III instrument, and development of the Disturbance Monitoring Package and Nadir Viewing Platform. The project commenced initial integration and testing of these elements.

SUSTAINABLE LAND IMAGING

NASA successfully launched the NASA/USGS Landsat Data Continuity Mission (LDCM)/Landsat 8 mission in February 2013. The USGS has fully commissioned Landsat 8, and it continues the 42-year record of moderate-resolution, multi-spectral measurements of all of the Earth's global landmasses. Landsat 8 provides high-accuracy, stable, well calibrated, measurements in the visible, near- and short-wave infrared, and the thermal infrared bands. These data support a broad range of users with monitoring and change/trend detection needs including land cover/land use change, crop and vegetation health, and – especially in the western US – essential high-resolution, regional-extent monitoring of evapotranspiration and water use, made possible by high-quality measurements in the thermal infrared band.

The Administration's Sustainable Land Imaging (SLI) program enables the development of a multi-decade, spaceborne system that will provide US users with high-quality, global, land-imaging measurements that are compatible with the existing 42-year record; that will address near- and longer-term issues of continuity risk; and that will evolve flexibly and responsibly through investment in, and introduction of, new sensor and system technologies.

Under the SLI program, NASA and USGS will continue to work together to ensure sustained access to land remote-sensing observations for U.S. research and operational users. The proposed plan reflects focused study and collaboration between NASA and USGS in developing program strategy and architecture, identifying user needs, and defining mission requirements. NASA will maintain responsibility for developing, launching and checking out space systems. The USGS will be responsible for developing the associated ground systems, operating the on-orbit spacecraft, and collecting, archiving, processing and distributing SLI system data to users.

The multi-decadal US Sustainable Land Imaging (SLI) system involves three NASA mission/development activities:

- Thermal-Infrared Free-Flyer (TIR-FF) for launch as soon as feasible, likely in 2019. The TIR-FF mission addresses the greatest near-term continuity risk in the present Landsat system, by developing and launching a rapid, low-cost, focused Thermal Infrared mission to fly in formation with either Landsat 8 or an international partner land imaging satellite such as the upcoming European Sentinel 2A (to be launched in April 2015). Analyses of the present US Landsat orbiting assets (Landsat 7 and Landsat 8) and international partner plans show clearly that thermal infrared measurements are at greatest risk for data gaps. Landsat 7 (launched in 1999) will run out of fuel by 2019, the Thermal Infrared Sensor (TIRS) instrument on Landsat 8 has a 3-year design lifetime, and no planned international partner missions include thermal infrared measurement capabilities. The TIR-FF mission will utilize mature, available infrared instruments along with a basic imager for cloud detection and to aid in the generation of combined products that overlay the measurements from TIR-FF and its formation-flying companion mission. Formation-flying techniques developed and demonstrated for more than a decade by NASA with the "A-Train" constellation of (now six) spacecraft will allow near-simultaneous measurements to be obtained from the TIR-FF and either Landsat 8 or an international partner mission such as the European Sentinel 2A.

- Landsat 9 as a fully Class-B rebuild of Landsat 8, for launch in 2023. Instrument procurement and mission design for Landsat 9 will begin immediately in FY 2015, with a target launch date in early 2023. This mission will substantially be a re-build of Landsat 8, including necessary upgrades to make both instruments – the moderate-resolution Operational Land Imager (OLI) multispectral sensor and the TIRS— Class-B (5-year design life with fuel for at least 10 years on-orbit operations), and to fix small design flaws in one of the Landsat 8 TIRS channels. Landsat 8 designs and subsystems will be used to the extent possible to minimize cost, schedule, and risk. However, the upgraded Class-B TIRS instrument for Landsat 9 will likely require additional refinements to the spacecraft design. The budget supports an immediate start on the instrument development and mission design with instrument deliveries in 2020. NASA will minimize mission costs and schedule risks by beginning spacecraft procurement/development in FY 2017, following instrument maturation. A NASA-provided launch vehicle will launch Landsat 9. Landsat 9 data will be fully compatible with Landsat 8 processing systems and standard measurement products.
- Land Imaging Technology and System Innovation. The overall SLI system includes an essential, sustained, multi-year technology development and system innovation activity to ensure that NASA can identify, mature, and test new measurement and processing approaches sufficiently early to inform design decisions and their use for future Landsat missions such as Landsat 10. The SLI budget supports annual technology development investments (the SLI Technology and System Innovation activity) focused on current NASA investigations in land imaging instruments and systems and programmatic activities. At the component/technology level investigations will include focal plane technology to support wide-swath, moderate resolution imagery for multispectral and hyperspectral instruments including thermal hyperspectral measurements. At the system level, investigations will include instrument miniaturization approaches to meet program observing objectives with smaller, less expensive satellites, along with integrated instrument approaches combining visible/near-infrared and thermal infrared channels. At the programmatic level, investigations will focus on commercial and hybrid commercial/governmental procurement and management approaches, as well as integration of multiple data sets from an open array of satellite observations to create a seamless land imaging archive for the user, including TIR-FF + Sentinel or TIR-FF+Landsat 8. In the near term, FY 2015 to FY 2018, the SLI Technology and System Innovation work will inform the design and configuration for Landsat 10.
- To minimize the risk of gaps while taking advantage of cost savings and capability enhancements owing to the technology development activity outlined above, NASA will make key strategic decisions on Landsat 10 payload/instrument approaches by the end of the decade, with the goal of beginning development of the Landsat 10 mission prior to the launch of Landsat 9.

OTHER MISSIONS AND DATA ANALYSIS

The Administration's plan supports a development schedule that minimizes technical risks and provides the opportunity to mature technologies that could be used in future Landsat missions—all within a funding profile that is sustainable with the proposed Earth science budget. Additionally, the Administration's plan is explicitly cognizant of planned international land imaging missions. Activities support efforts to minimize costs and maximize the overall utility for US users by engaging responsibly with international partners to ensure access to high-quality data and fusion of those measurements with those from the US Landsat missions. In particular, NASA conducted pre-launch cross-calibration investigations with the European developers of the Sentinel 2A/B land imaging system, ensuring uniform calibration of both Landsat 8 and Sentinel 2A/B instruments to the same standards. The USGS, supported by NASA and other agencies, is serving as the primary US Government point of contact to ensure access to, and archiving of, Sentinel 2 data products for US research and operational users. In late FY 2014, NASA released a competitive research solicitation for investigations aimed at developing and testing merged products derived from multiple land imaging systems (such as Landsat 8 and Sentinel 2A); selections will be determined in FY 2015.

EARTH FROM ISS

NASA's ISS Program sponsored the development of several Earth science instruments for the ISS. The Earth from ISS project ensures that the data collected by these instruments is processed appropriately and made available to the Earth Science research community. This project will invest in algorithm development, data production, distribution, and analysis and modeling for the four currently planned ISS Earth science payloads:

- The ISS Hyperspectral Imager for the Coastal Ocean (HICO) is an imaging spectrometer, and is the first space borne imaging spectrometer designed to sample the coastal ocean. Originally developed and operated by the Naval Research Laboratory, and launched to the ISS in 2009, HEOMD now operates HICO. The Earth from ISS project will manage ISS-HICO data acquisition, algorithm refinement, processing, and visualization software, as well as data archive and distribution within NASA GSFC's Ocean Biology Processing Group and Ocean Biology Distributed Active Archive Center (DAAC).
- ISS-RapidScat, installed on ISS in October 2014, is a space-based scatterometer that replaces the inoperable SeaWinds payload aboard the Quick Scatterometer (QuikSCAT) satellite. Scatterometers are radar instruments that measure wind speed and direction over the ocean, and are useful for weather forecasting, hurricane monitoring, and observations of large-scale climate phenomena such as El Niño. The ISS RapidScat instrument enhances measurements from other international scatterometers by crosschecking their data, and demonstrates a unique way to replace an instrument aboard an aging satellite. The RapidScat instrument used spare parts from QuikSCAT to provide a demonstration of the earth observing capabilities of the ISS as a platform for Earth Observations.
- The ISS Cloud Aerosol Transport System (CATS) instrument will collect data useful for improving our understanding of aerosol and cloud properties and interactions. In addition, the project will use data from CATS to advance operational aerosol forecast models to improve air quality prediction and monitoring and to improve hazard-warning capabilities for natural events (e.g., dust storms and volcanic eruptions). NASA plans to launch CATS in December 2014.
- The ISS Lightning Imaging Sensor (LIS) will make space-based lightning observations, and will provide important continuity in the lightning data record once the LIS instrument operating on the TRMM spacecraft is no longer functioning. LIS observations continue to support and used by the

global scientific research community across a wide range of disciplines that include weather and extreme storms, climate studies, atmospheric chemistry, and lightning physics. NASA plans to launch ISS-LIS in February 2016.

Recent Achievements

The RapidScat instrument arrived at the ISS on a SpaceX resupply mission in September 2014. The ISS arm took RapidScat from the space capsule and attached it to the ISS. The first uncalibrated but clearly functioning observations were available within 10 days. The project made a first pass at calibration and the data are available to a broader calibration/validation team to for assessment.

In FY 2014, the level zero and one CATS algorithms were completed and tested. The Environmental Protection Agency (EPA) conducted a study on the feasibility of using HICO's hyperspectral data to allow coastal ecosystem researchers to observe water quality in near real time, instead of having to send scientists into the field. However, in September 2014 the HICO computer experienced an upset, preventing communications to the instrument. The NRL is working to resolve this problem.

NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR)

Using advanced radar imaging that will provide an unprecedented, detailed view of Earth, the NISAR satellite is designed to observe and take measurements of some of the planet's most complex processes, including ecosystem disturbances, ice-sheet collapse, and natural hazards such as earthquakes, tsunamis, volcanoes and landslides.

Data collected from NISAR will reveal information about the evolution and state of Earth's crust, help scientists better understand our planet's processes and changing climate, and aid future resource and hazard management. The mission is a partnership between NASA and ISRO.

Recent Achievements

The L-band SAR mission study team completed a successful Mission Concept Review (MCR) at JPL in October 2013. The team successfully completed KDP-A gate review by the Science Mission Directorate Program Management Council (DPMC) members and entered the Formulation phase (Phase A) starting May 1, 2014. The Implementation Arrangement for NISAR has been coordinated and negotiated successfully with ISRO and the NASA Administrator and the ISRO Chairman signed the document on Sep 30, 2014.

PRE-AEROSOL, CLOUDS, AND OCEAN ECOSYSTEM (PACE)

The Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) mission will make global ocean color measurements essential for understanding the carbon cycle and how it both affects and is affected by climate change, along with polarimetry measurements to provide extended data records on clouds and aerosols. New and continuing global observations of ocean ecology, biology, and chemistry are required to quantify aquatic carbon storage and ecosystem function in response to human activities and natural events. The PACE mission will serve to make these measurements until the readiness of the more advanced Aerosol, Cloud, and Ecosystems (ACE) mission recommended by the National Academies Decadal Survey for its Tier 2 mission set.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

The PACE Project has been directed to Goddard Space Flight Center and is preparing to begin formulation activities.

TSIS-1

NASA now has responsibility for the Total and Spectral Solar Irradiance Sensor-1 (TSIS-1). The TSIS-1 mission will provide absolute measurements of the total solar irradiance (TSI) and spectral solar irradiance (SSI), important for accurate scientific models of climate change and solar variability. TSIS is comprised of two instruments, the Total Irradiance Monitor (TIM), and the Spectral Irradiance Monitor (SIM). Both instruments are in storage at the University of Colorado's Laboratory for Atmospheric and Space Physics awaiting flight. Currently, the data from an earlier NASA-managed TIM instrument, flying on the aging SORCE spacecraft, launched in 2003, provides the TSI data record as part of an unbroken 35-year long data record. The Total Solar Irradiance Calibration Transfer Experiment (TCTE) instrument, a joint mission with NOAA and the U.S. Air Force, launched in 2013 and currently augments the data record. The TSIS-1 project will begin formulation in FY 2016 and is planning for launch in time to overlap with the TCTE mission in order to maintain continuity of the solar irradiance measurement. NASA intends to fly TSIS-1 on the International Space Station by 2018.

TSIS-2

The TSIS-2 will be the follow-on instrument to the TSIS-1 instrument. The TSIS-2 instrument will maintain and extend the measurements of total solar irradiance and spectral solar irradiance provided by TSIS-1. TSIS-2 is a mission of opportunity, to be ready for integration onto a host spacecraft by January 2020. The TSIS-2 project will begin formulation in FY 2016.

EARTH RADIATION BUDGET SCIENCE (ERBS)

The goal of the Earth Radiation Budget Science (ERBS) Project is to produce climate data records of Earth's radiation budget and the associated cloud, aerosol and surface properties. The Project utilizes data from the multiple radiation budget instruments in orbit as well as ancillary measurements to produce data products, which are integrated and self-consistent over the entire suite of radiation budget instruments. In addition to the five currently operating Clouds and the Earth's Radiant Energy (CERES) instruments measuring broadband radiative fluxes from the Terra, Aqua, and Suomi-NPP platforms, the data products utilize coincident imager measurements from Terra, Aqua and Suomi NPP, and operational geostationary satellite observations. In total, 13 instruments on eight spacecraft produce an accurate and temporally consistent description of the radiation budget, not only at the top of the atmosphere but also at the surface and within the atmosphere.

Recent Achievements

The project currently produces 18 different data products. The algorithms the data products are based upon and the associated validation results are documented in peer-reviewed journals, conference presentations, and data quality summaries. The estimated number of peer-reviewed publications using CERES data is currently about 821, and these papers have received approximately 24,000 citations. Download statistics suggest that there are about 600 unique users of the current CERES data products.

OTHER MISSIONS AND DATA ANALYSIS

RADIATION BUDGET INSTRUMENT (RBI; PREVIOUSLY ROAM)

Radiation Budget Instrument (RBI) will fly on the Joint Polar Satellite System 2 (JPSS-2) mission planned for launch in November 2021, and will extend the unique global climate measurements of the Earth's radiation budget provided by the Clouds and the Earth's Radiant Energy Systems (CERES) instruments since 1998. Observations from RBI will help measure the effect of clouds on the Earth's energy balance, which strongly influences both weather and climate. Long-term satellite data from RBI will help scientists and researchers understand the links between the Earth's incoming and outgoing energy, and properties of the atmosphere that affect it. The data from RBI will provide fundamental inputs to extended range (10-day or longer) weather forecasting, and used to develop a quantitative understanding of the links between Earth's radiation budget and the properties of the atmosphere and surface that define that budget.

Recent Achievements

NASA selected Exelis Corp, of Ft. Wayne, IN, under an open competitive process as the vendor to build RBI, with the project managed by NASA LaRC.

OZONE MAPPING AND PROFILER SUITE-LIMB PROFILER (OMPS-LIMB)

The advanced Ozone Mapping and Profiler Suite (OMPS) tracks the health of the ozone layer and measures the concentration of ozone in the Earth's atmosphere. OMPS consists of three spectrometers: a downward-looking nadir mapper, nadir profiler, and limb profiler. The entire OMPS suite currently operates on the Suomi NPP spacecraft, and to ensure data continuity, a copy of this suite will fly on NOAA's Joint Polar Satellite System 2 (JPSS-2) mission. NASA is responsible for providing the OMPS-Limb profiler for integration on the OMPS instrument.

Recent Achievements

NASA awarded a contract to Ball Aerospace & Technologies Corp. for the OMPS instrument, including the limb sensor.

ALTIMETRY FOLLOW-ON

The Altimetry Follow-On (AFO) mission will continue ocean altimetry measurements beyond the Jason-3 mission that NOAA is pursuing in partnership with EUMETSAT and the French Centre National d'Etudes' Spatiales (CNES). The AFO project will begin formulation in FY 2016.

CLARREO PATHFINDER

The 2007 National Academies Earth Science Decadal Survey recommended the Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission as a Tier 1 mission that would be a key component of the future climate observing system. The CLARREO Pathfinder mission will demonstrate essential measurement technologies; validate the high accuracy radiometry required for long-term climate studies in support of other Decadal Survey and land imaging missions; and initiate measurements that will benchmark the shortwave reflectance and infrared climate record. NASA plans to host the two

CLARREO Pathfinder instruments, Reflected Solar (RS) and Infrared (IR) spectrometers, on the International Space Station in FY 2019.

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 in a pre-formulation phase conducting mission concept studies. The current portfolio of missions under study includes:

- CLARREO;
- Active Sensing of CO2 Emissions over Nights, Days, and Seasons (ASCENDS);
- GEOstationary Coastal and Air Pollution Events (GEO-CAPE);
- ACE; and
- HyspIRI.

Recent Achievements

Mission teams continue to make progress in requirements refinement and modeling, instrument concept and technology maturation, and algorithm development. Several mission teams, such as HyspIRI and ASCENDS, conducted airborne campaigns in 2014 to demonstrate measurement techniques and make further progress in algorithm 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; and
- SRB teams, who conduct independent reviews of the various flight projects in Earth Science.

PRECIPITATION SCIENCE TEAM

The Precipitation Science Team carries out investigations of precipitation using measurements from, but not limited to, TRMM launched in November 1997 and nearing its end of life, the GPM Core Observatory launched February 2014, and GPM mission constellation partner spacecraft (partners include NOAA, DoD, CNES, JAXA and EUMETSAT). This program supports scientific investigations in three research categories:

- Development, evaluation, and validation of TRMM and GPM retrieval algorithms;
- Development of methodologies for improved application of satellite measurements; and

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- Use of satellite and ground measurements for physical process studies to gain a better understanding of the global water cycle, climate, and weather and concomitant improvements in numerical models on cloud resolving to climate scales.

Recent Achievements

The GPM mission is setting a new standard for precipitation measurements from space. GPM has advanced capabilities significantly beyond the TRMM spacecraft. These enhanced capabilities allow for expanding the types of precipitation measured, most notably light rain, and snowfall. Light rain and falling snow account for about half of the precipitation in temperate mid-latitudes and cold high latitudes and are major contributors to freshwater resources in places like the United Kingdom and northern Europe, the southern Appalachian Mountains and the snow packs of the Rocky Mountains and the Sierra Nevada. In the future, it will be increasingly important to measure not only extreme precipitation or droughts but also blizzards and light rain, to understand the atmospheric water cycle and how it might be changing.

OCEAN WINDS SCIENCE TEAM

Ocean Winds Science Team (OWST) uses scientific data received from the QuikSCAT satellite, RapidScat instrument, and other international missions, which measure ocean surface winds by sensing ripples caused by winds at the ocean's surface. From this data, scientists can compute wind speed and direction thus acquiring global observations of surface wind velocity each day. The sparse wind data from ships and buoys serve to calibrate the satellite data.

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 has recently produced a specialized data set characterizing scatterometer winds in tropical cyclone (high wind) conditions during the entire satellite record. The primary use of near-real time QuikSCAT data continues to be calibration of OSCAT (Indian scatterometer data) and RapidScat to extend the Ku-band wind climate record.

LAND COVER PROJECT SCIENCE OFFICE (LCPSO)

The Land Cover Project Science Office (LCPSO) maintains over 40 years of calibration records for the Landsat 1 through Landsat 8 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.

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Recent Achievements

During FY 2014, the LCPSO focused on several activities geared toward improving the quality and quantity of remote sensing data available to the scientific community. The project made plans to cross-calibrate Landsat with the upcoming ESA Sentinel-2 data streams, and include the development of improved land cover products using the merged data streams. LCPSO deployed a Landsat 8 surface reflectance product in collaboration with USGS, and continued the provision of commercial imagery from the National Geospatial Intelligence Agency archives.

More information on Landsat science is at http://landsat.gsfc.nasa.gov.

Operating Missions

QUICK SCATTEROMETER (QUIKSCAT)

The QuikSCAT mission carries the SeaWinds instrument, originally designed for measuring ocean surface wind speeds 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 will conduct cross-calibration operations with the recently launched ISS-RapidScat to enable continuation of a climate-quality ocean wind vectors dataset; the mission will then end its extended operations and complete closeout, reprocessing, and documentation of the archival dataset by the end of FY 2015.

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, but in July 2014, the dwindling TRMM satellite fuel supply could no longer support orbit maintenance. The satellite has begun to descend and NASA expects it to re-enter late in FY 2015. Activities in FY 2016 will include a final mission report, reprocessing and documentation of the science dataset for archival and transition of the precipitation climate record to GPM.

Recent Achievements

TRMM has nearly completed its 17th year of operations, extending its long-term record of rainfall in the tropics. TRMM continued to provide data on tropical cyclones and heavy rainfall events, including such major storm events as hurricanes Arthur (US), Gonzalo (Bermuda), and Odile (Mexico); super typhoon Haiyan (Philippines); and other major rainfall events in the US, the Philippines, and elsewhere. NASA expects TRMM to provide a little more than one year of overlap with GPM.

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GLOBAL PRECIPITATION MEASUREMENT (GPM)

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
- 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.

Recent Achievements

The GPM Core Observatory successfully launched from Tanegashima Space Center, Japan, on February 27, 2014. The project conducted on-orbit checkout of spacecraft and instruments from launch through May 2014, with first light images from both instruments released on March 25, 2014. The mission transitioned to routine operations on May 29, 2014 and the first public release of data was June 2014 in time for the Atlantic Hurricane season, with final public release of data September 4, 2014. One of the first storms observed by GPM on March 17, 2014, in the eastern United States showed the full range of precipitation from heavy rain to light rain and falling snow. Heavy rains fell in the ocean off the North and South Carolina coasts. As the storm moved northward, GPM observed falling snow over West Virginia, Virginia, Maryland, and Washington. The GPM Microwave Imager observed an 547 mile- (880 kilometer) wide track of precipitation on the surface, while the DPR imaged every 820 feet (250 meters) vertically to get the three-dimensional structure of the rain and snowfall layer by layer inside the clouds.

LANDSAT DATA CONTINUITY MISSION (LDCM)

Landsat Data Continuity Mission (LDCM) (also known as Landsat 8) is the most recent 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 has contributed 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 US and global economies. USGS performs mission operations for Landsat 8, but NASA will provide science activities in support of the USGS and the Landsat Science Team for the period of prime mission operations.

Recent Achievements

Landsat 8 mission data are widely used by scientists, government agencies, and private organizations. Although operated by the USGS, NASA remains actively involved with Landsat 8 instrument

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characterization, calibration, and data quality evaluation. The only significant issue with Landsat 8 performance results from stray light in the thermal infrared imaging sensor, which causes uncertainty up to several degrees in certain situations. The NASA effort has led to an understanding of this stray light issue and development of an algorithm to correct the data and bring results back to the required accuracy. The project is currently implanting this algorithm in a test environment to evaluate it on numerous Landsat scenes with a goal of operational implementation in spring 2015. An additional key effort of the joint NASA-USGS calibration team is documentation of the Landsat 8 performance in the refereed scientific literature. The calibration effort is integral to extending the four-decade-long time series of observations documenting forest disturbance, glacial dynamics, urban expansion, fresh water consumption, food production, and a host of additional global land cover and land use changes. Further, NASA continues to engage the public to communicate the societal benefits of sustained land imaging.

OCEAN SURFACE TOPOGRAPHY MISSION (OSTM)

The Ocean Surface Topography Mission (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.

Recent Achievements

OSTM has played a unique and pivotal role in extending the climate record of global sea level that is the foundation of the IPCC's assessment of modern sea level change and its geographic variability. The 20-year record of Topex/Poseidon, Jason1, and OSTM has enabled global geographical reconstruction of sea level during pre-satellite times. This result is instrumental to the understanding of the multi-decadal variability of sea level.

The combination of OSTM with GRACE has demonstrated consistency with in-situ Argo data for understanding the causes of sea level change and relation to ocean heat storage. This promises an unprecedented space borne sea level and ocean heat observing system.

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. Last year NASA and NOAA established a joint review process to ensure that the mission continues to meet both agencies' objectives; both agencies are planning for the second annual review in February 2015. 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

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atmospheric composition, climate variability and change, carbon cycle, ecosystems, water and energy cycles, and weather.

Recent Achievements

Suomi NPP data is publicly available from NOAA, and the National Weather Service uses it 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 operational system. Their findings indicate that for most Earth observations, the Suomi NPP instruments are making quality measurements and the Science Team was re-competed in ROSES 2014 with the goal of producing data products suitable for Earth system science and applications. The Visible Infrared Imaging Radiometer (VIIRS) Calibration Support Team has completed a set of time-dependent VIIRS calibration coefficients. These coefficients enable the three VIIRS discipline-based computing facilities to create consistent data sets. The OMPS-Limb team has reprocessed the ozone and aerosol profile data products and is distributing the data to users through their Web site: http://ozoneaq.gsfc.nasa.gov/omps/.

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.

Recent Achievements

Terra¹s value continues to increase heading into its 15th year of operation with five healthy and well-calibrated instruments. Recent collaborations amongst the instrument teams resulted in similar products from the sensors agreeing to within 1 percent of each other. The data quality allowed for improvements in data latency and near real-time data; a large and diverse user community uses the data in applied research, numerical weather forecasting, health, and environmental monitoring. Usage of Terra data has increased as much as 30 percent for individual sensors and numbers of users have increased by more than 10 percent.

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.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

Hundreds of scientists around the world use Aqua data, and scientific citations of Aqua data now exceed 20,000. Among the many recent major scientific achievements during the period of the CERES record, Aqua data shows that there has been a 5 percent increase in absorbed solar radiation over the Arctic Ocean, closely tied to the coincident decline in Arctic sea ice and prominent seasonal drawdown of atmospheric carbon dioxide over highly vegetated areas. The Aqua data are also used for a variety of practical applications, including routine incorporation in NOAA and other weather forecast models; use of MODIS data to monitor forest fires in the US and elsewhere; use of MODIS ocean color products in operational monitoring of water quality including significant harmful algal blooms in western Lake Erie in the summer of 2014; and imaging of hurricanes around the world, including Super Typhoon Haiyan as it approached and then devastated the Philippines a year ago. AIRS continues to produce the highest impact to operational forecasts of any single satellite instrument and is currently the most downloaded data set for climate model validation as part of the Observations for Model Intercomparison Projects program. MODIS snow cover mapping at regional and global scales is invaluable for subsequent stream-flow and stream-discharge monitoring worldwide.

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

Data from Aura's Ozone Monitoring Instrument (OMI) reveal significant trends in near-surface nitrogen dioxide, one of the six common pollutants regulated by the EPA to protect human health. The gas comes primarily from combustion of gasoline in vehicle engines and of coal in power plants, and is a good proxy for the presence of air pollution. The decade-long time series reveals substantial decreases in this pollutant throughout the United States, especially in densely populated areas of the East Coast. Regulations, technology improvements, and economic changes are potentially responsible for the decrease, which is notable considering that the population and the number of cars on the roads have both increased. The global OMI data also show improvements in air quality in Europe, but pollutant levels in East Asia have continued to rise. Researchers use data from OMI and other Aura instruments to assess the global change in pollutants and the importance of changes in pollutants like tropospheric ozone to climate change.

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 and preliminarily through 2017, but it recognized that the satellite's aging batteries were highly degraded and that it might not survive past 2015. The next senior review will occur in 2015, and will re-evaluate the SORCE 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 SORCE mission reconfigured its operational modes to accommodate its degraded batteries and was able to resume daily operations in late February 2014. It has successfully achieved cross-calibration with the Total solar irradiance Calibration Transfer Experiment, to ensure the continuation of the 36-year Total Solar Irradiance climate data record. The project reprocessed improved versions of the Spectral Irradiance Monitor and Solar Radiation and Climate Experiment Comparison Experiment datasets and released them to the community to support the 2013 Senior Review-directed reconciliation of Solar Spectral Irradiance measurements.

EARTH OBSERVING-1 (EO-1)

The Earth Observing-1 (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. However, based on orbit predictions (the EO-1 satellite has been out of fuel for orbit maintenance since 2011), NASA has found that operations beyond 2015 would not be of sufficient quality for Earth imaging due to low sun angle. NASA plans to decommission the EO-1 mission on September 30, 2015; mission closeout; final reporting and final processing and documentation of the archival science dataset will occur in FY 2016.

Recent Achievements

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. The mission science team also developed experimental data products using the EO-1 sensors to support the Sustainable Land Imaging architecture study.

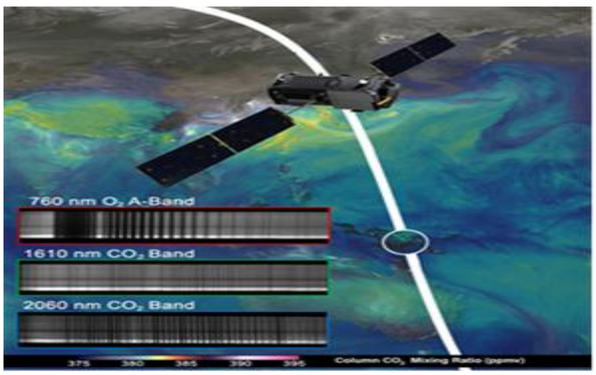
EARTH SYSTEM SCIENCE PATHFINDER

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Venture Class Missions	163.1	--	**185.2**	200.1	200.6	190.0	192.6
Other Missions and Data Analysis	94.3	--	**82.5**	72.7	54.8	48.7	52.1
Total Budget	**257.4**	--	**267.7**	**272.8**	**255.4**	**238.7**	**244.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



NASA's OCO-2 spacecraft collected "first light" data August 6, 2014 over New Guinea. OCO-2's spectrometers recorded the bar code-like spectra, or chemical signatures, of molecular oxygen or carbon dioxide in the atmosphere. The backdrop is a simulation of carbon dioxide created from GEOS-5 model data.

The Earth System Science Pathfinder (ESSP) program provides frequent, regular, competitively selected Earth science research 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 US 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The request enables NASA to develop and assemble an OCO-3 instrument using spare materials from OCO-2, and host the instrument on the International Space Station.

VENTURE CLASS MISSIONS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	163.1	--	185.2	200.1	200.6	190.0	192.6

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The Hurricane and Severe Storm Sentinel, one of five Earth Venture Suborbital missions, uses airborne observations to improve understanding of how hurricanes form and intensify. This photo shows the NASA Global Hawk returning to Wallops Flight Facility at sunrise, after completing its fourth and final overflight of Hurricane Edouard. During the 2014 campaign, the Global Hawk flew 236 hours over 10 science flights above three tropical cyclones and released 649 dropsondes above Hurricane Gonzalo.

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. NASA caps each solicitation at $150 million in FY 2014 dollars, and selects multiple investigations within each call, individually 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) will fly on space-borne platforms, which NASA will select. Each solicitation is cost capped at $90 million in FY 2014 dollars. NASA will release EVI solicitations at no more than 18-month intervals.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

VENTURE CLASS MISSIONS

ACHIEVEMENTS IN FY 2014

In July 2014, NASA selected ECOSTRESS and GEDI as the culmination of the second Earth Venture Instrument (EVI-2) Announcement of Opportunity.

All of the investigations for EVS-1 conducted data collection and data analysis during FY 2014. The Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality (DISCOVER-AQ) and Hurricane and Severe Storm Sentinel (HS3) missions completed their final airborne data collection during FY 2014. The Airborne Tropical TRopopause EXperiment (ATTREX), Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE), and Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) missions completed their FY 2014 airborne campaigns and will continue to collect data in FY 2015. ATTREX completed over 100 science flight hours in the NASA Global Hawk. Each investigation collected approximately 200 hours of science data over the course of the campaign year.

NASA approved the Tropospheric Emissions: Monitoring of Pollution (TEMPO) mission to proceed into Phase B of formulation. Additionally, NASA made the formal decision to use the Space and Missile Systems Center Hosted Payload Solutions contract to obtain hosting services for TEMPO. In July 2014, NASA awarded three study tasks to Boeing, OSC, and Space Systems/Loral on this contract to provide specific feedback on TEMPO hosting.

Cyclone Global Navigation Satellite System (CYGNSS) successfully completed Preliminary Design Review and NASA confirmed the project to enter into implementation at its KDP-C confirmation review.

WORK IN PROGRESS IN FY 2015

TEMPO prepared for its KDP-C review and confirmation to proceed into implementation. The Project expects the final Hosted Payload Solutions RFP release in the second quarter and the hosting award in the fourth quarter. CYGNSS completed CDR and is preparing to transition to Phase D of implementation.

For EVS-1, the ATTREX, CARVE, and AirMOSS missions will continue airborne data collection while the remainder will focus on scientific analysis, reporting and mission close out activities. The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) and Global Ecosystem Dynamics Investigation Lidar (GEDI) projects from the EVI-2 selection entered Phase A of formulation. Both instruments will fly on the ISS. NASA will announce the EVS-2 solicitation selections and release the EVI-3 solicitation.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, TEMPO plans to hold Mission Assessment Review. CYGNSS will complete its integration and testing and prepare for its October 2017 launch.

Early in the first quarter of FY 2016, NASA plans to conduct a KDP-C review for ECOSTRESS to evaluate the Project for authority to proceed from formulation, Phase B into implementation, Phase C/D.

VENTURE CLASS MISSIONS

Program Elements

CYGNSS (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 development and will launch in FY 2017.

CYGNSS's eight micro-satellite observatories will receive both direct and reflected signals from 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.

TEMPO (EVI-1, SELECTED IN 2012)

The TEMPO instrument will measure atmospheric pollution covering most of North America. The instrument will mount on a commercial communications satellite launching in 2018. 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 and nitrogen dioxide in the lowest part of the atmosphere. Measurements will be from geostationary 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 commercial host spacecraft through the USAF Space and Mission Command Hosted Payload Solutions contract.

ECOSYSTEM SPACEBORNE THERMAL RADIOMETER EXPERIMENT ON SPACE STATION (ECOSTRESS) (EVI-2, SELECTED IN 2014)

In July 2014, NASA selected ECOSTRESS as one of the new instruments in the Earth Venture Program that will observe changes in global vegetation from the International Space Station. The sensors will give scientists new ways to see how changes in climate or land use change affect forests and ecosystems. This project will use a high-resolution thermal infrared radiometer to measure plant evapotranspiration, the loss of water from growing leaves and evaporation from the soil. These data will reveal how ecosystems change with climate and provide a critical link between the water cycle and effectiveness of plant growth, both natural and agricultural.

ECOSTRESS will fill a key gap in our observing capability, advance core NASA and societal objectives, and allow NASA to address the following science objectives:

- Identify critical thresholds of water use and water stress in key climate sensitive biomes;
- Detect the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the daily cycle; and

- Measure agricultural water consumptive use over the contiguous United States at spatiotemporal scales applicable to improve drought estimation accuracy.

GLOBAL ECOSYSTEM DYNAMICS INVESTIGATION (GEDI) LIDAR (EVI-2, SELECTED IN 2014)

As one of the newly selected Earth Venture Instrument, GEDI will use a laser-based system to study a range of climates, including the observation of the forest canopy structure over the tropics, and the tundra in high northern latitudes. This data will help scientists better understand the changes in natural carbon storage within the carbon cycle from both human-influenced activities and natural climate variations. The instrument will be the first to systematically probe the depths of the forests from space by using a lidar instrument from the International Space Station and will provide a unique 3-D view of Earth's forests and provide information about their role in the carbon cycle. The Goddard Space Flight Center will build and manage the instrument.

EARTH VENTURE MANAGEMENT

The Earth Venture Management project provides for the development of Announcement of Opportunity (AO) solicitations and Technical and Management and Cost (TMC) evaluations of proposals received in response to the AO solicitations and Phase A concept studies. Additionally, this project supports Common Instrument Interface activities to identify a common set of Earth Science instrument-to-spacecraft interface guidelines that will improve the likelihood that these instruments can take advantage of future hosted payload opportunities.

VENTURE CLASS FUTURE MISSIONS

Earth Venture Class Future Mission funding supports future Earth Venture Suborbital, Earth Venture small Missions, and Earth Venture Instruments through Announcement of Opportunity solicitations.

EARTH VENTURE SUBORBITAL -1 (EVS-1; SELECTED IN 2010) INVESTIGATIONS INCLUDE:

- AirMOSS addresses the uncertainties in existing estimates by measuring soil moisture in the root zone of representative regions of major North American ecosystems;
- ATTREX studies chemical and physical processes at different times of year from bases in California and Guam;
- 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;
- DISCOVER-AQ improves the interpretation of satellite observations to diagnose near-surface conditions relating to air quality; and
- HS3 studies hurricanes in the Atlantic Ocean basin using two NASA Global Hawks flying high above the storms for up to 24 hours.

VENTURE CLASS MISSIONS

EARTH VENTURE SUBORBITAL -2 (EVS-2; SELECTED IN 2014) INVESTIGATIONS INCLUDE:

- Atmospheric Tomography explores the impact of human-produced air pollution on certain greenhouse gases. Airborne instruments will look at how various air pollutants affect atmospheric chemistry (including methane and ozone).
- North Atlantic Aerosols and Marine Ecosystems Study seeks to improve predictions of how ocean ecosystems would change with ocean warming. The mission will study the annual life cycle of phytoplankton, and the impact small airborne particles, composed of material derived from marine organisms, have on climate in the North Atlantic.
- Atmospheric Carbon and Transport-America quantifies the sources of regional carbon dioxide, methane and other gases, and documents how weather systems transport these gases in the atmosphere.
- Observations of Aerosols above Clouds and their Interactions investigates how smoke particles from massive biomass burning in Africa influences cloud cover over the Atlantic. Particles from this seasonal burning interact with permanent stratocumulus "climate radiators," which are critical to the regional and global climate system.
- Oceans Melting Greenland project studies the role of warmer, saltier Atlantic Ocean subsurface waters in Greenland glacier melting. The study will help pave the way for improved estimates of future sea level rise by observing changes in glacier melting where ice contacts seawater.

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
Dec 2014	TEMPO Confirmation Review
2016	EVI-5 (instrument) solicitation released
May 2017	CYGNSS launch readiness
2017	EVS-3 (suborbital) solicitation released
2018	EVI-6 (instrument) solicitation released
2019	EVM-3 (mission) solicitation released
2020	EVI-7 (instrument) solicitation released

Program Management & Commitments

The Earth System Science Pathfinder (ESSP) program manages Venture Class missions and investigations, and assigned responsibility for implementation to the ESSP Program Manager at LaRC.

Program Element	Provider
EVS-2: Atmospheric Tomography Experiment	Provider: Harvard College Lead Center: ARC Performing Center(s): LaRC, ARC, GSFC, AFRC Cost Share Partner(s): NOAA
EVS-2: North Atlantic Aerosols and Marine Ecosystems Study	Provider: Oregon State University Lead Center: LaRC Performing Center(s): LaRC, GSFC, ARC Cost Share Partner(s): N/A
EVS-2: Atmospheric Carbon and Transport-America	Provider: Pennsylvania State University Lead Center: LaRC Performing Center(s): LaRC, GSFC, JPL Cost Share Partner(s): N/A
EVS-2: Observations of Aerosols above Clouds and their Interactions	Provider: ARC Lead Center: ARC Performing Center(s): ARC, LaRC, GSFC, AFRC, JPL Cost Share Partner(s): University of Namibia
EVS-2: Oceans Melting Greenland	Provider: JPL Lead Center: JPL Performing Center(s): JPL, GSFC, AFRC Cost Share Partner(s): Danish National Space Institute, Stockholm University
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
EVI-2: ECOSTRESS	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): USDA

VENTURE CLASS MISSIONS

Program Element	Provider
EVI-2: GEDI	Provider: University of Maryland Lead Center: GSFC Performing Center(s): 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

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jun 2013	CYGNSS Mission Design Review	Project approved to enter Phase B of formulation	Jan 2014
Perform-ance	SRB	Jan 2014	CYGNSS PDR	Successful	Feb 2014
Perform-ance	SRB	Feb 2014	CYGNSS KDP-C Milestone Review	Project approved to enter development	Feb 2015
Perform-ance	SRB	Feb 2015	CYGNSS CDR	TBD	N/A
Perform-ance	SRB	Q4 FY 2016	CYGNSS ORR	TBD	N/A
Perform-ance	SRB	Apr 2014	KDP-B Milestone review to determine readiness of TEMPO to enter Phase B	Project approved to enter Phase B of formulation	Jul 2014

VENTURE CLASS MISSIONS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jul 2014	TEMPO Instrument PDR	Successful	Q1 FY 2015
Perform-ance	SRB	Q1 FY 2015	KDP-C Milestone Review to determine readiness of TEMPO to enter development	TBD	Jun 2017
Perform-ance	SRB	Q2 FY 2015	ECOSTRESS System Requirements Review/Mission Definition Review	TBD	Q3 FY 2015
Perform-ance	SRB	Q3 FY 2015	ECOSTRESS KDP-B	TBD	Q4 FY 2015
Perform-ance	SRB	Q4 FY 2015	ECOSTRESS PDR	TBD	TBD
Perform-ance	SRB	Jun 2017	TEMPO Instrument CDR	TBD	Q3 FY 2018
Perform-ance	SRB	Q3 FY 2018	TEMPO ORR		N/A
Perform-ance	SRB	2015	GEDI System Requirement Review/Mission Design Review		TBD

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
ESSP Missions Research	13.9	--	**13.9**	15.6	17.6	17.8	21.1
Orbiting Carbon Observatory-3	16.8	--	**33.1**	26.5	9.7	6.2	7.7
Aquarius	4.7	--	**5.5**	5.9	5.9	5.9	6.1
GRACE	5.3	--	**5.3**	3.2	2.3	1.3	0.0
Cloudsat -	8.7	--	**8.3**	4.2	4.1	0.0	0.0
Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)	6.8	--	**7.0**	7.1	7.1	7.1	7.2
OCO-2	38.2	--	**9.4**	10.2	8.1	10.4	10.0
Total Budget	**94.3**	**--**	**82.5**	**72.7**	**54.8**	**48.7**	**52.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

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

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 2014, CloudSat observations showed that current orbital land precipitation observations significantly underestimate light rain and snowfall, the most frequent types of global precipitation. CloudSat measurements helped link cloud vertical structure and large-scale meteorological parameters in global climate models. For example, data from CloudSat showed that in deep convection, the cloud's center of gravity, cloud top, and rain top all increase with increased aerosol loading.

OCO-3

The Orbiting Carbon Observatory 3 (OCO-3) is a space instrument that will investigate important questions about the distribution of carbon dioxide on Earth as it relates to growing urban populations and changing patterns of fossil fuel combustion. OCO-3 will explore, for the first time, daily variations in the release and uptake of carbon dioxide by plants and trees in the major tropical rainforests of South America, Africa, and South-East Asia, the largest stores of aboveground carbon on our planet. Measuring the daily variations in these major carbon systems addresses an important missing component in our knowledge and is crucial for explaining global variations in atmospheric carbon dioxide levels. NASA will develop and assemble the instrument using spare materials from OCO-2 and host the instrument on the International Space Station (expected launch date in late 2017).

Recent Achievements

OCO-3 passed its PDR in 2014 and is ready to proceed into development.

Operating Missions

OCO-2

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

From its vantage point in low Earth orbit, OCO-2 will measure the carbon dioxide levels across the globe, collecting data on how carbon dioxide is distributed. With this data, scientists will have better insight into how much of the Earth's carbon dioxide is from natural sources versus human activities, and into what processes are removing carbon dioxide from the atmosphere. This information may help decision makers determine the best ways to reduce human impact on the environment.

Recent Achievements

NASA successfully launched OCO-2 on July 2, 2014 from Vandenberg Air Force Base (VAFB), CA. The instrument is making high-precision measurements, and data processing is proceeding on schedule. The observatory is now the sixth member of the international constellation of Earth-observing satellites commonly referred to as the Afternoon Constellation, or "A-Train."

Initial data released from OCO-2 during instrument checkout in August 2014 included both carbon dioxide levels and Solar Induced Florescence data. OCO-2 officially entered its prime operations phase in October 2014. The project will formally release science data in the second quarter of FY 2015.

AQUARIUS

The Aquarius spacecraft observes and models seasonal and year-to-year variations of sea-surface salinity, and how those 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, operated by the Argentine space agency, Comisión Nacional de Actividades Espaciales. Aquarius launched in June 2011 and has just completed its prime operations phase. The project will hold an End-of-Prime Mission Review to verify achievement of the Level 1 Requirements in January 2015. NASA will evaluate the Aquarius mission as part of the 2015 Senior Review for 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 2014, Aquarius salinity measurements contributed to the ocean climate assessment. Monthly salinity maps from Aquarius data show detailed and robust seasonal variations in the tropics, providing new insights air-sea freshwater fluxes seasonal cycle. The most prominent surface salinity changes measured by Aquarius from 2012 to 2013 were freshening patterns in the western tropical Pacific warm pool and along a band in the South Pacific. These features are associated with anomalously strong precipitation in 2013, Upper Ocean cooling, and more eastward surface velocity change from 2012 to 2013. They also suggest influence of a slow down or southward shift of the South Equatorial Current.

In addition, approximately 30 research papers based on Aquarius data were accepted in the Journal of Geophysical Research [Oceans] Special Section "Early scientific results from the salinity measuring satellites Aquarius/SAC-D and SMOS," to be published in a special volume in 2015.

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 Aerospace 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 and University scientists analyzed observations from the GRACE mission to study temporal and spatial variations in surface loading, groundwater storage, and sea level. Research showed water storage associated with a large change in precipitation patterns over South America and in Australia could explain the 2011 drop in sea level. The GRACE measurements of soil moisture and underground water storage have provided insight on ground water storage trends caused by the current drought in the western United States. With the recent release of GRACE Level-2 Release-05 data products, produced with new and improved modeling, researchers will have an even better dataset to assess California's drought.

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.

Recent Achievements

CloudSat continues to provide unique, vertically resolved global observations of cloud and precipitation that are leading to a clearer understanding of how clouds influence Earth's climate. This improved understanding of the role of clouds in the Earth's climate system resulted in improvements in weather and climate models. NASA used CloudSat data directly in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment. Analysis of CloudSat data, combined with other A-Train satellite observations, gives a much clearer picture of how aerosols in the atmosphere affect clouds and precipitation. CloudSat is providing unique information about convection in the atmosphere and has provided the first global information on snowfall.

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

Cloud-Aerosol LIDAR and Infrared Pathfinder Satellite Observation (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.

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. 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

CALIPSO measurements helped advance our understanding of the geographical and vertical distribution of clouds over the globe and of how much water and ice they hold. From these findings during the past year, NASA gained new insight into the effects of aerosols on mixed-phase clouds, the coupling between clouds and large-scale atmospheric circulations, and characterization of weaknesses in how global models represent clouds.

EARTH SCIENCE MULTI-MISSION OPERATIONS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**179.0**	**--**	**190.7**	**192.5**	**193.7**	**192.4**	**195.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Modern Era Retrospective-analysis for Research and Applications (MERRA) Snow Mass data provides a multi-year time series showing the highs and lows of snowfall in the Sierra. Drought conditions in California have reduced the snowpack in the Sierras – which many Californians rely on for their water supply and agricultural irrigation – to a very low level. The time series shows that the snow mass in the Sierra Nevada Mountains varies year to year, and the low level this year is due to three straight years of below-average winter snow mass.

The Earth Science Multi-Mission Operations (MMO) program acquires, preserves, and distributes observational data from operating spacecraft to support Earth Science research focus areas. The Earth Observing System Data and Information System (EOSDIS), which has been in operations since 1994, primarily accomplishes this. 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 program supports the science data segment for Suomi NPP, as well as the data archive and distribution for the recently launched GPM and OCO-2 missions and the upcoming SMAP, CYGNSS, OCO-3 and ICESat-2 missions. EOSDIS data centers also support Earth Ventures 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://science.nasa.gov/earth-science/earth-science-data.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The MMO budget has been increased to support the archiving of expected new data sets from GRACE-FO, CYGNSS, Earth Science ISS payloads, and the European Sentinel missions, which will provide a range of data sets over the budget horizon, including radar and multi-spectral imaging instruments for land, ocean and atmospheric monitoring. In addition, the MMO budget increase will support management

EARTH SCIENCE MULTI-MISSION OPERATIONS

efforts associated with the Climate Data Initiative (CDI), the Big Earth Data Initiative (BEDI), and the Climate Resilience Toolkit (CRT).

ACHIEVEMENTS IN FY 2014

EOSDIS expanded its capabilities to accommodate the GPM and OCO-2 missions. The Advancing Collaborative Connections for Earth System Science (ACCESS) program selected 12 projects that will be exploring various techniques for improving access to NASA Earth science data. The EOSDIS architecture hosts a new Sea Level Change portal. The Sea Level Change web portal provides scientists and the public with current sea level change information and data, including interactive tools for accessing and viewing regional data, a virtual dashboard of sea level indicators, and ongoing updates through a suite of editorial products that include content articles, graphics, videos, and animations.

As the technical lead for the implementation of the White House Climate Data Initiative, NASA launched the new http://www.data.gov/climate/ web site on March 19, 2014. Initial focus themes of the Climate Data Initiative are Coastal Flooding Risks and Food Resilience. NASA selected five new EOSDIS Science Investigator-led Processing Systems (SIPS) to support the data processing of Suomi NPP instrument suite.

WORK IN PROGRESS IN FY 2015

The project plans to fully implement the Suomi NPP SIPS and archive and distribute their data products in the appropriate science discipline oriented DAACs. Development of several new themes is underway for the Climate Data Initiative, and the team will roll them out throughout the year. NASA Earth Science Data Systems is a key partner in the Big Earth Data Initiative to promote open, interoperable, and machine-readable environmental data. Coordinating those activities through the US Group on Earth Observations, they will greatly improve the tools and techniques needed to discover, access, and use NASA data as well as ensure interoperability with other national and international Earth science data systems. NASA will continue planning and incorporation of data systems support for the SMAP and DSCOVR missions into the EOSDIS. The Sea Level Change portal development continues and the system will deploy in the EOSDIS.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will continue to operate and maintain the EOSDIS, and all accompanying infrastructure and functions. NASA also anticipates providing data systems support for the CYGNSS mission and the Lightning Imaging Sensor aboard the International Space Station missions as well as preparations for the ICESat-2 and GRACE FO missions. Additional enhancements include support for the development of the Global Change Information System (GCIS) consistent with BEDI principles and USGCRP priorities. This includes facilitating data interoperability within GCIS data and information with other major Federal climate websites and improving data accessibility. In addition, crowd-sourced observations and citizen science-driven data applications will be enhanced that complement NASA climate science research.

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;
- 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.

Date	Significant Event
Q2 FY 2015	ROSES ACCESS Solicitation Released
Q2 FY 2017	ROSES MEaSUREs Solicitation Released
Q2 FY 2017	ROSES ACCESS Solicitation Released

Program Management & Commitments

The Earth Science Data & Information Systems Project Office at GSFC has primary responsibility for day-to-day operations. DAACs are also co-located with other federal agencies [USGS Earth Resources Observation and Science Data Center, DOE-Oak Ridge National Laboratory] 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

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	American Customer Satisfaction Index	2014	Survey current EOSDIS users to assess current status and improve future services	EOSDIS scored 78 out of 100, a strong score and above the Federal government average of 66 (Jan 2014). EOSDIS improved in several areas including "likelihood to recommend" (88) and "likelihood to use services in the future." (89	2015, annually thereafter

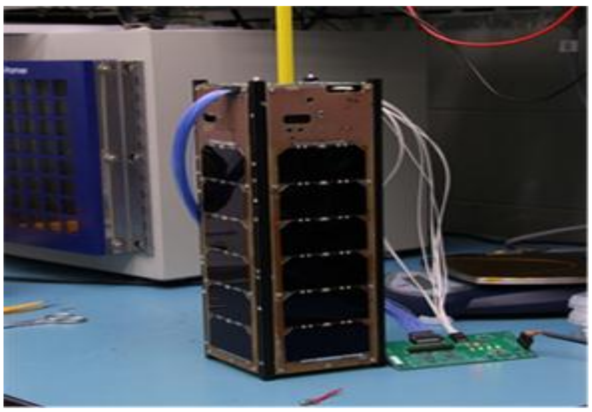
EARTH SCIENCE TECHNOLOGY

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	59.6	--	60.7	62.1	61.5	61.2	62.7

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



The GEO-CAPE Readout Integrated Circuit Experiment (GRIFEX) CubeSat undergoing final development and testing at the University of Michigan. The 3-unit (3U) CubeSat will verify the performance of a state-of-the-art readout integrated circuit/focal plane array in the space environment. It will launch with SMAP in January 2015.

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 and information systems.

EXPLANATION OF MAJOR CHANGES IN FY 2016

After initiating a pilot of the In-space Validation of Earth Science Technology (InVEST) program element in FY 2013, NASA established an ongoing program element that released a solicitation in FY 2015 with selection of awards anticipated in the first quarter of FY 2016.

ACHIEVEMENTS IN FY 2014

The program awarded 17 Instrument Incubator tasks in the second quarter of FY 2014 and initiated work. In the Advanced Component Technology program element, the program made 11 new awards in the fourth quarter of FY 2014. During the third quarter of FY 2014, the program awarded a fifth InVEST task in cooperation with Heliophysics. During FY 2014, 55 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 35 percent into various missions and identified a path for future incorporation for an additional 46 percent.

WORK IN PROGRESS IN FY 2015

In FY 2015, 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 systems capabilities. Instrument, component, and information systems technology activities awarded in prior solicitations will advance toward incorporation into decadal survey and

Venture-class missions, and NASA Earth science deployments. The program delivered the GEO-CAPE Read-Out Integrated Circuit In-Flight Performance Experiment technology validation CubeSat and completed preparations for its launch with the SMAP mission in January 2015. The four flight validation awards made in FY 2013 will be in their third year of development. The program will continue work on 11 Advanced Component Technologies efforts awarded in the fourth quarter FY 2014. The Advanced Information Systems Technology (AIST) project made 24 awards in the first quarter of FY 2015 and these efforts will continue. Work continues on advancing technology developments in all of the 17 awards made in the Instrument Incubator-13 solicitation.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will make new awards from the InVEST 2015 solicitation. The Instrument Incubator and AIST program elements will release solicitations in FY 2016 ROSES call with selections anticipated in the second quarter of FY 2017.

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.

The In-Space Validation of Earth Science Technologies (InVEST) program element selects new technologies to validate in space prior to use in a science mission. This is necessary because the space environment imposes stringent conditions on components and systems, some of which we cannot test on the ground or in airborne systems. Validation of Earth science technologies in space will help reduce the risk of new technologies in future Earth science missions.

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.

EARTH SCIENCE TECHNOLOGY

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 four areas needed to support future Earth science measurements:

- Concept Development of Improved Sensor Measurements, which includes tools to help assess various types of measurements and how to make them, including technologies that aid in the design and analysis of quantitative observations;
- Data Acquisition and Management, which refers to the collection and management of high-volume and/or high-rate data and supports the building and operation of infrastructures that are necessary for sensor data acquisition;
- Data Product Generation, which is the creation of interdisciplinary products that aggregate observational data, thus improving the scientific value of the data at reduced costs; and
- Exploitation of Data for Earth Science and Applications, which focuses on the transformation of data products into actionable information and includes modeling and visualization tools, as well as collaborative environments. In general, projects aim to advance the discovery, access, and use of sensor data within the Earth Science community.

Program Schedule

Date	Significant Event
Q2 FY 2015	ROSES-2015 solicitation
Q1 FY 2016	ROSES-2015 selection no earlier than 6 months of receipt of proposals
Q2 FY 2016	ROSES-2016 solicitation
Q1 FY 2017	ROSES-2016 selection no earlier than 6 months of receipt of proposals
Q2 FY 2017	ROSES-2017 solicitation
Q1 FY 2018	ROSES-2017 selection no earlier than 6 months of receipt of proposals
Q2 FY 2018	ROSES-2018 solicitation
Q1 FY 2019	ROSES-2018 selection no earlier than 6 months of receipt of proposals
Q2 FY 2019	ROSES-2019 solicitation
Q1 FY 2020	ROSES-2019 selection no earlier than 6 months of receipt of proposals
Q2 FY 2020	ROSES-2020 solicitation

EARTH SCIENCE TECHNOLOGY

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, MSFC, 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 primarily procures tasks 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.

MAJOR CONTRACTS/AWARDS

None.

EARTH SCIENCE TECHNOLOGY

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	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 esto.nasa.gov	2016, 2018

APPLIED SCIENCES

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	35.0	--	47.6	48.7	48.4	47.6	48.8

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

In 2014, SERVIR created a new online resource that provides images from a space station camera. The above image shows a screen-capture of the new online map showing available images taken by the ISERV system. Users can click on a location to see images uploaded by project scientists. The ISERV camera is part of the SERVIR Earth observation program, and has been a successful collaboration between NASA and the U.S. Agency for International Development (USAID). The program provides satellite-based Earth observation data and science applications to help developing nations in Central America, Africa, and Asia assess environmental threats and the damage from and their response to natural disasters.

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:

- Development of drought indicators with National Drought Mitigation Center to support end users' conservation and agriculture decisions;
- Advances in fishery stock assessments with National Marine Fisheries Service for sustainable management of important commercial species;
- Support early warnings and risk maps of infectious diseases to help health officials anticipate outbreaks and take timely actions for disease control and prevention; and
- Improved forecasts of crop water needs in California's Central Valley to account for optimal irrigation rates when scheduling irrigation.

The program supports the 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

EXPLANATION OF MAJOR CHANGES IN FY 2016

Applied Sciences will begin initiatives in areas of food security and freshwater availability, enabling and expanding the use of Earth observations in social and economic systems for sustainability, security, and humanitarian purposes. NASA will also initiate efforts to support disaster response as part of a new preparatory-based approach, working with more disaster groups that can carry forward NASA-developed information and tools to support the responders they serve. NASA will pursue these initiatives in part through partnerships with leading organizations addressing these global challenges.

Given growing concerns on food supply, production, and price volatility, the program will begin a targeted effort to assist organizations' use of Earth observations in addressing the global challenge of food security and resiliency. In addition, freshwater is a critical resource for human and ecological uses. The program will engage stakeholders and water resource managers for utilizing Earth observations and models as well as for identifying key applied research topics; the initiative begins in 2016 with a Western US focus and grows into a global effort in future years.

ACHIEVEMENTS IN FY 2014

The EPA integrated Aura, Aqua, and Terra satellite data into the AirNow air-quality system, which health officials use to alert the public about hazardous pollution. A project with the National Marine Fisheries Service applied Jason-2, Aqua, and other satellite data of sea surface height, temperature, and chlorophyll to reduce whale ship strikes. The California Department of Water Resources applied MODIS, VIIRS, and TOPS products in irrigation management trials for crops, decreasing total applied water for tested crops by over 30 percent relative to standard practice. NOAA used MODIS data to monitor and assess the intensity of harmful algal blooms in Lake Erie, assisting the State of Ohio and the City of Toledo in the issuance of urgent do-not-drink water notices. A research sensor that NASA transferred to the US Forest Service made its debut in wildfire operations.

NASA used the vantage point of space to support the response to numerous national and international disasters. NASA supported the international response to Typhoon Haiyan in Southeast Asia, providing information products on rainfall, power outages, and building damage assessments derived from satellite data. NASA provided data from Suomi NPP, Terra, Aqua, TRMM, and other satellites for numerous wildfires, floods, earthquakes, volcanic ash, landslides, tornadoes, and other disasters.

In the SERVIR program (managed jointly with USAID), a project enabled the application of Jason-2 data to improve a flood forecasting system in Bangladesh; the Institute of Water Modelling there extended its forecasts from three to eight days. In Kenya, an automated frost mapping system incorporated Aqua and Terra data to assist farmers and businesses in managing the risk of frost damage to major Kenyan export crops, such as tea and coffee.

NASA continued a new, phased approach to conduct applications projects – initially supporting a set of feasibility studies and then selecting a subset to pursue as in-depth projects. The program selected nine wildfire-related feasibility studies and 10 disasters studies for in-depth applications projects.

The DEVELOP program, an endeavor for young professionals to apply Earth science data, included over 350 people in 81 projects, and it introduced a new track for military veterans' involvement in projects. The Program’s training endeavor on remote sensing for professionals held its first-ever course on ecosystems and land management and conducted nine trainings overall, reaching hundreds of people in the US and globally.

The program continued to engage the applications community in planning for upcoming satellites. Together with the Centers for Disease Control (CDC), the SMAP mission held a workshop on public health, disease exposure, and future applications of SMAP data. The ICESat-2 team held a joint vegetation tutorial with Landsat 8 as well as a sea ice applications meeting with the Naval Research Laboratory.

Applied Sciences continued its efforts to communicate applications of Earth observations for societal and economic benefits. The program received a Gold Hermes Creative Award from the Association of Marketing and Communication Professionals, and the host of the SERVIR Hub in Kathmandu received the Environmental Systems Research Institute (Esri) Special Achievement in Geographic Information Systems (GIS) award in 2014.

WORK IN PROGRESS IN FY 2015

NASA will complete a new strategic plan for the Applied Sciences Program to cover the 2015-2020 timeframe. The plan conveys the goals and objectives for the timeframe, introduces initiatives, and articulates the implementation bases and the principles that the Program follows in its execution.

Together with USAID, NASA announced a new hub in Southeast Asia for the SERVIR program. This new SERVIR-Mekong hub helps governments and other key decision-makers in Burma, Cambodia, Laos, Thailand and Vietnam take advantage of publicly available satellite imagery, geospatial data and maps to make more informed decisions on issues such as water management, land use planning, disaster risk reduction, infrastructure development and natural resource management.

Applied Sciences is scoping a preparatory-based approach for NASA support to disaster response and recovery, identifying new tools, information, and methods to support disaster groups that serve first responders.

Using the new, two-phased approach to conduct applications projects, the Ecological Forecasting applications area peer will review the results of numerous feasibility studies and then select a subset to pursue as in-depth projects. Ten Disasters application projects will begin their in-depth development phase as will nine projects in the crosscutting Wildfires theme. The Water Resources applications area will begin new projects addressing seasonal outlooks of water supply conditions. The Health & Air Quality applications area will begin new projects addressing applications of Earth observations for air quality, environmental health risks, and infectious diseases.

The Applied Remote SEnsing Training (ARSET) programs will expands its reach through new technology investments to include more people in each of its on-line trainings. ARSET will also increase the number of land management trainings it offers.

The program will hold the fifth international workshop on socioeconomic benefits of Earth observations, focusing on valuation methods for open data and advances in methodologies. The program will complete impact analyses on several projects and initiate new analyses.

APPLIED SCIENCES

Through support from Applied Sciences, the SMAP and ICESat-2 missions will accept additional Early Adopters, and SWOT and other missions initiate Early Adopters programs. Early Adopter activities help organizations understand how they can use Earth Science data products to improve decision-making.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Projects from the first NASA Air Quality Applied Sciences Team will complete, providing new tools for air quality managers to improve forecasting and planning decisions. The first SERVIR Applied Sciences Team will also complete their core projects, delivering results on uses of Earth observations to advance water management, agriculture, health, and disaster preparedness in Africa, Himalayas, Central America, and Southeast Asia. NASA will fund the next generation of these Applied Sciences Teams to continue efforts to inform decisions and support international development.

The program will deliver results in projects focused on use of Earth observations to improve drought forecasts and land management practices. Initial results from decision-support projects in the areas of disasters, health and air quality, long-term water availability forecasts, ecosystems, and wildfire management will become available. The program will deliver initial indications on applicability of SMAP data to support and improve management and decision making activities. Results from new SERVIR-Mekong will become routine, and NASA and USAID will likely have a new hub in West Africa to increase use of Earth observations and geospatial information in that region.

NASA will commence initiatives on Freshwater Availability and on Food Security, supporting the nation's use of Earth observations to address these global challenges. NASA will expand its efforts to support disaster response as part of a new preparatory-based approach, working with more disaster groups that can carry forward NASA-developed information and tools to support the responders they serve.

Program Elements

CAPACITY BUILDING

The Capacity Building project enhances US and developing countries' capacity – including human, scientific, technological, institutional, and resource capabilities – to make decisions informed by Earth science data and models. Capacity Building builds skills in current and future workforce, and it creates opportunities in under-served areas to broaden the benefits of Earth observations. This project supports training, information product development, internships, data access tools, short-term application test projects, user engagement, and partnership development. In 2016, this project will have three primary elements: SERVIR for supporting developing countries, ARSET for professional-level training on Earth observations, and DEVELOP for workshop development through hands-on internships with state and local governments.

MISSION AND APPLIED RESEARCH

The Mission & Applied Research project enables involvement by applications-oriented users in the planning, development, and other activities of Earth science satellite missions. The Mission & Applied Research project enables end user engagement to identify applications early and throughout mission life cycle, integrate end-user needs in design and development, enable user feedback, and broaden advocacy.

APPLIED SCIENCES

Mission & Applied Research organizes community workshops to identify priority needs as well as studies to inform design trade-offs and identify ways to increase the applications value of missions. In this project, Applied Sciences advises flight projects on activities to develop the applications dimension of the mission to help broaden benefits and maximize the return from the investment in the mission.

DISASTER SUPPORT

The Disaster Support project enables development of innovative applications using NASA satellite mission data to ensure timely, valuable support to responders when disasters occur. The Disaster Support project sponsors uses and integration of Earth observations in disaster-related organizations' decisions and actions, including use of feasibility studies, in-depth projects, workshops, and needs assessments. The project also sponsors activities to improve a preparatory-based approach to enhance value and usability of NASA Earth science products in support of disaster response and recovery. This project pursues partnerships with disaster groups that can carry forward NASA-developed information and tools to support the responders they serve.

APPLICATIONS

The Applications project organizes its development activities on priority themes related to societal and economic topics important to end user communities and their management, policy, and business activities. The Applications project sponsors the integration of Earth observations in community organizations' decisions and actions. Specific topics within an area evolve to reflect new priorities and opportunities. In 2016, there will be four formal applications areas in Ecosystems, Health, and Water and Wildfires. The project will conduct ad hoc activities on other themes and formalize areas when warranted or additional resources are available. Each applications area supports feasibility studies, in-depth projects, applied science teams, consortia, workshops, and needs assessments. Each applications area participates in major conferences and events that their partners attend in order to meet and engage managers and users.

Program Schedule

Date	Significant Event
Q2 2014	ROSES-2015 solicitation
	ROSES-2015 selection no earlier than 6 months of receipt of proposals

Program Management & Commitments

NASA Headquarters manages the Applied Sciences Program.

Program Element	Provider
Applications	Provider: Various Lead Center: HQ Performing Center(s): ARC, GSFC, JPL, LaRC Cost Share Partner(s): US Forest Service, National Park Service, US Fish and Wildlife Service, EPA, US Department of Agriculture, NOAA, USGS, Bureau of Land Management, Centers for Disease Control and Prevention.
Capacity Building	Provider: Various Lead Center: HQ Performing Center(s): ARC, GSFC, JPL, LaRC, MSFC, SSC Cost Share Partner(s): USAID
Disaster Support	Provider: Various Lead Center: HQ Performing Center(s): GSFC, JPL, LaRC, MSFC, SSC Cost Share Partner(s): DHS, NOAA, USDA, USGS, USAID
Mission and Applied Research	Provider: Various Lead Center: HQ Performing Center(s): ARC, GRC, GSFC, JPL, JSC, KSC, LaRC, MSFC, SSC Cost Share Partner(s): USDA, CNES, ISRO, JRC

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.

MAJOR CONTRACTS/AWARDS

None.

APPLIED SCIENCES

INDEPENDENT REVIEWS

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

PLANETARY SCIENCE

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Planetary Science Research	221.8	--	**276.3**	282.0	292.0	291.7	285.7
Discovery	297.4	--	**156.1**	201.6	277.2	337.4	344.9
New Frontiers	231.6	--	**259.0**	124.0	81.5	85.7	137.8
Mars Exploration	288.0	--	**411.9**	539.3	561.3	531.5	464.2
Outer Planets	152.4	--	**116.2**	117.7	81.6	87.6	110.5
Technology	143.1	--	**141.7**	155.5	164.4	168.5	184.7
Lunar Quest Program	11.4	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**1345.7**	**--**	**1361.2**	**1420.2**	**1458.1**	**1502.4**	**1527.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Planetary Science

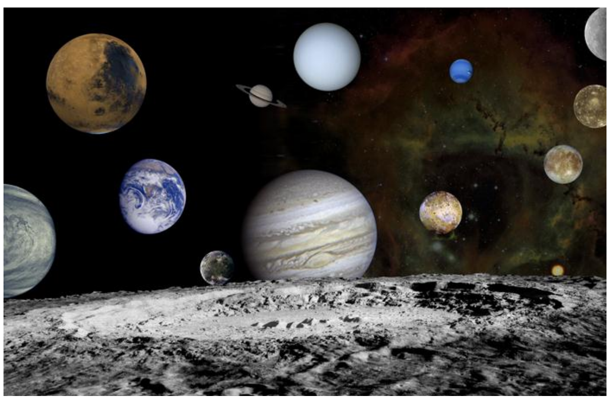
PLANETARY SCIENCE RESEARCH

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Planetary Science Research and Analysis	130.0	--	**162.5**	164.0	166.7	170.6	170.6
Directorate Management	4.0	--	**7.1**	7.4	7.4	7.4	7.4
Near Earth Object Observations	40.5	--	**50.0**	50.0	50.0	50.0	50.0
Other Missions and Data Analysis	47.3	--	**56.7**	60.6	67.9	63.7	57.7
Total Budget	**221.8**	**--**	**276.3**	**282.0**	**292.0**	**291.7**	**285.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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.

The Planetary Science Research program provides the scientific foundation for 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; and
- Identify and characterize objects in the solar system that pose threats to Earth or offer resources for human exploration.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The request includes the Science Innovation Fund, which funds competitively selected innovative researchers at the NASA Centers. It also includes an increase for Near-Earth Object Observations (NEOO), to accelerate the use of space-based capabilities to identify and track near-Earth objects (NEOs).

PLANETARY SCIENCE RESEARCH

ACHIEVEMENTS IN FY 2014

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 (Comet C-S) in 2014. The Robotics Alliance Project (RAP) selected 310 teams for receipt of the For Inspiration and Recognition of Science and Technology (FIRST) Robotics Student Competition 2014 Grant award.

In 2014, the NEOO project catalogued an additional 1,288 new NEOs, of which 88 are potentially hazardous to Earth and warrant future monitoring. There were only 497 known NEOs before the inception of this project in 1998. Now, NASA and other entities have found 11,448 objects, and of these NASA supported search teams have found over 97 percent.

The NEOO project has now found about 96 percent of the estimated population of 1 kilometer and larger objects and in FY 2014 increased efforts for finding and characterizing smaller asteroids down to 140 meters in size. To date, researchers have found only about 10 percent of the estimated population of 100 meter sized asteroids.

In 2014, NEOO completed the reactivation of the Wide-Field Infrared Survey Explorer (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. Since reactivation, NEOWISE has found 34 previously unknown NEOs and three comets. NASA expects NEOWISE to discover a few hundred NEOs and provide infrared characterization data on a few thousand more already known asteroids during the estimated three-year remainder of its useful life.

WORK IN PROGRESS IN FY 2015

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 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, the Asteroid Terrestrial-impact Last Alert System (ATLAS), designed to detect smaller asteroids as they approach the Earth;
- Support the continued and enhanced operation of planetary radar capabilities at the National Science Foundation's Arecibo and NASA's Goldstone facilities;
- Investigate both ground and space-based concepts for increasing capacity to detect, track, and characterize NEOs of all sizes; and
- The European Space Agency's (ESA) Rosetta mission, with NASA participation, is orbiting the Comet C-S. The Philae lander separated from the Rosetta orbiter and landed on the comet on November 12.

PLANETARY SCIENCE RESEARCH

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016 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 project 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. The project will begin planning for space-based assets to accelerate the identification of NEOs.

Program Elements

PLANETARY SCIENCE RESEARCH AND ANALYSIS (R&A)

Planetary Science R&A 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 bodies other than the Earth or the sun.

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, using ground and space-based assets, 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, including the Robotics Alliance. The Robotics Alliance project increases 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 work with engineering and technical professionals from government, industry, and universities to gain hands-on experience and mentoring.

PLANETARY SCIENCE RESEARCH

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 2015.

Program Management & Commitments

Program Element	Provider
R&A	Provider: NASA Lead Center: Headquarters (HQ) Performing Center(s): Ames Research Center (ARC), Glenn Research Center (GRC), Goddard Space Flight Center (GSFC), Jet Propulsion Laboratory (JPL), Johnson Space Center (JSC), Langley Research Center (LaRC), Marshall Space Flight Center (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): National Science Foundation (NSF), United States Air Force (USAF), Smithsonian Astrophysical Observatory (SAO)

Acquisition Strategy

The R&A budget will fund competitively selected activities from the ROSES omnibus research announcement.

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Planetary Science Subcommittee	2014	Review to assess goals and objectives of program.	Recommendation was to maintain a strong program consistent with the decadal survey.	2015

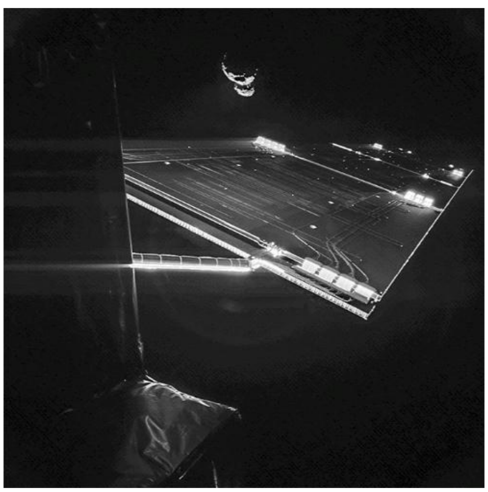
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Joint Robotics Program for Exploration	10.0	--	**10.0**	10.0	10.0	10.0	10.0
Planetary Science Directed R&T	0.0	--	**6.6**	12.3	22.3	22.0	16.0
Science Innovation Fund	0.0	--	**5.0**	6.0	6.0	6.0	6.0
Planetary Data System	12.2	--	**14.0**	14.5	15.0	16.0	16.0
Astromaterial Curation	6.3	--	**6.4**	6.6	6.7	7.0	7.0
Science Data & Computing	2.3	--	**2.3**	2.4	2.5	2.7	2.7
Rosetta	16.5	--	**12.4**	8.8	5.4	0.0	0.0
Total Budget	**47.3**	**--**	**56.7**	**60.6**	**67.9**	**63.7**	**57.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



This Rosetta spacecraft selfie was snapped on October 7th. At the time the spacecraft was about 472 million kilometers from planet Earth, but only 16 kilometers from the surface of comet 67P/Churyumov-Gerasimenko. Looming beyond the spacecraft near the top of the frame, dust and gas stream away from the comet's curious double-lobed nucleus and bright sunlight glints off one of Rosetta's 14 meter long solar arrays. Image Credit: ESA/Rosetta/Philae/CIVA

Other Missions and Data Analysis includes supporting mission functions such as Planetary Data Systems, Science Data and Computing, and Astromaterials Curation, as well as the NASA portion of the 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 SMD will jointly conduct many of these research and analysis activities with the Human Exploration and Operations Mission Directorate (HEOMD) to maximize the benefit to both science and exploration objectives, as was done successfully with the Lunar Reconnaissance Orbiter (LRO) mission.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

In 2014, the Joint Robotics Program for Exploration established the Solar System Exploration Research Virtual Institute (SSERVI) and research teams, which 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 nine winning research teams, which SSERVI will support for five years.

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 2017.

SCIENCE INNOVATION FUND

The Science Innovation Fund provides small amounts of funding to NASA Centers to invest in scientific research that will enhance scientific innovation, NASA's ability to meet future missions, NASA's ability to forge new collaborations, and recruitment and retention of scientists. The purpose of the Science Innovation Fund is twofold: 1) Promote the conduct of highly innovative, exploratory, and high-risk/high return scientific research in support of the strategic direction of the Agency; and 2) Promote the vitality of the NASA Centers through strategic investments in scientific research, capabilities, and people. While this project is in the Science account, it is for use by the entire NASA science workforce, including SMD and HEOMD.

PLANETARY DATA SYSTEM

The Planetary Data System (PDS) is an online data archive. Scientists with expertise in planetary science disciplines designed the PDS, and they curate its data. The PDS 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 PDS archive.

Recent Achievements

NASA enabled a PDS modernization effort for two of the latest planetary science missions: Lunar Atmosphere and Dust Environment Explorer (LADEE) and Mars Atmosphere and Volatile EvolutioN (MAVEN). These missions effectively interacted with the new PDS version during their archive design and data delivery to the PDS.

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

OTHER MISSIONS AND DATA ANALYSIS

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.

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 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 is enabling scientists to look at some of the most primitive material from the formation of the solar system 4,600 million years ago. Rosetta is studying 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 is 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 arrived at Comet C-S in FY 2014.

Science observation and operations are underway after Rosetta's Comet C-S orbit insertion and mapping with the lander touching down on Comet C-S in November 2014. Rosetta will orbit and study the comet for a total of 17 months.

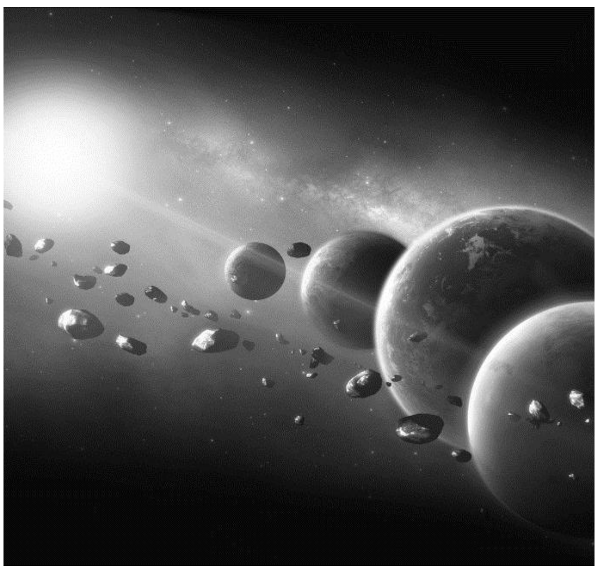
DISCOVERY

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
InSight	203.3	170.0	**92.1**	13.3	8.7	9.0	9.0
Other Missions and Data Analysis	94.1	--	**64.0**	188.4	268.5	328.4	335.9
Total Budget	**297.4**	--	**156.1**	**201.6**	**277.2**	**337.4**	**344.9**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



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 identify 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 three operational spacecraft: MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) – which will end its mission in April 2015, LRO, and Dawn; and one flight mission in development: the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight). The program is also developing the Strofio instrument as a part of ESA's BepiColombo mission to Mercury.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

NASA approved the InSight mission's continuation into the implementation phase. The project completed its Critical Design Review (CDR) and spacecraft integration has begun.

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.

DISCOVERY

LRO completed its first extended science mission, completing all of the science requirements. LRO has greatly changed and improved our understanding of the Moon. LRO researchers recently published a discovery that widespread volcanism ended as recently as 50 million years ago, rather than one billion years ago as previously thought, substantially changing our understanding of the thermal history and potential for recent and current geological activity on the Moon.

The project completed the Strofio instrument and delivered it to the Italian Search for Exospheric Refilling and Emitted Natural Abundances (SERENA) instrument suite for launch in 2016.

WORK IN PROGRESS IN FY 2015

Upon fuel depletion, MESSENGER will complete its orbital mission at Mercury, with impact on the surface by April 2015. Dawn will arrive at Ceres in March to begin science operations orbiting the largest main belt asteroid. InSight will continue with integration and tests.

NASA released a new Announcement of Opportunity (AO) for Discovery. The program will conduct in-depth science, technical, cost, and management evaluations and select new mission candidates to enter concept studies in FY 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will receive and evaluate Concept Study Reports for those potential missions competitively selected for Phase A studies, and make the final down selection to a flight mission in FY 2016.

InSight will undergo final integration with the launch vehicle and final tests. After the required Readiness Reviews, Insight will launch in March 2016. After a six-month trip to Mars, the spacecraft will enter Mars orbit and land on the surface in September 2016.

MESSENGER will complete data analysis and archiving following end of operations in 2015.

Dawn will end its orbiting of Ceres followed by data analysis and archiving. LRO will cease operations.

Program Schedule

Date	Significant Event
Feb 2015	Proposal Submittals Received
Jun 2015	Step-1 Selections
Apr 2016	Phase A Concept Study Report
Sept 2016	Downselection of Investigation for Flight (target)

Program Management & Commitments

The Planetary Missions Program Office at MSFC provides program management.

Program Element	Provider
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 (APL) Lead Center: MSFC Performing Center(s):NA Cost Share Partner(s):NA
Dawn	Provider: NA Lead Center: JPL Performing Center(s): NA Cost Share Partner(s): DLR, Agenzia Spaziale Italiana (ASI)
LRO	Provider: N/A Lead Center: GSFC Performing Center(s): GSFC,JPL Cost Share Partner(s): NA
International Missions Contributions	Provider: NA Lead Center: HQ Performing Center(s): JPL, ARC Cost Share Partner(s): NA
Strofio	Provider: Southwest Research Institute Lead Center: MSFC Performing Center(s): NA Cost Share Partner(s): NA

Acquisition Strategy

All acquisitions for current projects are complete. The AO for Discovery 2014 is currently open to all interested parties with proposals due in February 2015.

MAJOR CONTRACTS/AWARDS

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

DISCOVERY

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 Implement-ation Review (PIR)	Standing Review Board (SRB)	2010	Review implementation of Program	Passed	FY 2016

INSIGHT

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	BTC	Total
Formulation	98.9	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	98.9
Development/Implementation	88.9	203.3	170.0	**79.6**	0.0	0.0	0.0	0.0	0.0	541.8
Operations/Close-out	0.0	0.0	0.0	**12.4**	13.3	8.7	0.0	0.0	0.0	34.4
2015 MPAR LCC Estimate	**187.8**	**203.3**	**170.0**	**92.0**	**13.3**	**8.7**	**0.0**	**0.0**	**0.0**	**675.1**
Total Budget	**187.8**	**203.3**	**170.0**	**92.1**	**13.3**	**8.7**	**9.0**	**9.0**	**0.0**	**693.1**
Change from FY 2015				**-77.9**						
Percentage change from FY 2015				**-45.8%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

PROJECT PURPOSE

InSight is a Mars lander mission planned for launch in spring 2016. InSight will investigate fundamental issues of terrestrial 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 2016

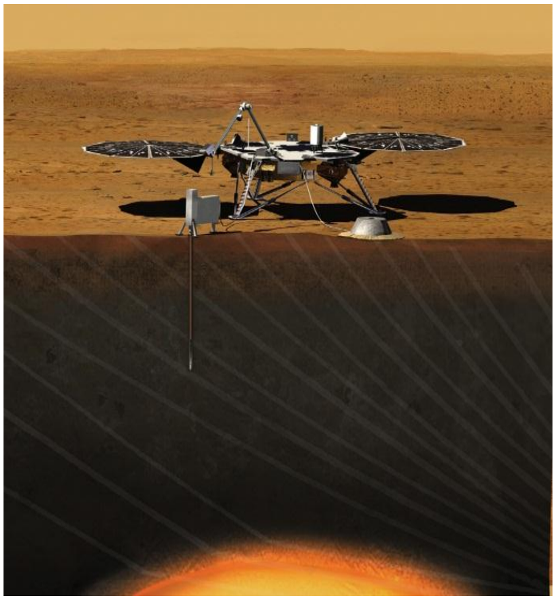
None.

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



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.

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. NASA expects the first science return in October 2016. The prime mission ends in September 2018.

ACHIEVEMENTS 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 completed the CDR.

WORK IN PROGRESS IN FY 2015

InSight will complete Phase C, conduct an SIR for the Independent SRB in February 2015, and start Phase D after a successful SIR and Key Decision Point (KDP)-D decision.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

InSight will launch from Vandenberg Air Force Base in March 2016 and land on Mars in September 2016.

INSIGHT

Formulation	Development	Operations

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-C	Dec 2013	Dec 2013
SIR	Oct 2014	Feb 2015
KDP-D	Nov 2014	Mar 2015
Operational Readiness Review (ORR)	Dec 2015	Dec 2015
Launch	Mar 2016	Mar 2016
KDP-E	Apr 2016	Apr 2016
Mars Landing	Sep 2016	Sep 2016
End of Prime Mission	Sep 2018	Sep 2018

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	541.8	70	2015	541.8	0	LRD	Mar 2016	Mar 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)
TOTAL:	**541.8**	**541.8**	**0.0**
Aircraft/Spacecraft	196.9	202.9	6.0

INSIGHT

Formulation	Development	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
Payloads	18.1	44.7	26.6
Systems I&T	0.0	0.0	0.0
Launch Vehicle	159.9	159.8	-0.1
Ground Systems	7.4	9.3	1.9
Science/Technology	7.1	9.9	2.8
Other Direct Project Costs	152.4	115.1	-37.3

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 5 meters 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

INSIGHT

Formulation	Development	Operations

Element	Description	Provider Details	Change from Baseline
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

Project Risks

Risk Statement	Mitigation
If: Growth of lander avionics and payload electronics continues to strain volume of thermal enclosure, Then: The heritage design of the thermal enclosure and aeroshell is at risk. The project cannot grow the size of the thermal enclosure.	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.
If: If Mars environment, entry conditions, or spacecraft behavior is not as anticipated, Then: Landing may not be successful.	Project will build comprehensive simulations of landing scenarios and test entry descent and landing systems, including independent verification of analysis. The project employs personnel who conducted previous successful Mars landings. The project will certify potential landing ellipses 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.
If: Deployment of SEIS is not successful, Then: The science objectives will be compromised.	The project will conduct extensive testing of deployments in testbeds, including fault scenarios. Testbeds will also be available during mission operations to verify actual deployment moves, with ground verification deployed at each step during operations. The project will certify potential landing ellipses for elevation, slopes, and rock abundance.

Formulation	Development	Operations

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, CO

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Aug 2013	PDR	InSight successfully met the criteria for PDR and the PMC decision authority approved the project to continue to the next phase at KDP-C.	N/A
Perform-ance	SRB	May 2014	CDR	InSight successfully met the criteria for CDR.	N/A
Perform-ance	SRB	Feb 2015	SIR	TDB	N/A
Perform-ance	SRB	Dec 2015	ORR	TBD	Feb 2016
Perform-ance	JPL System Review Team and SRB	Feb 2016	FRR	TBD	N/A

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Strofio	1.3	--	**0.7**	0.6	0.7	0.7	0.6
International Mission Contributions (IMC)	0.7	--	**2.8**	2.0	2.8	3.7	2.6
Discovery Future	35.2	--	**15.8**	163.5	238.1	298.5	312.2
Discovery Management	13.4	--	**14.9**	8.5	15.1	13.9	9.6
Discovery Research	14.4	--	**12.3**	12.8	11.8	11.6	10.9
Lunar Reconnaissance Orbiter Science Mission	12.4	--	**0.0**	0.0	0.0	0.0	0.0
Dawn	1.5	--	**14.2**	1.0	0.0	0.0	0.0
MESSENGER	12.2	--	**3.3**	0.0	0.0	0.0	0.0
Gravity Recovery and Interior Laboratory	3.0	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**94.1**	**--**	**64.0**	**188.4**	**268.5**	**328.4**	**335.9**

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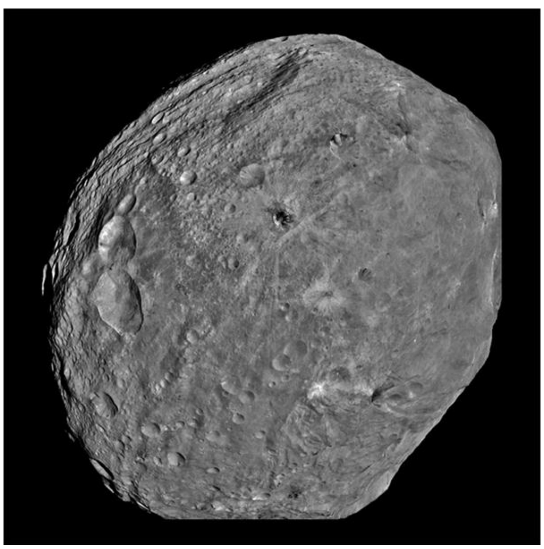
FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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.

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 instrument Strofio; operating missions (Dawn, MESSENGER, LRO); missions whose operations have ceased but data analysis continues Gravity Recovery and Interior Laboratory (GRAIL); competed research; funding for future mission selections; and program management activities.

Mission Planning and Other Projects

STROFIO

Strofio is a unique mass spectrometer, part of the SERENA 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.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

ESA has installed STROFIO on the BepiColombo spacecraft while completing the SERENA suite. The spacecraft level testing will continue in 2015 to prepare the spacecraft for launch in July of 2016.

DISCOVERY FUTURE

Technology development continued in FY 2014 to enhance infusion of new technology into the next Discovery Mission, including a new 3D woven thermal protection system, a Deep Space Optical Communications demonstration, and NASA’S Evolutionary Xenon Thrusters and Power Processing Units. The Discovery AO released in November 2014, is for a mission to launch no later than December 2021. Assuming the proposed notional out year budget is realized, the next Discovery AO would be released in 2017.

DISCOVERY MANAGEMENT

Discovery Management fully funds the Planetary Missions Program Office at the MSFC, which manages all of the Planetary Science 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. The project supports the LaRC Independent Program Analysis Office, which forms review boards and ensures that all missions in development undergo rigorous Life Cycle Reviews.

DISCOVERY RESEARCH

Discovery Research funds analysis of archived data from Discovery missions, and supports participating scientists for the MESSENGER, Dawn, InSight, 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.

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 element 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 PDS recently added datasets from the Dawn and MESSENGER missions, and the Planetary Mission Data Analysis program element is facilitating efforts to understand the interiors of asteroid Vesta and the planet Mercury through image processing, geological mapping, and spectroscopic analyses. As part of the 2014 restructure of Research and Analysis programs, NASA split the Planetary Mission Data Analysis program element into a Discovery Data Analysis program element and a Planetary Data Archiving, Restoration & Tools program element.

Operating Missions

LUNAR RECONNAISSANCE ORBITER (LRO)

LRO will cease operations by FY 2016. NASA moved LRO to the Discovery Program because the Lunar Quest Program ended.

DAWN

Dawn is completing its 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 theses bodies, enabling scientists to answer questions about the formation and evolution of the solar system. Their surfaces 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 March 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 is healthy other than two failed reaction wheels, and is preparing to accomplish its mission objectives at Ceres without reaction wheels.

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

The MESSENGER mission is an investigation of 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.

OTHER MISSIONS AND DATA ANALYSIS

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 will complete its mission around April 2015, when it will deplete its fuel and crash on the surface of Mercury.

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. The Akatsuki mission will attempt orbit insertion at the beginning of FY 2016 and study Venus for two years.

NEW FRONTIERS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Origins Spectral Interpretation Resource	207.3	216.8	**189.7**	44.0	38.1	43.1	27.7
Other Missions and Data Analysis	24.3	--	**69.3**	80.0	43.4	42.6	110.1
Total Budget	**231.6**	**--**	**259.0**	**124.0**	**81.5**	**85.7**	**137.8**

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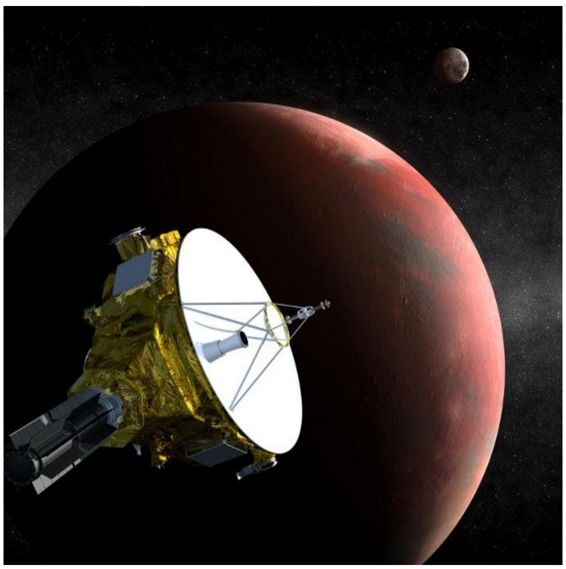
FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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 program is currently comprised of three missions: two operating missions (New Horizons and Juno), and one under development, the Origins Spectral Interpretation Resource Identification and Security-Regolith Explorer (OSIRIS-REx).

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 and 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 operate human and robotic missions safely, in close proximity to a large NEO.

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

NEW FRONTIERS

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 2016

The New Frontiers Program will begin planning for the next AO for a new mission.

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

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	144.3	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	144.3
Development/Implementation	89.3	207.3	216.8	**183.0**	13.3	0.0	0.0	0.0	0.0	709.7
Operations/Close-out	0.0	0.0	0.0	**6.7**	30.7	38.1	43.1	27.7	64.0	210.3
2015 MPAR LCC Estimate	**233.6**	**207.3**	**216.8**	**189.7**	**44.0**	**38.1**	**43.1**	**27.7**	**64.0**	**1064.3**
Total Budget	**233.6**	**207.3**	**216.8**	**189.7**	**44.0**	**38.1**	**43.1**	**27.7**	**64.0**	**1064.3**
Change from FY 2015				**-27.1**						
Percentage change from FY 2015				**-12.5%**						

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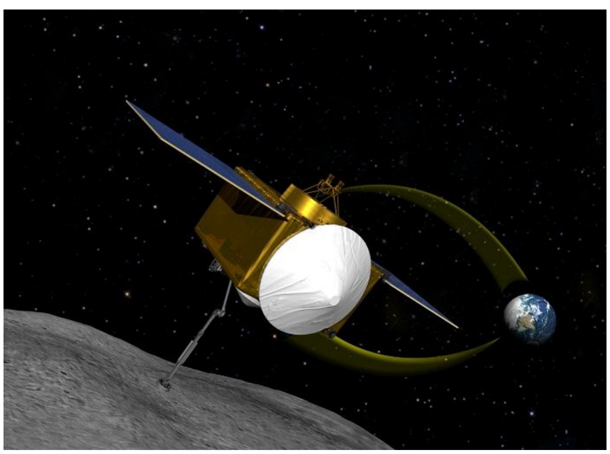
FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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 (101955) Bennu, a near-Earth carbonaceous asteroid formerly designated 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 and re-emits that energy as heat. The small force adds up over time, but it is uneven due to an

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

Formulation	Development	Operations

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 2016

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 near the asteroid for almost another two 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. JSC will make subsamples available for research to the worldwide science community.

ACHIEVEMENTS IN FY 2014

On April 9, 2014, OSIRIS-REx successfully completed its CDR. This independent review evaluated 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. The CDR determined that the design was mature and the project was ready to continue with Phase C.

WORK IN PROGRESS IN FY 2015

OSIRIS-REx will conduct its SIR in February 2015. Based on the results of the SIR and the recommendations of the chair of the independent Standing Review Board, the project will request NASA approval to begin Phase D at a KDP-D Program Management Council meeting. In FY 2015, OSIRIS-REx will deliver the instruments to the spacecraft provider and assemble the spacecraft.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, OSIRIS-REx will start environmental testing of the flight system and deliver it to Kennedy Space Center for launch processing. In June 2016, the OSIRIS-REx mission will complete its ORR, the major independent review to evaluate the readiness of the project to operate the flight system and

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

Formulation	Development	Operations

associated ground systems. In August 2016, OSIRIS-REx will complete its FRR to evaluate the readiness of the project and all project and supporting systems for a safe and successful launch and flight/mission. OSIRIS-REx will be ready for launch at the end of FY 2016. The planetary launch window opens in September 2016 and continues into early October 2016, the beginning of FY 2017.

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 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 Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	778.6	70	2015	709.7	-8.9	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

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**778.6**	**709.7**	**-68.9**
Aircraft/Spacecraft	220.2	265.6	44.3
Payloads	32.2	47.8	15.6
Systems I&T	24.9	30.4	5.5
Launch Vehicle	234	178.3	-55.7
Ground Systems	34.3	34.1	-0.2
Science/Technology	17.8	18.8	0.9
Other Direct Project Costs	215.3	134.9	-80.4

Project Management & Commitments

NASA selected the OSIRIS-REx project through the New Frontiers 2009 AO. The principal investigator is from the University of Arizona and delegated day-to-day management of the 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: N/A Performing Center(s): N/A Cost Share Partner(s): N/A	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

Project Risks

Risk Statement	Mitigation
If: The Guidance, Navigation, and Control (GNC) Lidar is not ready for integration onto the spacecraft by Fall 2015, 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: The schedule erosion experienced during the OSIRIS-REx Camera Suite (OCAMS) Engineering Qualification Model (EQM) build and test reoccurs during Flight Instrument build and test, Then: On-time delivery of a fully tested and verified suite of cameras (and electronics) is in jeopardy.	Careful management and monitoring of progress of the OCAMS development
If: Baseline GNC Lidar 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

Acquisition Strategy

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

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Spacecraft, Integration and Test	Lockheed Martin Space Systems Company (LMSSC)	Denver, CO
Payload – OCAMS Instrument	University of Arizona	Tucson, AZ
Payload – OTES Instrument	Arizona State University	Tempe, AZ
Ground System – Science Processing and Operations Center (SPOC)	University of Arizona	Tucson, AZ

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

Formulation	Development	Operations

Element	Vendor	Location (of work performance)
Launch Vehicle and Services	ULA	Cape Canaveral, FL

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Mar 2013	PDR	OSIRIS-REx successfully met the requirements for PDR and the PMC decision authority approved the project to continue to Final Design & Fabrication Phase C at KDP-C.	N/A
Perform-ance	SRB	Apr 2014	CDR	OSIRIS-REx successfully met the requirements for CDR.	Feb 2015
Perform-ance	SRB	Feb 2015	SIR		Jun 2016
Perform-ance	SRB	Jun 2016	ORR		Aug 2016
Perform-ance	GSFC System Review Team (GSRT)	Aug 2016	FRR		N/A

OTHER MISSIONS AND DATA ANALYSIS

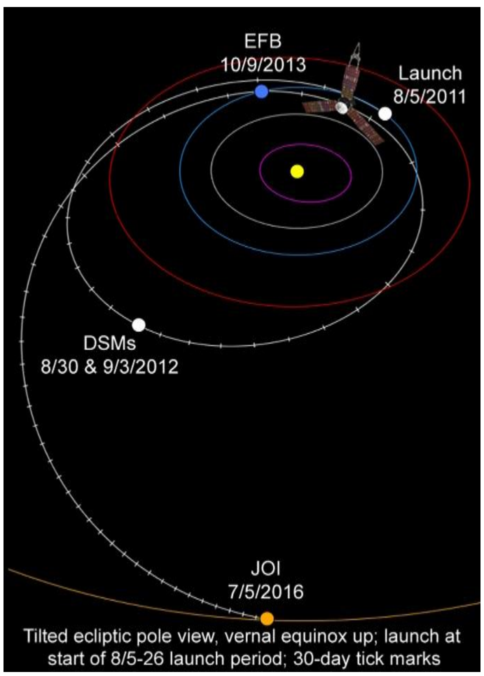
FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
New Frontiers Future Missions	0.0	--	**2.0**	9.0	24.0	35.1	96.2
New Frontiers Research	0.0	--	**0.0**	4.3	4.9	7.5	13.9
New Horizons	12.9	--	**21.5**	27.6	0.0	0.0	0.0
Juno	7.7	--	**45.8**	39.1	14.5	0.0	0.0
New Frontiers Management	3.7	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**24.3**	**--**	**69.3**	**80.0**	**43.4**	**42.6**	**110.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

New Frontiers Other Missions and Data Analysis supports operating New Frontiers missions (New Horizons, Juno).



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.

Mission Planning and Other Projects

NEW FRONTIERS FUTURE

New Frontiers Future supports technology development for future missions, and provides the funding required for the next AO. NASA plans to announce the next opportunity by the end of FY 2016.

NEW FRONTIERS RESEARCH

New Frontiers Research funds analysis of archived data from, and supports participating scientists for the New Frontiers missions. New Frontiers 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. NASA will make selections in 2017, based upon the New Horizons mission data returned from Pluto.

New Frontiers Other Missions and Data Analysis supports operating New Frontiers missions (New Horizons, Juno).

OTHER MISSIONS AND DATA ANALYSIS

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 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 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 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

In FY 2014, New Horizons successfully completed several critical milestone reviews in support of the 2015 Pluto Encounter, including Guidance and Control Readiness; Mission Operations Readiness; Flight System Readiness, and Risk Reviews. The project also completed the set-up of the Remote Mission Operations Center at JPL.

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 will be the first solar panel power spacecraft to orbit the giant planet beginning in July 2016.

During its approximately one-year mission, Juno, with the first-ever polar orbit of Jupiter, 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.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

In January 2014, Juno completed the commissioning of the last of the nine instruments (Jade instrument). Also in FY 2014, the configuration and enabling of all Solar Array strings for preparation of Jupiter Orbit Insertion and Science Operation succeeded.

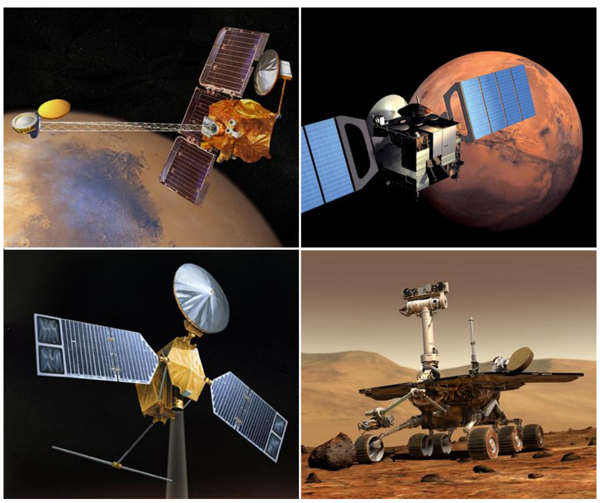
MARS EXPLORATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Other Missions and Data Analysis	288.0	--	**411.9**	539.3	561.3	531.5	464.2
Total Budget	**288.0**	**--**	**411.9**	**539.3**	**561.3**	**531.5**	**464.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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.

Today, our robotic scientific explorers are paving the way. Together, humans and robots will pioneer Mars and the solar system.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

MAVEN launched in early FY 2014 and successfully inserted into Mars orbit at the end of the fiscal year after its 10-month cruise phase.

MARS EXPLORATION

The Mars 2020 mission formally entered Phase A of Formulation in November 2014. NASA completed the evaluation of 53 proposals submitted in response to the Mars Rover 2020 Investigations AO. NASA selected seven science and exploration technology investigations for the Mars Rover 2020 payload.

Curiosity arrived at Mt. Sharp in late FY 2014, achieved all of its Program-level requirements, and met the documented criteria for full mission success. In doing so, it determined that the ancient Mars environment could have supported microbial life. The Mars Organic Molecule Analyzer Mass Spectrometer (MOMA-MS) instrument completed its Confirmation Review, entered the development phase, and completed its CDR.

WORK IN PROGRESS IN FY 2015

MAVEN will begin primary science operations in early FY 2015.

The Mars Rover 2020 mission will complete Phase A/Formulation with the SRR/Mission Definition Review and begin Phase B/Formulation.

Curiosity, now at the base of Mt. Sharp, will investigate the transition of Mars from a warm, wet world to the cold, dry planet of today. MRO, Odyssey, and Opportunity will conduct extended mission science operations.

MOMA-MS will ship the Structural-Thermal Model to Germany in early FY 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, MAVEN will complete its primary science phase.

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

The Mars orbiters will support InSight entry, descent, and landing telemetry and data relay.

Program Management & Commitments

Program Element	Provider
Mars Rover 2020	Provider: JPL Lead Center: JPL Performing Center(s): JPL, GSFC Cost Share Partner(s): CNES; Norwegian Forsvarets Forskning Institute (FFI); Center for the Development of Industrial Technology (CDTI) and the National Institute of Aerospace Technology (INTA) of Spain
MOMA-MS	Provider: GSFC Lead Center: GSFC Performing Center(s): GSFC Cost Share Partner(s): N/A

MARS EXPLORATION

Program Element	Provider
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 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 spacecraft and flight systems for the Mars 2020 mission through JPL and the radioisotope power system through the Department of Energy (DOE), taking advantage of the previous investment in the MSL project to maximize heritage. By using contracts existing from the MSL project to procure new versions of the as-flown hardware, JPL plans to achieve the lowest possible costs. NASA competitively selected the Mars 2020 investigations payload.

MAJOR CONTRACTS/AWARDS

NASA released an AO for the Mars 2020 rover instruments on September 24, 2013, with selections announced on July 31, 2014. NASA selected seven science instruments and exploration technology investigations for the Mars Rover 2020 payload.

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Mars Organic Molecule Analyzer (MOMA)	20.9	--	**14.3**	6.8	5.2	4.6	3.0
Mars Rover 2020	78.3	--	**228.0**	377.5	397.5	370.2	308.0
ExoMars	3.1	--	**2.6**	1.4	1.4	1.5	1.5
Mars Program Management	18.1	--	**19.1**	19.2	19.3	19.5	19.5
Mars Future Missions	0.5	--	**0.0**	0.0	0.0	0.0	0.0
Mars Mission Operations	1.5	--	**1.8**	1.9	1.9	1.9	1.9
Mars Research and Analysis	19.5	--	**10.0**	10.0	10.0	10.0	10.0
Mars Technology	4.0	--	**4.0**	4.0	9.0	8.3	4.8
2011 Mars Science Lab	69.6	--	**58.0**	58.0	58.0	58.0	58.0
Mars Reconnaissance Orbiter 2005 (MRO)	29.2	--	**29.5**	30.5	30.5	30.5	30.5
Mars Exploration Rover 2003	14.0	--	**0.0**	0.0	0.0	0.0	0.0
Mars Odyssey 2001	12.3	--	**12.3**	0.0	0.0	0.0	0.0
Mars Express	2.1	--	**3.0**	3.0	3.0	3.0	3.0
Mars Atmosphere & Volatile EvolutioN	14.9	--	**29.3**	27.0	25.5	24.0	24.0
Total Budget	**288.0**	--	**411.9**	**539.3**	**561.3**	**531.5**	**464.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Other Missions and Data Analysis includes the Mars 2020 Rover that is in formulation. It also includes the NASA contribution to the European Space Agency ExoMars 2018 rover, the operating Mars missions, Mars Research and Analysis, Mars Technology, and Mars Program Management. Also included are the NASA-contributed Electra communications radios that NASA delivered to the European Space Agency to fly on their 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-MS is the NASA-provided subsystem of MOMA, which is in development. It is composed of a dual-source mass spectrometer to detect a wide range of organic molecules in Martian samples. Organic structure and distribution can be indicators of past or present life.

OTHER MISSIONS AND DATA ANALYSIS

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 2014, the MOMA-MS project successfully completed its Confirmation Review. In FY 2015, MOMA-MS will conduct CDR and begin production of the flight model in preparation for delivery to ESA.

MARS 2020

The 2020 Mars science rover is a mission, currently in formulation, that will advance the scientific priorities detailed in the National Research Council's Planetary Science Decadal Survey, entitled "Vision and Voyages for Planetary Science in the Decade 2013-2022." In addition, the mission provides an opportunity for payload elements provided by the HEOMD and the Space Technology Mission Directorate (STMD) that are aligned with their priorities and compatible with SMD priorities for the Mars 2020 mission. The Mars 2020 mission is the essential next step in an evolving program of Mars exploration that will ultimately involve human exploration.

The 2020 mission will deliver a rover to the surface of Mars, designed to take scientific in situ measurements that focus on establishing the geologic context of the landing area, assessing the habitability and preservation potential of biosignatures of that area, and searching for potential biosignatures in the rock record. The measurements will consist of imaging, determining mineralogy and chemistry, and detecting the presence of and broadly characterizing organic matter. A wide range of scales (from meters to microscopic) will be covered in order to provide coordinated and nested measurements, allowing key science advances and enhancing the ability to detect and interpret the geology, mineralogy, chemistry and potential biosignatures of the Martian surface. The mission will also acquire, encapsulate, and cache individual samples of Martian material for possible return to Earth by a subsequent mission. The mission will also acquire, encapsulate, and cache individual samples of Martian material for possible return to Earth by a subsequent mission. NASA and ESA telecommunications relay assets in Mars orbit will support the mission.

Recent Achievements

During FY 2014, the Mars 2020 rover project entered formulation after a successful KDP-A. NASA selected payloads for the Mars 2020 rover mission, including two contributed by international partners and one to demonstrate a needed human exploration technology.

EXOMARS

The ESA Exobiology on Mars (ExoMars) program is a series of missions designed to understand if life ever existed on Mars. The first mission in the ExoMars program is the 2016 Trace Gas Orbiter (TGO).

OTHER MISSIONS AND DATA ANALYSIS

For this mission, NASA contributed two Electra telecommunication radios, identical to those used successfully on NASA's Mars Reconnaissance Orbiter and MAVEN. Electra acts as a communications relay and navigation aid for Mars spacecraft. Electra's ultra high frequency (UHF) radios support navigation, command, and data-return needs.

Recent Achievements

In FY 2014 NASA delivered the two Electra UHF radio flight units to ESA, one in June 2014 and the other in September 2014. ESA installed both units on the 2016 ExoMars/TGO spacecraft and successfully tested them in preparation for launch in 2016.

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 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; and
- Critical Data Products, which provides data for the safe arrival, aero-maneuver, entry, descent, and landing at Mars.

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 fundamental measurements and discoveries and testable hypotheses about the Martian environment through these programs.

Recent Achievements

The Mars R&A program provided funding for more than 200 research projects, with 62 new awards in FY 2014 and six new graduate student research fellowships. These projects increase our scientific understanding of Mars' geology and environment, disseminating the results through publication in the scientific literature. Mars R&A also funded work to identify potential hazards and landing sites for future missions, including human missions, and a program for scientists to participate in models and observations of Comet Siding Spring, which passed very close to Mars in October 2014.

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 2014, the Mars Technology Development program advanced a variety of technologies to enable and improve future missions to Mars. Two technologies (Lander Vision System and Fast Traverse) achieved their maturity goals, and are candidates for use on future Mars missions, such as the Mars 2020 rover mission.

Operating Missions

2011 MARS SCIENCE LAB

MSL and its Curiosity rover, which successfully landed in August 2012, has completed its prime mission exploration activities. The Curiosity rover is exploring and quantitatively assessing regions on Mars as potential past habitats for life. Curiosity 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, and making measurements of the Martian atmosphere, the radiation environment, and the weather. 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 rover to make use of a nuclear power source, which gives the rover the ability to travel up to 12 miles during the 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 was the arrival at its prime science target - the base of Mt. Sharp. Driving more than 6.2 miles from the landing site, this is the first rover ever to traverse outside its landing ellipse. At Mt. Sharp, the rover is examining the local surface along the way. One key finding from the data returned by Curiosity is the discovery that Mars was once habitable. In addition, the measured isotope ratios point to the significant loss (over 85 percent) of the Martian atmosphere. 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. 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 1.0 Sievert, which represents an approximate 5 percent increase in the risk of developing fatal cancer. 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 third 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 the Martian atmosphere transports dust and water. 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, including continuing discoveries of warm-season flows of salty water. The camera also identified and characterized the landing site for the Curiosity rover and is now identifying the landing sites targets for the 2016 InSight Mars lander. MRO will also identify landing sites for future landers in 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

In addition to the extensive landing site targets observations for the ExoMars and InSight missions, MRO data continues to reveal a growing collection of evidence indicating that the present surface of Mars is still geologically active. MRO showed that the Mars carbon dioxide cycle is responsible for much of the present surface modification at high latitudes, including seasonally significant gully formation. MRO also continues the investigation of the dark markings or streaks, 0.5 to 5 meters in 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. MRO recently found the streaks in the neighborhood of the Curiosity rover.

MARS EXPLORATION ROVER 2003

For over 10 years, the Mars Exploration Rover Opportunity has explored geological settings on the surface of Mars. It has expanded understanding of the history and the geological processes that shaped Mars, particularly those involving water. Opportunity has trekked for 25 miles across the Martian surface, (recently breaking the distance record for traverse on a planetary body beyond Earth), conducting field geology, making atmospheric observations, finding evidence of ancient Martian environments where intermittently wet and habitable conditions existed, and sending back to Earth well over 200,000 spectacular, high-resolution images. After a long, productive mission life, Opportunity has started to show signs of age, including recent problems with its flash memory. NASA plans to end Opportunity operations by FY 2016.

Recent Achievements

In FY 2014, the Mars Exploration Rover Opportunity continued to explore the area around Endeavour Crater. Examination of a rock that “mysteriously” appeared in images (dubbed Pinnacle Island) revealed high levels of elements such as manganese and sulfur, suggesting these water-soluble ingredients were concentrated in the rock by the action of water. It was determined that the rock had broken off an outcrop and landed in view of the rover. At a location called Pillinger’s Point, the rover determined that bright-toned veins in the rock contain calcium sulfate. Scientists deduce that water deposited this mineral as it moved through fractures on Endeavour’s rim. The rover earlier found veins of calcium sulfate farther north along the rim. Opportunity took an image of Comet Siding Spring as it passed close to Mars and continues to move south along the edge of Endeavour Crater toward a location that evidence from orbital spacecraft indicate may contain a mineral called montmorillonite, which may indicate the past presence of mild, non-acidic water.

MARS ODYSSEY 2001

Mars Odyssey, currently in its sixth 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 continues that role for the Opportunity and Curiosity rovers.

Recent Achievements

Mars Odyssey is the longest-lived Martian spacecraft in history. 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 Mb of data per week on average. In addition, it continues to be a key communications link for Mars Science Laboratory/Curiosity transmitting 885 Mb 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 (MARSIS) and Analyzer of Space Plasmas and Energetic Atoms (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.

OTHER MISSIONS AND DATA ANALYSIS

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 AND 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 contingency relay support during its primary science mission and eventually evolve into a more regular communications role.

Recent Achievements

In FY 2014, MAVEN continued its excellent cost and schedule performance through launch, cruise, and arrival at Mars. MAVEN launched in November 2013 and achieved successful Mars Orbit Insertion in September 2014. MAVEN is transitioning to science phase operations, which will begin in November 2014. Even during its transition operations, MAVEN was able to observe Mars' atmosphere before and after the arrival of Comet Siding Spring.

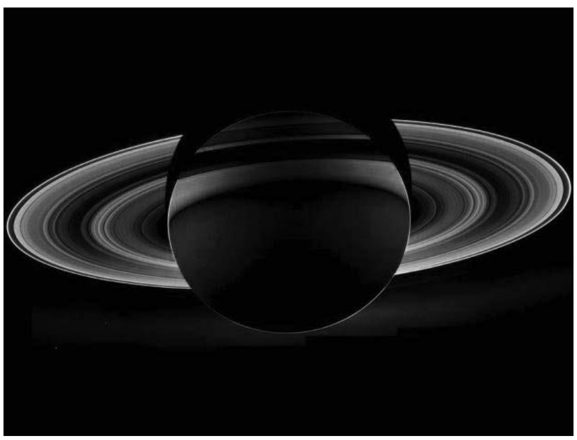
OUTER PLANETS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
JUICE - Jupiter Icy Moons Explorer	5.3	--	**18.9**	20.5	12.9	4.1	2.0
Jupiter Europa	80.0	100.0	**30.0**	30.0	50.0	75.0	100.0
Outer Planets Research	15.5	--	**8.5**	8.5	8.5	8.5	8.5
Cassini	51.6	--	**58.8**	58.7	10.2	0.0	0.0
Total Budget	**152.4**	**--**	**116.2**	**117.7**	**81.6**	**87.6**	**110.5**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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 2016

For the first time, the budget supports the formulation and development of a Europa Mission, allowing NASA to begin project formulation, Phase A.

ACHIEVEMENTS IN FY 2014

Achievements of the Cassini mission this year include new discoveries from Saturn, Titan, and Enceladus. The mission completed the highest inclination portion of its orbits, which allowed the spacecraft to study the polar regions on Saturn and the rings circling the planet. The science team continued analyzing data from earlier flybys of Titan and other moons. At Titan, Cassini monitored the changing seasons, observing clouds and rainstorms on the moon and detecting evidence of lakes drying up and leaving evaporites behind. Cassini also observed a mysterious island in one of the lakes that seems to appear and disappear. At Saturn, Cassini was able to gather the best images yet of the Hexagon, the unique six-sided jet stream centered at Saturn's north pole, which provides extensive information on the atmospheric dynamics at Saturn. The spacecraft caught what could be the formation of a new moon in Saturn's rings, something never before seen. For Enceladus, scientists analyzing data were able to map over 100 water geysers from this tiny and amazing moon. Cassini data provided more evidence of a moderately sized underground water ocean on Enceladus.

NASA continued pre-formulation activities for a Europa mission. Most notably, NASA study teams further developed the Europa fly-by mission concept, determining that NASA could accomplish over 80 percent of the science that a Europa Orbiter would achieve for about 50 percent of the cost with a mission that stays in Jupiter orbit and conducts many focused flybys of Europa. NASA completed a series of trade studies, technology efforts, and independent reviews, including determining the technical feasibility of conducting the flyby mission concept with solar power. NASA conducted a Center-led Mission Concept Review on the flyby mission design. NASA also addressed a long-standing risk for a Europa mission by continuing the funding of 15 grants for instrument development and risk reduction under the Instrument Concepts for Europa Exploration program, and solicited proposals for flight instruments for a potential mission to Europa.

WORK IN PROGRESS IN FY 2015

Jupiter Icy Moons Explorer (JUICE) instruments development will continue based on the approved schedule. ESA mission adoption, a critical step in the approval of the mission, occurred in November 2014.

Europa instrument proposals will undergo thorough evaluations of science, cost, technical, and management with awards expected in the spring of 2015. Pre-formulation will continue with risk reduction activities in all key science and engineering areas. NASA plans to conduct a Europa mission Agency KDP-A prior to entering formulation in spring 2015.

Cassini will continue to observe seasonal and temporal change in the Saturn system to understand hemispherically asymmetric behavior on Titan, the role of sunlight in Enceladus plume activity, and the origin of surprising asymmetry in Saturnian polar circulation. During FY 2015, Cassini will fly by Titan another eight times and begin lowering the inclination of its orbit to enable it to fly by Dione and Enceladus as well.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

JUICE design activities will continue in 2016 in preparation for Instrument Preliminary Design reviews, with the start of implementation activities in the summer of 2016.

Mission Planning and Other Projects

JUPITER ICY MOONS EXPLORER (JUICE)

NASA is collaborating with ESA on this ESA-led mission to Ganymede and the Jupiter system. ESA plans to launch the mission in 2022 for arrival at Jupiter in 2030. It has a tentative model payload of 11 scientific instruments. The NASA contribution consists of three separate projects: one full instrument, Ultra Violet Spectrometer; two sensors for the Particle Environment Package suite of instruments; and the transmitter and receiver hardware for the Radar for Icy Moon Exploration instrument.

OUTER PLANETS

JUPITER EUROPA

Jupiter's moon Europa is one of the most likely places to find current life beyond our Earth. For over 15 years NASA has developed concepts to explore Europa and determine if it is habitable based on characteristics of its vast oceans (twice the size of all of Earth's oceans combined), the ice surface – ocean interface, the chemical composition of the intriguing, irregular brown surface areas, and the current geologic activity providing energy to the system. After thorough investigation of concept options, the study teams have identified a flyby concept that delivers the most science for the least cost and risk of all the concepts studied. The flyby concept appears to be feasible based on solar power and without requiring any new technology development, despite the harsh radiation environment that the spacecraft will encounter during the flybys.

NASA will establish a Europa project in FY 2015, initiating the formulation phase. In FY 2016, the project will formulate requirements, architecture, planetary protection requirements, risk identification and mitigation plans, cost and schedule range estimates, and payload accommodation for a potential mission to Europa. The leading mission concept may require significant modification depending on what researchers learn in FY 2015 about the existence of active plumes from Europa's south pole and the accommodations requirements in the awarded instrument proposals.

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).

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. 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. 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 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. The Cassini mission will end after the proximal orbits when a final encounter with Titan will send the Cassini probe into Saturn's atmosphere.

OUTER PLANETS

Program Schedule

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 Management & Commitments

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 ESA built the Huygens probe.
JUICE	Provider: JPL (RIME), APL (PEP), SWRI (UVS) Lead Center: MSFC Performing Center(s): Cost Share Partner(s): ESA

Acquisition Strategy

Cassini Data Analysis is included in the annual ROSES NASA Research Announcement. All major acquisitions and contracts for Cassini are in place.

OUTER PLANETS

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Systems Require-ment Review & Mission Definition Review	SRB	NET Jun 2016	Ensure that requirements and concept defined for the project will satisfy mission goals and the concept is complete, feasible, and consistent with available resources.	TBD	NET Mar 2018

TECHNOLOGY

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**143.1**	**--**	**141.7**	**155.5**	**164.4**	**168.5**	**184.7**

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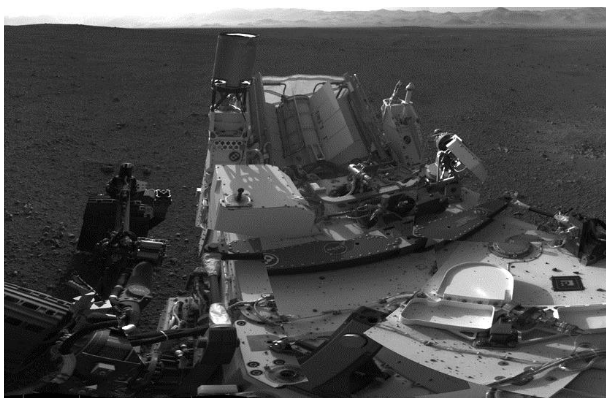

The Mars Science Laboratory rover, Curiosity, took this self-portrait, which shows its Multi-Mission Radioisotope Thermoelectric Generator, or MMRTG. This power source was selected for the rover's mission to provide greater flexibility in accessing difficult or remote terrain, to enable effective operation 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, trips far from the Sun where the spacecraft 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, as well as targeted investments in high payoff technologies or technologies addressing specific mission needs, such as advanced electric propulsion and power systems.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The Plutonium budget decreases $11 million from the projection in the FY 2015 request, due to the delayed need for new plutonium (Pu)-238 for projected planetary science radioisotope missions.

ACHIEVEMENTS IN FY 2014

The RPS program continued to advance the Stirling radioisotope generator technology, including solving key manufacturing issues, and completing the assembly of a second engineering unit based on the existing design, which began operation in September 2014. This achievement retires risk for the development of future Stirling power systems to address the continued need for high efficiency to mitigate plutonium supply issues and address emerging mission requirements.

The RPS program has successfully matured advanced thermoelectric power conversion technology in the laboratory, and has begun transferring it to industry for potential future applications to advanced or enhanced Radioisotope Thermoelectric Generators. The program funded the systems studies that identified the potential benefits and defined the potential designs for such systems.

Finally, the RPS program sponsored an internal study of the future nuclear power needs for planetary exploration in order to guide future investments in technology and development projects.

WORK IN PROGRESS IN FY 2015

The program is sustaining the Agency's investment in free-piston Stirling technology by advancing the maturity through in-house testing of the second engineering unit and a series of development converters 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 2014 successes in advancing transformational technologies to flight for the benefit of future planetary missions.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The RPS program will continue to retire risk for future development of a Stirling radioisotope power system through ground testing and a potential flight demonstration. RPS will continue the development of advanced radioisotope thermoelectric generator couples by validating lifetime and four-couple module power. The RPS program will also continue to transition mature thermoelectric technology to industry to support potential future RTG developments and enhancements. RPS will also fund DOE safety testing to verify safety models for solid upper stages.

Program Elements

PLUTONIUM

NASA and DOE are implementing a 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.

DOE RADIOISOTOPE POWER SYSTEM INFRASTRUCTURE

The DOE Space and Defense Infrastructure subprogram has begun charging customers for the cost of maintaining its Pu-238 infrastructure. Funding to support this infrastructure is now included in NASA's budget request. NASA is currently the only user of radioisotope power systems.

EUROPA TECHNOLOGY

In FY 2015, NASA will investigate technologies for the study and characterization of the surface and subsurface of Europa.

TECHNOLOGY

ADVANCED TECHNOLOGY

NASA continues to study future planetary mission requirements to identify needs for technology investment. NASA also engages with stakeholders to ensure the relevance and priorities for existing investments. NASA will continue investments in advanced energy production and conversion technologies and spacecraft technologies that can uniquely enable future planetary missions, including a new Stirling-based generator for radioisotope power systems.

Operating Missions

ADVANCED MULTI-MISSION OPERATION SYSTEM (AMMOS)

AMMOS provides multi-mission operations, navigation, design, and training tools and services 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, command, control, assessment, 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 and services lowers individual mission cost and risk by providing a mature base for mission operations systems at significantly reduced development time.

AMMOS also provides support to our international space agency partners, on an as-needed basis. This support typically pertains to navigation assistance and scheduling of NASA's Deep Space Network (DSN) assets. NASA supports this activity when it is in the best interest of the Agency.

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

TECHNOLOGY

Program Element	Provider
AMMOS	Provider: JPL Lead Center: JPL Performing Center(s): JPL Cost Share Partner(s): N/A

Acquisition Strategy

DOE provides radioisotope systems, production operations, and the Plutonium Restart project on a reimbursable basis.

ASTROPHYSICS

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Astrophysics Research	145.2	--	**187.7**	228.1	226.9	229.1	253.2
Cosmic Origins	224.2	--	**199.3**	200.4	199.1	207.9	244.5
Physics of the Cosmos	112.6	--	**107.6**	81.9	86.9	96.0	106.6
Exoplanet Exploration	106.7	--	**64.2**	67.8	148.4	302.2	365.7
Astrophysics Explorer	89.6	--	**150.3**	148.2	108.1	170.4	168.3
Total Budget	**678.3**	**--**	**709.1**	**726.5**	**769.5**	**1005.5**	**1138.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Astrophysics

ASTROPHYSICS RESEARCH

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Astrophysics Research and Analysis	63.3	--	**72.3**	73.7	73.0	73.0	73.0
Balloon Project	32.9	--	**34.2**	34.3	37.3	37.4	37.4
Other Missions and Data Analysis	49.1	--	**81.1**	120.1	116.6	118.7	142.8
Total Budget	**145.2**	--	**187.7**	**228.1**	**226.9**	**229.1**	**253.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

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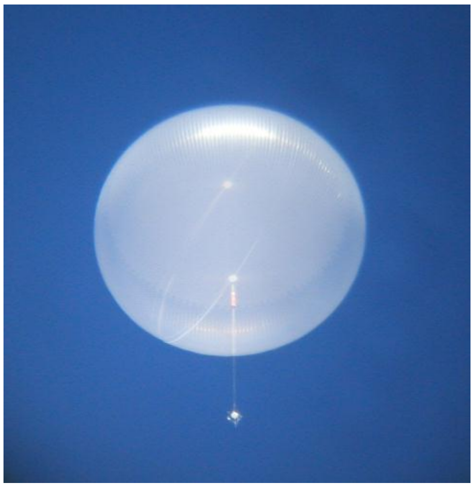


Photograph of 7 MCF Super-Pressure balloon at float. The SPB is a major technological advance that offers an order of magnitude increase in flight capability.

The Astrophysics Research program develops innovative technologies for future missions to explore and understand the cosmos, from the nature of planets circling other stars to the birth of distant galaxies and the earliest cosmic history. High-altitude balloon and sounding rocket flights test new types of instruments. These flights also allow a quick response to unexpected events, such as the appearance of a new comet.

The program provides basic research awards for scientists to test their theories, and to understand how they can best use data from NASA missions to gain new knowledge from the cosmos. Awardees analyze the data from Astrophysics missions to understand astronomical events, such as the explosion of a star or the fingerprints of early cosmic history in the microwave background.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 request reflects the allocation of the budget to extend operating Astrophysics missions in response to the Astrophysics Senior Review of operating missions, held in spring 2014.

ACHIEVEMENTS IN FY 2014

In 2014, NASA made the first awards for Theory and Computational Astrophysics Networks, a new joint program element with the Astronomical Sciences Division of the National Science Foundation (NSF), created in response to a recommendation in the 2010 Astrophysics Decadal Survey. The three-year awards fund networked teams, distributed across multiple distinct institutions, addressing key challenges of a scale and complexity that require sustained, multi-institutional collaborations. The networks will address topics 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?

ASTROPHYSICS RESEARCH

Three groups launched experiments on sounding rockets in 2014. One experiment used an array of micro-calorimeters, cooled nearly to absolute zero that can measure the energy of X-rays from hot gas between the stars with unprecedented accuracy. Another payload showed unexpectedly large quantities of hydrogen gas streaming from Comet ISON as it approached the Sun. The third payload observed a hot young star. Silicon, iron, and oxygen in the surrounding gas left over as the star formed blocked the star's ultraviolet light at characteristic wavelengths.

The Balloon campaign in Hawaii evaluated new technologies for landing heavy loads on Mars in support of the Space Technology Mission Directorate. Using the thin air of the Earth's upper atmosphere as a stand-in for the red planet, the flight used a combination of a large inflatable doughnut and a large parachute to slow the test vehicle's descent.

The Balloon project also supported a campaign with eight conventional flights from Fort Sumner, New Mexico. One of the flights tested technology to study brief, powerful bursts of gamma rays, which may signal the birth of a black hole as the core of an exploding star collapses. Another payload aimed to measure the polarization of energetic X-rays from gas circling close to black holes. Yet another flight observed Comet Siding Spring as it approached Mars. For the first time at the balloon facility in Fort Sumner, NASA launched three flights on three consecutive days.

WORK IN PROGRESS IN FY 2015

Research on exoplanets will confirm the nature of exoplanet candidates identified by the Kepler project, and explore the nature of planets circling other stars.

Four groups plan to launch Astrophysics experiments on sounding rockets in 2015. One of the experiments will measure the light of the infrared cosmic background that lurks between galaxies. Another experiment will provide a uniform brightness calibration for stars from infrared to ultraviolet wavelengths, which is required to link data from different space telescopes together accurately. A third experiment will test a novel grating for X-ray spectroscopy, and the fourth experiment will measure the ultraviolet light from young stars.

The Balloon project plans to support the annual Antarctic long-duration balloon flights, campaigns to Hawaii and New Zealand, as well as a campaign with about eight conventional flights from Fort Sumner.

NASA plans to launch three balloon payloads from Antarctica. One of the payloads, the first science payload to fly on the 18.8 million cubic foot Super Pressure Balloon (SPB), will measure the energy, direction, and polarization of soft gamma rays with unprecedented accuracy. The payload will downlink its data in real time, enabling tracking of the payload and facilitating its recovery. Another payload will measure the radiation that fills the Milky Way and map the tiny fluctuations in the cosmic microwave background that are the seeds of the largest cosmic structures. Lastly, one of the largest balloon payloads ever flown will detect radio signals from ultra-high energy neutrino interactions in the deep Antarctic ice and extremely high-energy cosmic rays when they penetrate the Earth's atmosphere.

The Hawaii campaign will again support flights for the Space Technology Mission Directorate and the Jet Propulsion Laboratory (JPL) to evaluate new technologies for landing heavy payloads on Mars. One of the planned balloon flights from Fort Sumner will map the cosmic microwave background, and the other will test a new technology for direct imaging of exoplanets.

ASTROPHYSICS RESEARCH

NASA is configuring the successful balloon-borne Cosmic Ray Energetics and Mass (CREAM) payload for a one-year minimum, three-year goal exposure on the International Space Station (ISS). 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 with international collaboration teams from the United States, South Korea, Mexico, and France.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will continue a competed Astrophysics Research program, with emphasis on suborbital payloads and on development of key technologies for use in future missions. Theoretical work will provide the foundation to develop science requirements for new missions. Research on exoplanets will confirm the nature of Kepler exoplanet candidates, and explore the nature of planets circling other stars.

The Balloon project plans to support three campaigns outside the continental US, including the annual Antarctic long-duration balloon flights, a SPB launch from New Zealand, and a campaign to Hawaii, plus one domestic campaign with about eight conventional flights from Fort Sumner. The Hawaii campaign would again support technology flights for the Space Technology Mission Directorate and JPL, to test new technologies for landing heavy payloads on Mars.

The ISS-CREAM payload should be in its first full-year of exposure on the ISS. Its science goal is to extend the energy reach of direct measurements of cosmic rays to the highest energy possible to probe their origin, acceleration, and propagation. The long exposure above the atmosphere offers more than an order of magnitude improvement in data. ISS-CREAM will pursue the balloon payload discoveries with much greater statistical accuracy and lower background.

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 and Analysis solicits technology development for detectors and instruments for potential use on future space flight missions and science and technology investigations using sounding rockets, high-altitude balloons, and similar platforms. A new type of scientific instrument often flies first on a stratospheric balloon mission or on a sounding rocket flight, which takes it briefly outside Earth's atmosphere. Instruments for balloons and sounding rockets are not as expensive as those for orbital missions, and experimenters can build them quickly to respond to unexpected opportunities, such as a newly discovered comet. The experimenter usually retrieves the equipment after the flight so that novel instruments can be tested, improved, and flown again. 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 element 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.

The Exoplanet Research Program element solicits observations to detect and characterize planets around other stars, and their origins.

The Nancy Grace Roman Technology Fellowship develops early career researchers, who could lead future flight instruments and missions. NASA selects Fellows initially for one year, during which they conduct preliminary work and develop a detailed plan. NASA selects a subset of the fellows for a four-year award to complete the investigation.

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, heliospheric physics, and Earth upper-atmosphere chemistry as well as selected planetary science, such as comet observations. 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 an 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.

ASTROPHYSICS RESEARCH

Date	Significant Event
Feb 2015	NASA Research Announcement (NRA) Solicitation
Apr 2015	Senior Review Data Archives
Feb 2016	NRA Solicitation
Mar 2016	Senior Review Operating Missions
Feb 2017	NRA Solicitation
Feb 2018	NRA Solicitation
Mar 2018	Senior Review Operating Missions
Apr 2019	Senior Review Data Archives
Mar 2020	Senior Review Operating Missions

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: Wallops Flight Facility (WFF) Lead Center: WFF Performing Center(s): WFF, HQ 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.

ASTROPHYSICS RESEARCH

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Balloon Management	Physical Science Laboratory, New Mexico State University will continue to operate the facility in Palestine, TX until the new vendor (Orbital Science Corporation) transitions in February 2015	Palestine, TX and other balloon launch sites

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	2014	A comparative evaluation of Astrophysics operating missions	Ranking of missions, citing strengths and weaknesses	2016, 2018, 2020

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Astrophysics Directed R&T	0.0	--	**8.6**	10.0	10.9	9.9	35.9
Contract Administration, Audit & Quality Assurance Services	13.0	--	**16.0**	16.0	16.1	16.1	16.1
SMD STEM Activities	0.9	--	**20.0**	20.0	20.0	20.0	20.0
Astrophysics Senior Review	0.0	--	**0.2**	37.7	33.2	36.2	34.3
Astrophysics Data Program	17.0	--	**17.6**	17.6	17.6	17.6	17.6
Astrophysics Data Curation and Archival Research	18.2	--	**18.7**	18.8	18.8	18.9	18.9
Total Budget	**49.1**	**--**	**81.1**	**120.1**	**116.6**	**118.7**	**142.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Launch of the Cosmic Infrared Background Experiment rocket (CIBER) sounding rocket mission from WFF in June 2013 to measure the light of the earliest stars and galaxies. Recently, CIBER detected a surprising surplus of infrared light in the dark space between galaxies, a diffuse cosmic glow as bright as all known galaxies combined.

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.

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.

OTHER MISSIONS AND DATA ANALYSIS

SMD STEM ACTIVITIES

The FY 2016 Budget supports restructured science education efforts that are coordinated across all Science Mission Directorate (SMD) science disciplines. During FY 2016, SMD will award new cooperative agreement(s) to enable SMD scientists and engineers to engage with learners of all ages, consistent with the agency's overall efforts to support the goals of the Federal STEM Education 5-Year Strategic Plan. This restructured education program will allow for more streamlined and effective implementation of SMD education efforts. It also will provide a return on the US taxpayer's investment in NASA's scientific research, effectively and efficiently linking NASA science exploration of our home planet, the solar system, and the universe beyond with educational environments.

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. The next senior review will take place in spring 2016.

ASTROPHYSICS DATA ANALYSIS PROGRAM (ADAP)

The Astrophysics Data Analysis Program (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 the 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, Chandra, and the Stratospheric Observatory for Infrared Astronomy (SOFIA).

Recent Achievements

The number of proposals submitted to ADAP has tripled over the last several years, reflecting a dramatic increase in demand for 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 2014, the program received 306 proposals in response to its annual solicitation. Of those, NASA selected 62 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 the Wide-field Infrared Survey Explorer (WISE) to understand the evolution of planetary systems and circumstellar disks around stars of different ages and spectral types;
- Combining Chandra, X-ray Multi-Mirror Mission (XMM-Newton), and Nuclear Spectroscopic Telescope Array (NuSTAR) observations and archival data to understand the physical processes that operate at the heart of a black hole;

- Using Kepler data to statistically characterize the atmospheres of super-Earth, mini-Neptune, and Neptune-sized exoplanets;
- Combining Suzaku, XMM-Newton, and NuSTAR data to understand how massive binary stellar systems evolve and affect the evolution of both the local and interstellar environment;
- Using Spitzer archival data to quantify and characterize a common and important reservoir of accessible carbon across the universe; and
- Constraining stellar evolution models by using Spitzer and Hubble data to understand star formation history in the early universe.

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. Astrophysics Data Curation and Archival Research (ADCAR) covers the activities of the Astrophysics Data Centers and NASA's participation in the Virtual Astronomical Observatory.

Recent Achievements

The Astrophysics Data Centers are tackling challenges and opportunities presented by a tremendous growth of content. In FY 2014, the Astrophysics Data System Project deployed new Application Programming and User interfaces to increase access to and usability of its platform; it also increased its citation database by 12 percent from the previous year. The Space Telescope archive had 20 million database searches and delivered more than 200 terabytes of data to the astronomical community and the public; more than 1,200 scientific publications used the data. New products included the initial release of the Source Catalog, the Frontier Fields, and the Discovery Portal. The High Energy Astrophysics Science Archive Center has released 582 data sets. The High Energy Astrophysics Science archive also implemented major upgrades to its cloud-based analysis environment, which now supports all the major high-energy astrophysics analysis packages, and to its virtual telescope. The Infrared Science Archive responded to 12 million user queries in FY 2014—the most in its history—and upgraded data access services so that all images and catalogs are now available through Virtual Observatory protocols. The Extragalactic Database improved its efficiency considerably and grew the multi-wavelength object holdings by 21 percent, to 215 million. The archives are collaborating on a joint initiative to provide continued support for critical Virtual Observatory infrastructure as a follow-on to the successful NASA/NSF Virtual Astronomical Observatory program. The NASA Archives accepted responsibility for these services in a smooth transition at the end of FY 2014.

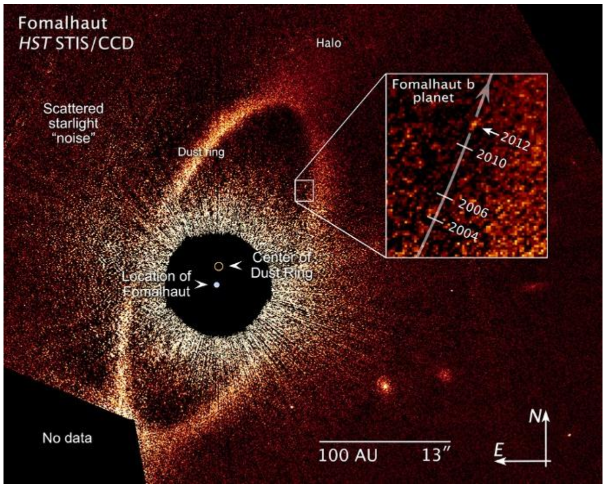
COSMIC ORIGINS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Hubble Space Telescope (HST)	98.3	--	**97.1**	93.5	97.7	89.3	89.3
Stratospheric Observatory for Infrared Astronomy (SOFIA)	84.4	--	**85.2**	85.1	86.2	89.1	91.0
Other Missions and Data Analysis	41.5	--	**17.0**	21.7	15.3	29.5	64.2
Total Budget	**224.2**	--	**199.3**	**200.4**	**199.1**	**207.9**	**244.5**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Newly released Hubble Space Telescope images of a vast debris disk encircling the nearby star Fomalhaut, and of a mysterious planet circling it, may provide forensic evidence of a titanic planetary disruption in the system. The latest Hubble images have allowed a team of astronomers to calculate that the planet follows an unusual elliptical orbit that carries it on a potentially destructive path through the vast dust ring.

"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, and 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/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The budget reflects ongoing support for the SOFIA project.

HUBBLE SPACE TELESCOPE OPERATIONS

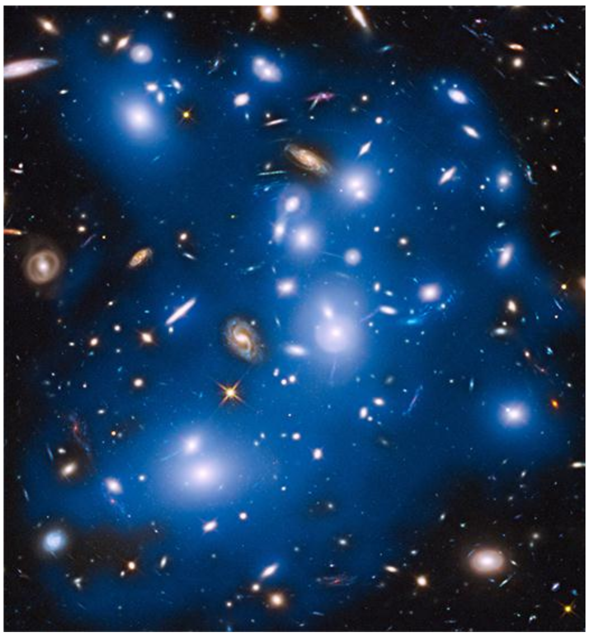
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	98.3	--	97.1	93.5	97.7	89.3	89.3

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



When galaxies group together in massive clusters, some of them can be ripped apart by the gravitational tug of other galaxies. Astronomers using the Hubble Space Telescope to probe the massive galaxy cluster Abell 2744, nicknamed Pandora's Cluster, have found forensic evidence of galaxies torn apart long ago in the form of a phantom-like faint glow, filling the space between the galaxies. This glow comes from stars scattered into intergalactic space because of a galaxy's disintegration.

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, helping resolve 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 by a Space Shuttle crew, completed in 2009, added new batteries, gyroscopes, and instruments to extend its life even further into the future.

April 24, 2015, will mark the start of Hubble's 25th year in orbit. The observatory is currently in its most scientifically productive period.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

Astronomers used Hubble's Wide Field Camera 3 and a technique called transmission spectroscopy to find evidence for clear skies and water vapor in a Neptune-sized planet around the star HAT-P-11. As a planet passes in front of its star, starlight filters through the rim of the planet's atmosphere, and this transmission provides information about the contents of that atmosphere. If molecules like water vapor are present, the molecules absorb some of the starlight, leaving distinct signatures in the light that reaches Earth. Closer to home, Hubble has uncovered three Kuiper Belt objects (KBOs) that NASA's New Horizons spacecraft could potentially visit after it flies by Pluto in July 2015.

HUBBLE SPACE TELESCOPE OPERATIONS

Formulation	Development	Operations

WORK IN PROGRESS IN FY 2015

In FY 2015 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 Hubble's gyroscopes.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The Space Telescope Science Institute (STScI), which manages Hubble's science program, will select Cycle 24 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. Hubble will be included in the Astrophysics Senior Review of Operating Missions in spring 2016. Hubble Fellowships previously funded by the Cosmic Origins SR&T project, will be funded by HST Operations beginning in FY 2016.

Project Schedule

Date	Significant Event
Jun 2015	Announcement of Selected Cycle 23 Investigations
Dec 2015	Release of Cycle 24 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/ Association of Universities for Research in Astronomy (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
Perform-ance	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

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	84.4	--	85.2	85.1	86.2	89.1	91.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

SOFIA, a joint project of NASA and the German Aerospace Center (DLR), operates from Palmdale, CA. The SOFIA Science Center is located at NASA/ARC. Deployments to the Southern Hemisphere are from Christchurch International Airport in New Zealand.

SOFIA is an airborne astronomical observatory, optimized for infrared wavelengths and capable of observing a wide variety of astronomical objects and phenomena. SOFIA investigates star birth and death and the formation of new planetary systems; identifies complex molecules in space; and observes planets, comets, and asteroids in our solar system, as well as nebulae and dust in galaxies.

SOFIA officially entered the operations phase in May 2014.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The budget assumes ongoing operations of SOFIA.

ACHIEVEMENTS IN FY 2014

SOFIA entered the operational phase after passing its Key Decision Point (KDP) E in May 2014. There were six instruments available to the observing community for Cycle 3 observations. SOFIA made its Heavy Maintenance Visit (HMV) in Germany in July 2014. The HMV renewed critical aircraft systems and upgraded the telescope.

WORK IN PROGRESS IN FY 2015

Germany completed the HMV in November 2014. SOFIA completed Cycle 2 observations in FY 2015. The project is beginning Cycle 3, which includes a six-week deployment to the Southern Hemisphere to observe targets of high interest.

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will commission and use SOFIA's US second-generation instrument, High-resolution Airborne Wideband Camera (HAWC+), in science flights. SOFIA will begin Cycle 4, including another Southern Hemisphere deployment, and select investigations for Cycle 5. SOFIA will be participating in its first Astrophysics Senior Review of Operating Missions in spring 2016.

Project Schedule

Date	Significant Event
Apr 2015	Release of Cycle 4 Call for Proposals
Oct 2015	Announcement of Selected Cycle 4 Investigations

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 Formulation Agreement
Science Operations Center	Science Operations Center will solicit and select new investigations, schedule observations, and manage data acquisition and processing	Provider: ARC/Universities Space Research Association (USRA) Lead Center: ARC Performing Center(s): ARC Cost Share Partner(s): DLR/Deutsches SOFIA Institut (DSI)	N/A
Flight Operations	Flight crew, maintenance, and fuel	Provider: AFRC/Computer Sciences Corporation (CSC) DynCorp Lead Center: AFRC Performing Center(s): AFRC Cost Share Partner(s): DLR/DSI	N/A
Upgraded 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)

STRATOSPHERIC OBSERVATORY FOR INFRARED ASTRONOMY (SOFIA)

Formulation	Development	Operations

Acquisition Strategy

The project has awarded all major contracts.

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	USRA	Palmdale and Moffett Field, CA

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Implementation Review (PIR)	SRB	Aug 2013	Assess program performance and review progress against Full Operational Capability milestone	Ready for Operations and proceed to KDP-E	N/A
Quality	Mission Senior Review Panel	N/A	A comparative evaluation of Astrophysics operating missions	Ranking of missions, citing strengths and weaknesses	2016, 2018, 2020

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Cosmic Origins Program Management	2.6	--	**2.9**	3.0	3.1	3.1	3.1
Cosmic Origins SR&T	10.0	--	**3.5**	9.3	10.9	25.1	58.7
Cosmic Origins Future Missions	0.1	--	**1.0**	0.9	1.3	1.3	2.4
SIRTF/Spitzer	17.3	--	**7.2**	7.5	0.0	0.0	0.0
Herschel	11.6	--	**2.4**	1.0	0.0	0.0	0.0
Total Budget	**41.5**	--	**17.0**	**21.7**	**15.3**	**29.5**	**64.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Massive stars can wreak havoc on their surroundings, as can be seen in this new view of the Carina nebula from Spitzer. 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.

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 ESA on the 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 they analyze data from both observatories.

Mission Planning and Other Projects

COSMIC ORIGINS PROGRAM MANAGEMENT

Cosmic Origins (COR) program management provides programmatic, technical, and business management, as well as program science leadership.

Recent Achievements

The COR program office did an updated analysis of the Hubble Space Telescope disposal timing and requirements, where they verified drift rate analysis at lower altitudes, and monitored relevant technologies. The study concluded the worst-case scenario for Hubble re-entry is no earlier than FY 2027 with a nominal prediction of FY 2036.

OTHER MISSIONS AND DATA ANALYSIS

COSMIC ORIGINS STRATEGIC RESEARCH AND TECHNOLOGY (SR&T)

COR Strategic Research and Technology (SR&T) supports 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.

Recent Achievements

The COR program released its updated Program Annual Technology Report. This report summarizes the status of technology development funded by the program in FY 2014, and describes the prioritization of future technology needs.

A copy of the report is available at http://cor.gsfc.nasa.gov/docs/2014_COR_PATR.pdf.

COSMIC ORIGINS FUTURE MISSIONS

COR Future Missions funding supports future mission concept studies.

Recent Achievements

The program is engaging with the scientific community to lay the groundwork for design studies and technology development that will eventually provide inputs to the 2020 Astronomy and Astrophysics Decadal Survey.

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 that uses 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. NASA accepted the 2014 Senior Review of Operating Missions recommendation to continue Spitzer operations through FY 2016.

Recent Achievements

Spitzer astronomers observed a wide range of objects from within the solar system to the distant regions of the universe. Spitzer observations detected the potential Asteroid Retrieval Mission target 2011MD and determined its most probable size to be about 20 feet in diameter. The exoplanet science community continued to use Spitzer to measure the characteristics of exoplanet systems. Observations were made of the two outermost of the seven exoplanets in the system Kepler-90. An infrared increase in brightness in the star system NGC 2547-ID8 from a dust eruption suggests the possible collisions of asteroids. The star HD 95086, observed by the Spitzer and Herschel space telescopes, identified two dust bands around the star, considered similar to the solar system's asteroid and Kuiper belts. Spitzer mapped an extremely dark, dusty clump of material in the galaxy, estimated to have a mass of 70,000 suns and extending over a region 50 light years in diameter. Scientists believe the dark cores found in this cloud region to create stars as large as 100 suns in mass. The Spitzer and Hubble observatories are nearing completion of the Frontier Fields Initiative, a coordinated effort using Spitzer and Hubble 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 that magnify the extremely distant, faint universe.

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 bulk up with new stars. It has the largest single mirror ever built for a space telescope and 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 onboard 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

Although the Herschel Space Observatory ended astronomical observations upon cryogen exhaustion on April 29, 2013, the NASA Herschel Science Center continues development of data analysis software in collaboration with the ESA Herschel Science Center. The NASA Herschel Science Center continues to host activities that inform the Herschel Space Observatory user community on data analysis techniques and use of the science mission archives. Herschel was 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.

Operating Missions

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 that uses 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. NASA accepted the 2014 Senior Review of Operating Missions recommendation to continue Spitzer operations through FY 2016.

PHYSICS OF THE COSMOS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Other Missions and Data Analysis	112.6	--	**107.6**	81.9	86.9	96.0	106.6
Total Budget	**112.6**	**--**	**107.6**	**81.9**	**86.9**	**96.0**	**106.6**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Images of planetary nebula NGC 2392 show X-ray data from Chandra (purple), depicting the location of million-degree gas near the center of the planetary nebula. Hubble data shows the intricate pattern of the ejected outer layers of the star. // X-ray: NASA/CXC/IAA-CSIC/N. Ruiz, et al.; Optical: NASA/STScI

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 continue to provide answers to these fundamental questions and more. 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 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 the 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

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 request provides funding to extend Fermi, Planck, and XMM-Newton, as recommended by the Astrophysics Senior Review in spring 2014.

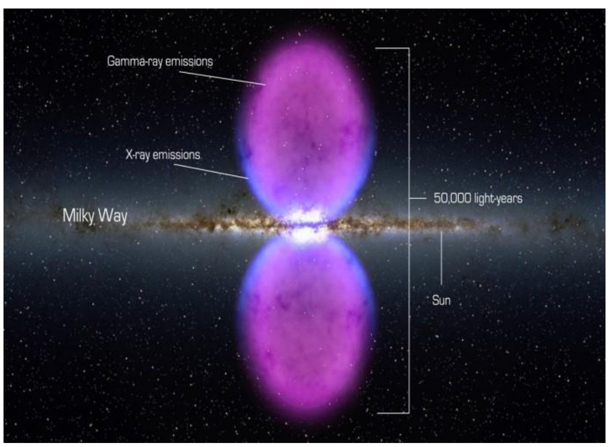
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Physics of the Cosmos SR&T	15.1	--	**12.5**	16.3	19.7	27.6	34.2
Euclid	17.1	--	**14.6**	6.6	6.5	7.7	9.9
Physics of the Cosmos Program Management	2.7	--	**2.8**	2.9	3.0	3.0	3.0
Physics of the Cosmos Future Missions	0.0	--	**1.3**	0.5	2.1	2.1	2.5
Fermi Gamma-ray Space Telescope	14.3	--	**15.9**	0.0	0.0	0.0	0.0
Chandra X-Ray Observatory	55.5	--	**55.4**	55.6	55.6	55.6	57.0
XMM	1.9	--	**2.9**	0.0	0.0	0.0	0.0
Planck	6.2	--	**2.2**	0.0	0.0	0.0	0.0
Total Budget	**112.6**	**--**	**107.6**	**81.9**	**86.9**	**96.0**	**106.6**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



From end to end, the newly discovered gamma-ray bubbles extend 50,000 light-years, or roughly half of the Milky Way's diameter, as shown in this illustration. ROSAT, a Germany-led mission operating in the 1990s , first observed hints of the bubbles' edges in X-rays (blue)y. The gamma rays mapped by Fermi (magenta) extend much farther from the galaxy's plane.

Other Missions and Data Analysis supports PCOS SR&T, PCOS Program Management, PCOS Future Missions, Euclid, Fermi, Chandra, XMM-Newton, and Planck.

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 and continue discussions with ESA on a partnership on their Large 2 Athena mission with a goal to define the partnership. The Space Technology (ST) 7 project is developing enhanced thrusters, scheduled for launch 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 grain of sand, enabling ESA to conduct the LISA Pathfinder gravitational technology demonstration experiment.

OTHER MISSIONS AND DATA ANALYSIS

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 2014 and describes the prioritization of future technology needs.

A copy of the report is at: http://pcos.gsfc.nasa.gov/technology/2014_PCOS_PATR.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 October 2014, NASA signed the startup contract with Teledyne to begin development of the detectors. NASA plans to sign a contract with Teledyne in January 2015 to provide flight detectors for the Euclid mission.

PCOS PROGRAM MANAGEMENT

PCOS program management provides programmatic, technical, and business management, as well as program science leadership.

Recent Achievements

The NASA Astrophysics Division is pursuing a partnership with ESA on their Large 2 mission, Athena, an X-ray Observatory dedicated to high-resolution spectroscopy. The details of the contribution are still under discussion. PCOS is leading the management of this contribution.

PCOS FUTURE MISSIONS

PCOS Future Missions funding supports concept studies of future missions.

Recent Achievements

The program is engaging with the scientific community to lay the groundwork for design studies and technology development that will eventually provide inputs to the 2020 Astronomy and Astrophysics Decadal Survey.

OTHER MISSIONS AND DATA ANALYSIS

Operating Missions

FERMI

The Fermi Gamma-ray Space Telescope explores extreme environments in the universe from black holes to gamma ray bursts, to expand 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. Fermi entered extended mission operations in August 2013.

Recent Achievements

In December of 2013, Fermi adopted a new observing strategy, intended to enable enhanced observations of the center of our galaxy while retaining coverage of the entire sky. This change has made it possible for Fermi to search the inner galaxy for new pulsars and evidence of the presence of dark matter, and to look for gamma rays emitted as a gas cloud passed near the super-massive black hole at the galactic center. Fermi will return to its previous all-sky survey mode of observing in December 2014. Other notable accomplishments by Fermi during the last year include the identification of classical novae as gamma ray sources, the first ever gamma ray measurements of a gravitational lens, and the first detections of seismic vibrations excited by small bursts in magnetars (intensely magnetized neutron stars). The third Fermi Large Area Telescope point source catalogue, planned for release by end of this year, will contain more than 3,000 sources, representing an increase of a factor of ten in the number of known sources since NASA launched Fermi.

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 clusters of galaxies that provide direct evidence for the existence of dark matter, and greatly strengthens 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. Chandra will be included in the Astrophysics Senior Review of Operating Missions in spring 2016.

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. Chandra observed a fast-moving pulsar escaping from a supernova remnant while spewing out a record-breaking jet of high-energy particles, the longest of any object in the Milky Way galaxy. Using precise measurements of how the gravity from the El Gordo galaxy cluster's mass warps images of far more distant background galaxies, astronomers have calculated El Gordo’s mass to be as much as 3 million billion times the mass of our Sun, far exceeding previous mass estimates. An exceptionally close stellar explosion in the nearby M82 Cigar galaxy gave astronomers a unique opportunity to eliminate one of the main possible explanations for what causes the explosion of white dwarfs.

OTHER MISSIONS AND DATA ANALYSIS

X-RAY MULTI-MIRROR MISSION (XMM-NEWTON)

XMM-Newton, an ESA-led mission with substantial NASA contributions, launched in December 1999. XMM-Newton 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. NASA provides the US Guest Observer Facility at GSFC.

Recent Achievements

During the past year, XMM-Newton observations yielded a number of important new science results. XMM-Newton recently discovered a new neutron star close to the supernova remnant Kesteven 79, which has an extreme magnetic field. An outburst of X-rays from the magnetar, likely caused by a dramatic change in the structure of its magnetic field, enabled the detection. XMM-Newton observations have also revealed a unique pair of hidden black holes that orbit around each other in a normal galaxy. The discovery marks the first candidate for a binary black hole in a quiescent galaxy. In a combined study using XMM-Newton and Chandra, astronomers have found a supermassive black hole six billion light years from Earth, which is spinning extremely rapidly. The observations are the first direct measurement of the spin of such a distant black hole, which advances our understanding of how black holes grow over time.

PLANCK

Planck's objective is to analyze, with the highest accuracy ever achieved, the remnants of 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 of 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. In October 2013, having already placed the spacecraft in its final heliocentric orbit, ESA ended mission operations. NASA accepted the 2014 Senior Review of Operating Missions recommendation to continue Planck data analysis and archival activities through FY 2016.

Recent Achievements

In FY 2014, the Planck team continued to work towards its second data release, expected in late November 2014, which will include polarization data. The team submitted a scientific paper with a preliminary description of the polarization results to the Astronomy and Astrophysics journal in September 2014.

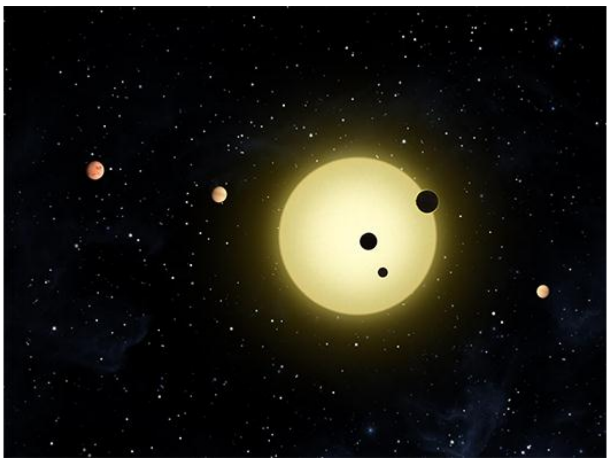
EXOPLANET EXPLORATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Other Missions and Data Analysis	106.7	--	**64.2**	67.8	148.4	302.2	365.7
Total Budget	**106.7**	**--**	**64.2**	**67.8**	**148.4**	**302.2**	**365.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Two new exoplanets, Kepler 20e and 20f, are part of a five-planet system orbiting a sun-like star, similar to the artist's rendering above.

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 1,700 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 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/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 request reflects the new Kepler extended mission, as recommended by the Astrophysics Senior Review in spring 2014.

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Astrophysics Decadal Strategic Mission	56.0	--	**14.0**	21.1	108.2	267.7	331.8
Exoplanet Exploration SR&T	18.1	--	**19.4**	27.6	26.9	26.6	26.0
Exoplanet Exploration Program Management	4.9	--	**5.5**	5.8	6.0	5.9	5.9
Exoplanet Exploration Future Missions	0.8	--	**1.1**	0.5	1.1	2.0	2.0
Keck Operations	5.7	--	**6.1**	6.1	6.2	0.0	0.0
Large Binocular Telescope Interferometer	2.6	--	**1.6**	1.3	0.0	0.0	0.0
Kepler	18.7	--	**16.5**	5.3	0.0	0.0	0.0
Total Budget	**106.7**	**--**	**64.2**	**67.8**	**148.4**	**302.2**	**365.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Relative sizes of habitable-zone planets discovered by the Kepler spacecraft, shown alongside Earth. NASA-Ames / JPL-Caltech.

Mission Planning and Other Projects

ASTROPHYSICS DECADAL STRATEGIC MISSION (ADSM)

NASA is studying options for how to address the NRC 2010 Astronomy and Astrophysics Decadal Survey's highest-ranked 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 exoplanet characterization mission.

Recent Achievements

NASA has continued to develop the conceptual design for the WFIRST mission, which utilizes the Astrophysics Focused Telescope Assets (AFTA) transferred to NASA. The design leverages these telescope assets, while fully meeting the WFIRST requirements articulated in the Decadal Survey and potentially enabling additional science opportunities in exoplanet coronagraphy and guest investigator science. NASA has made significant progress in maturing the technology for the exoplanet high-contrast imaging instrument, along with the infrared detector technology required for the wide-field infrared survey.

OTHER MISSIONS AND DATA ANALYSIS

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 2014, NASA supported approximately 13 competitively selected technology development projects involving 32 different investigators, and 21 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, revealing 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. Technology development continues for the Precision Radial Velocity initiative, to enable better measurements of exoplanet masses. These measurements, in conjunction to the transit photometric information that provides the exoplanet radii, will result in the determination of exoplanet densities and structures before possible follow-ups in the search of chemical biomarkers of life.

Recent Achievements

New coronagraph techniques have demonstrated suppression of starlight glare to a few parts per 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 imagining of exoplanets and the search for spectral biosignatures. 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. Program management coordinates, supports, and tracks the progress of the program's numerous technology development tasks, and oversees the program's portfolio of projects.

Recent Achievements

Scientists have confirmed more than 1,700 exoplanets, with more than 3,200 additional candidates discovered 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 mission opportunities and identification of coronagraph instrument options supporting the WFIRST/AFTA concept study. The program is also engaging with the scientific community to lay the groundwork for design studies and technology development that will eventually provide inputs to the 2020 Astronomy and Astrophysics Decadal Survey.

OTHER MISSIONS AND DATA ANALYSIS

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 (medium size) exoplanet mission concepts. One is a coronagraphic telescope approach and the second is a starshade flying in long-range formation with a separate free flying telescope. An associated technical/engineering study group supported each Science and Technology Definition Team. These teams delivered interim reports in the spring and summer of 2014 and will deliver a final report in February 2015. NASA is initiating follow-on tasks to build upon the work of these teams.

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 Astrophysics and Planetary Science programs. The project allocates observing time for Exoplanet Exploration, Cosmic Origins, and Physics of the Cosmos science goals, as well as solar system objects and direct space missions support. Observation time is competed, selected, and managed by the NASA Exoplanet Science Institute. The Institute recently has awarded a significant portion of the observing time to studies of potential planets identified by Kepler.

Recent Achievements

The Keck Observatory Archive (KOA), in partnership with the NASA Exoplanet Science Institute, ingests and curates existing and new data from the Keck Observatory. During 2014, the KOA completed the ingestion for all 10 Keck active and decommissioned instruments and made these data available to the community. This archive covers more than 14,000 nights of observations and occupies more than 15 terabytes of astronomical data. For the second semester in 2014, NASA received 74 proposals requesting 155 nights to use either of the two Keck telescopes in the Single Aperture mode. This is a healthy oversubscription combined rate of 3 to 1 for both 10-meter telescopes. In the last 6 years, the combined oversubscription rate has varied between 5.7 and 2.5.

LARGE BINOCULAR TELESCOPE INTERFEROMETER

The Large Binocular Telescope Interferometer (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 dust clouds around 50 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 by direct imaging.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

Commissioning and testing of LBTI occupied most of FY 2014. Some delays occurred due to poor weather and observatory performance issues at the host facility on Mount Graham in Arizona. The project expects the LBTI instrument to be ready for full scientific operations by spring 2015. During the commissioning nights, researchers observed actual science targets. The project reduced and analyzed the data, yielding the first science results, compiled in three articles published in the refereed literature.

KEPLER

Kepler, launched in March 2009, surveys stars in the local 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.

In June 2014, NASA approved Kepler to enter a new phase of operations in which the spacecraft observes along the ecliptic plane, opening up new possibilities for discovery. The 2014 Senior Review of Operating Missions favorably evaluated this new operating mode, which compensates for the loss of an attitude control actuator.

Recent Achievements

In February 2014, the Kepler science team announced the discovery of 715 new planets. These newly verified worlds orbit 305 stars, revealing multiple-planet systems much like our own solar system. Nearly 95 percent of these planets are smaller than Neptune, which is almost four times the size of Earth. This discovery marks a significant increase in the number of known small-sized planets more akin to Earth than previously identified exoplanets. Astronomers in July 2014 announced the discovery of a transiting exoplanet with the longest known year. Kepler-421b circles its star once every 704 days. In comparison, Mars orbits our Sun once every 780 days. Most of the 1,800-plus exoplanets discovered to date are much closer to their stars and have much shorter orbital periods.

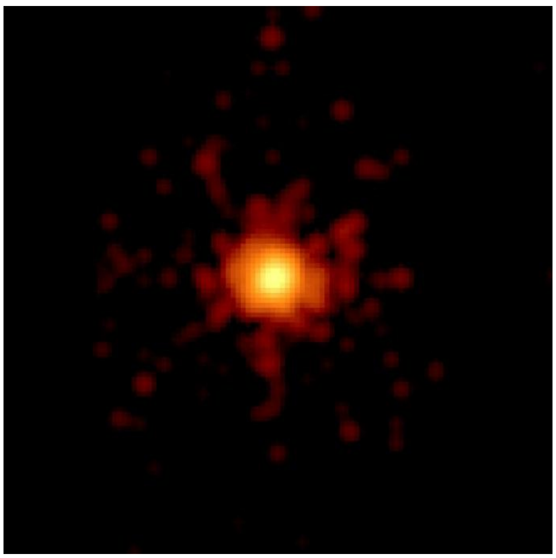
ASTROPHYSICS EXPLORER

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Transiting Exoplanet Survey Satellite (TESS)	35.9	80.1	**88.0**	82.6	17.8	9.1	2.5
Other Missions and Data Analysis	53.7	--	**62.4**	65.6	90.3	161.3	165.8
Total Budget	**89.6**	**--**	**150.3**	**148.2**	**108.1**	**170.4**	**168.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



A titanic burst of energy from a dying star 13 billion light years away has been spotted (center) from Earth.

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.

Medium-Class Explorers (MIDEX) missions cost up to $250 million in total, excluding launch services. Small Explorers (SMEX) may cost about half that total, 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 types are partnering MOs: investigations that are part of a non-NASA space mission. NASA conducts these missions 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 MOs associated with each announcement of opportunity issued for MIDEX and SMEX investigations.

For more information on Explorer missions, see: http://explorers.gsfc.nasa.gov/missions.html.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ASTROPHYSICS EXPLORER

ACHIEVEMENTS IN FY 2014

The NuSTAR mission completed its prime mission phase, and NASA approved a two-year mission extension based on the 2014 Senior Review. The ASTRO-H project delivered the Soft X-Ray Spectrometer (SXS) to the Japan Aerospace Exploration Agency (JAXA). NASA confirmed the Neutron star Interior Composition ExploreR (NICER) to proceed into implementation. The Transiting Exoplanet Survey Satellite (TESS) mission completed formulation. The Explorers Program had its program independent review and released an Announcement of Opportunity (AO) for a new SMEX and MO.

WORK IN PROGRESS IN FY 2015

ASTRO-H will complete its integration and testing and prepare for launch. The NICER mission will continue its development. The TESS mission successfully passed its KDP-C on October 31, 2014, and proceeded into implementation. The teams selected for the next SMEX and MO will begin their concept studies.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The ASTRO-H mission will launch no later than March 2016. The TESS mission will continue its development. The selected SMEX and MO teams will be complete their Phase A studies. NASA will begin the down selection process.

Program Schedule

Date	Significant Event
Sep 2014	AO announcement of SMEX and MO opportunity to propose
Aug 2015	SMEX and Explorer MO KDP-A
Late 2016	AO announcement for MIDEX and MO opportunity to propose
Feb 2017	Down select one SMEX and one MO mission for implementation
Aug 2017	MIDEX and Explorer MO KDP-A
Feb 2019	Down select one MIDEX and one MO mission for implementation
Late 2019	AO announcement of SMEX and MO opportunity to propose

Acquisition Strategy

NASA selects all Explorer missions through a competitive AO.

ASTROPHYSICS EXPLORER

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Indepen-dent Review	SRB	Oct 2014	Assess performance of program	Successful	Sep 2019

TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

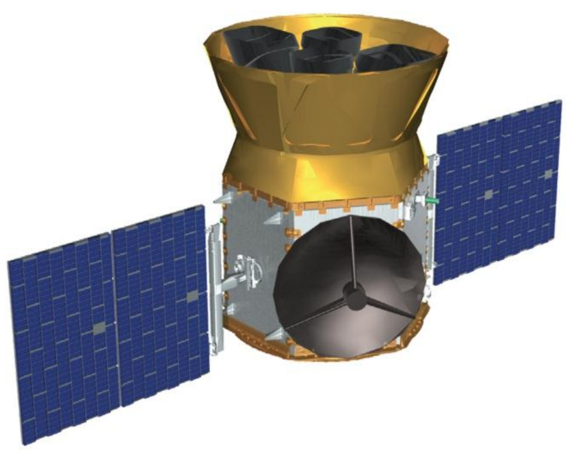
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	26.6	0.5	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	27.1
Development/Implementation	9.1	35.4	80.1	**88.0**	78.8	5.0	0.0	0.0	0.0	296.4
Operations/Close-out	0.0	0.0	0.0	**0.0**	3.8	12.8	9.1	2.5	0.0	28.2
2015 MPAR LCC Estimate	**35.7**	**35.9**	**80.1**	**88.0**	**82.6**	**17.8**	**9.1**	**2.5**	**0.0**	**351.7**
Total Budget	**35.7**	**35.9**	**80.1**	**88.0**	**82.6**	**17.8**	**9.1**	**2.5**	**0.0**	**351.7**
Change from FY 2015				**7.9**						
Percentage change from FY 2015				**9.9%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



The TESS mission will detect small planets with bright host stars in the solar neighborhood, so that other telescopes can perform detailed characterizations of the planets and their atmospheres.

PROJECT PURPOSE

The TESS mission objective is to survey bright nearby stars for transitioning exoplanets over a three-year period, including two years of TESS observations, and an additional third year of follow-up ground-based astronomical observations. The TESS mission will use an array of wide-field cameras to perform an all-sky survey.

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 may discover ~30 Earth sized planets, ~200 Super-Earth sized planets, and ~400 sub-Neptune sized planets around other stars in the solar neighborhood.

With TESS, it will be possible to study the masses, sizes, densities, and orbits of small exoplanets, 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 (JWST), as well as other future large ground-based and space-based telescopes.

TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations

EXPLANATION OF MAJOR CHANGES IN FY 2016

NASA confirmed TESS to enter its Phase C Implementation phase after completing a successful Preliminary Design Review (PDR). This budget reflects the commitments agreed upon at the KDP-C review.

PROJECT PARAMETERS

NASA will launch TESS into a high Earth elliptical orbit. TESS will make observations in the visible and infrared spectrum utilizing four telescopic charge-coupled device (CCD) cameras. TESS will obtain imagery from both northern and southern hemispheres of the sky. TESS will orbit the Earth every 13.7 days. TESS will downlink, via KA-band, the data it has collected over a period of approximately five hours each orbit. TESS will be a three axis-stabilized spacecraft using both momentum wheels and hydrazine thrusters.

ACHIEVEMENTS IN FY 2014

TESS completed the Systems Requirements Review (SRR) in February 2014 and the PDR in September 2014.

WORK IN PROGRESS IN FY 2015

NASA confirmed TESS to begin implementation at its KDP-C review on October 31, 2014.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

TESS will continue its development of the instrument and spacecraft bus elements leading to its system integration review in October 2016.

SCHEDULE COMMITMENTS/KEY MILESTONES

NASA plans to launch TESS in June 2018 to begin a three-year prime mission.

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-C	Nov 2014	Nov 2014
CDR	Apr 2015	Apr 2015
SIR	Oct 2016	Oct 2016
Start Phase D	Nov 2016	Nov 2016
ORR/FRR	Under review	Under review

TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations

Milestone	Confirmation Baseline Date	FY 2016 PB Request
LRD/IOC/IC	Jun 2018	Jun 2018
Start Phase E/FC/IC	Aug 2018	Aug 2018
End Prime Mission	Aug 2021	Aug 2021

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2015	323.2	70	2015	296.4	-8	LRD	Jun 2018	Jun 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

This is the first report of development costs for this mission. The current year development cost estimate reflects savings from the award of the Launch Vehicle contract in December 2014.

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**323.2**	**296.**4	**-26.**8
Aircraft/Spacecraft	43.0	43.7	0.7
Payloads	23.2	23.6	0.4
Systems I&T	3.7	3.7	0.0
Launch Vehicle	114.1	87.4	-26.7
Ground Systems	16.7	16.7	0.0
Science/Technology	7.5	7.5	0.0

TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
Other Direct Project Costs	115.0	113.8	-1.2

Project Management & Commitments

Goddard Space Flight Center is responsible for Project Management.

Element	Description	Provider Details	Change from Baseline
Instrument	Visible-IR telescopic CCDs detectors	Provider: Massachusetts Institute of Technology (MIT) 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: Space Exploration Technologies Corporation (SpaceX) Lead Center: Kennedy Space Center Performing Center(s): N/A Cost Share Partner(s): N/A	None

Project Risks

Risk Statement	Mitigation
If: Schedule reserves as identified at the September 2014 Preliminary Design Review remain tight, Then: Instrument and spacecraft development may not be ready for subsequent observatory integration.	At the TESS KDP-C (October 2014), the TESS project announced the release of additional schedule reserves to selected aspects of both the TESS instrument and spacecraft, in order to mitigate schedule concerns.

TRANSITING EXOPLANET SURVEY SATELLITE (TESS)

Formulation	Development	Operations

Acquisition Strategy

NASA selected the mission through a competitive Announcement of Opportunity.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Spacecraft Bus	Orbital Sciences Corporation	Dulles, VA

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Feb 2014	SRR	Successful	PDR
Perform-ance	SRB	Sep 2014	PDR	Successful	CDR
Perform-ance	SRB	Apr 2015	CDR	TBD	Systems Integration Review (SIR)
Perform-ance	SRB	Oct 2016	SIR	TBD	Launch Readiness Review (LRR)
Perform-ance	SRB	2018	LRR	TBD	N/A

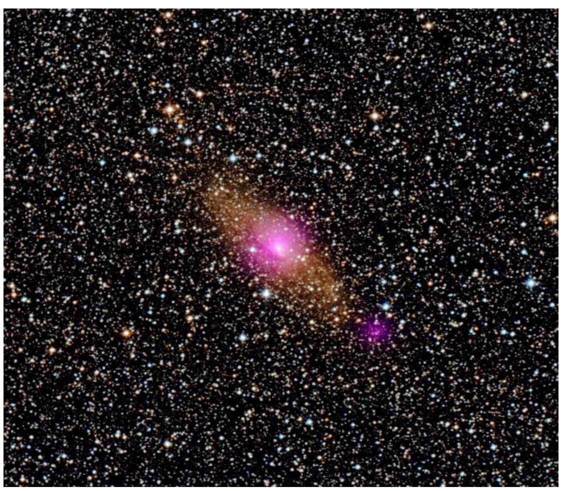
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Wide-Field Infrared Survey Explorer	0.2	--	**0.0**	0.0	0.0	0.0	0.0
ASTRO-H (SXS)	13.4	--	**14.7**	12.0	11.4	9.5	0.0
Astrophysics Explorer Future Missions	0.0	--	**14.4**	40.8	70.2	147.2	161.3
Astrophysics Explorer Program Management	6.9	--	**9.7**	9.4	7.4	4.6	4.5
Neutron Star Interior Composition Explorer (NICER)	25.6	--	**11.0**	3.5	1.3	0.0	0.0
SWIFT	4.8	--	**5.1**	0.0	0.0	0.0	0.0
Suzaku (ASTRO-E II)	0.3	--	**0.6**	0.0	0.0	0.0	0.0
Nuclear Spectroscopic Telescope Array (NuSTAR)	2.5	--	**6.9**	0.0	0.0	0.0	0.0
GALEX	0.0	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**53.7**	**--**	**62.4**	**65.6**	**90.3**	**161.3**	**165.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



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.

Astrophysics Explorers Other Missions and Data Analysis includes funding for small missions in formulation and development (ASTRO-H SXS, NICER), operating missions (NuSTAR, Swift, Suzaku), and funding for future mission selections and program management functions.

Mission Planning and Other Projects

ASTRO-H (SXS)

NASA is providing a High-Resolution Soft X-Ray Spectrometer (SXS) instrument to Japan for launch no earlier than 2015 onboard JAXA's H- IIA rocket. 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, and 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

The ASTRO-H project delivered the Calorimeter Spectrometer Insert to JAXA in April 2014, and supported integrations performance testing of the instrument in October and November 2014.

ASTROPHYSICS EXPLORER FUTURE MISSIONS

Astrophysics Explorer Future Missions funding supports future astrophysics Explorer missions and missions of opportunity through concept studies and selections.

ASTROPHYSICS EXPLORER PROGRAM MANAGEMENT

Astrophysics Explorer program management provides programmatic, technical and business management of ongoing missions in formulation and development.

NEUTRON STAR INTERIOR COMPOSITION EXPLORER (NICER)

The NICER instrument, to be located on the external logistics carrier of the ISS, 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 known cosmic particle accelerators.

Recent Achievements

NASA confirmed the NICER project to proceed to implementation at its KDP-C review in February 2014, and successfully completed a CDR in September 2014. The project started fabrication of the instrument.

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 MIDEX class mission that launched in 2004 and is now in extended mission operations.

OTHER MISSIONS AND DATA ANALYSIS

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 Type Ia supernovae showed that supergiant stars, and even sun-like stars in a later red giant phase, likely are not present in the host binaries. Swift detected no ultraviolet emission 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. The Institute of Space and Astronautical Science of JAXA (ISAS/JAXA) developed Suzaku in collaboration with US (NASA and MIT) and Japanese institutions. NASA provides software to analyze Suzaku data and operates at a GO facility for US observers.

Recent Achievements

A systematic analysis of Suzaku observations of supernova remnants revealed a new technique to distinguish whether the supernova was due to the core collapse of a massive star, or due to the thermonuclear explosion of a white dwarf. These explosions lead to different imprints of how iron is heated to X-ray emitting temperatures, and hence different energies of the iron emission line, which Suzaku can measure more accurately than with any other observatories. Another major result exemplifies the synergy of the imaging resolution of Chandra and the spectroscopic capabilities of Suzaku. The latter led to the estimate that a black hole with the mass of 3-6 billion suns powers a quasar at the center of a cluster of galaxies. The Chandra study of the cluster had previously led to the conclusion that a past energetic outburst of the quasar was responsible in shaping the X-ray emitting intracluster gas. The new Suzaku result showed that the quasar outburst needed to have been extreme.

NUCLEAR SPECTROSCOPIC TELESCOPE ARRAY (NUSTAR)

Launched in June 2012, the NuSTAR mission completed its prime mission in July 2014 and is now in extended mission operations. NuSTAR 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 implemented a GO facility for US observers and will commence Guest Observations in April 2015.

Recent Achievements

Scientists are finally unraveling one of the biggest mysteries in astronomy, how stars explode in supernova explosions, with the help of NASA's NuSTAR mission. The high-energy X-ray observatory has created the first map of radioactive material in a supernova remnant. The results, from a remnant named Cassiopeia A, reveal how shock waves likely rip apart massive dying stars. The high temperatures and particles created in the blast fuse light elements together to create heavier elements, including the gold in jewelry, the calcium in bones, and the iron in blood. While small stars like our sun die less violent deaths, stars at least eight times as massive as our sun end in supernova explosions.

JAMES WEBB SPACE TELESCOPE

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**	**197.5**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

James Webb Space Telescope

JAMES WEBB SPACE TELESCOPE

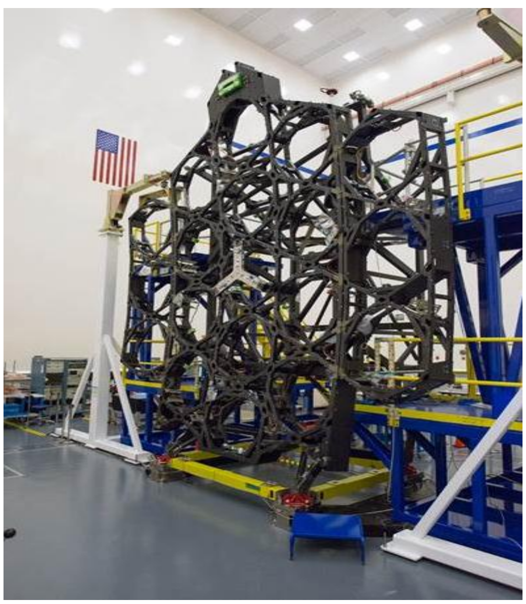
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	1800.1	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	1800.1
Development/Implementation	2887.0	658.2	645.4	**620.0**	569.4	534.9	228.0	47.5	0.0	6190.4
Operations/Close-out	0.0	0.0	0.0	**0.0**	0.0	0.0	77.0	150.0	0.0	227.0
2015 MPAR LCC Estimate	**4687.1**	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**	**197.5**	**0.0**	**8217.5**
Total Budget	**4615.0**	**658.2**	**645.4**	**620.0**	**569.4**	**534.9**	**305.0**	**197.5**	**610.0**	**8755.4**
Change from FY 2015				**-25.4**						
Percentage change from FY 2015				**-3.9%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76. The 2015 MPAR LCC Estimate includes $72.1 million for Construction of Facilities (CoF) funds in FY 2010 to FY 2012, which are budgeted in the CECR account.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



JWST flight backplane assembled at Northrop Grumman.

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

Formulation	Development	Operations

- 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 2016

None.

PROJECT PARAMETERS

JWST is an infrared optimized observatory that will conduct imaging and spectrographic observations in the 0.6 to 28 micrometer wavelength range and will be 100 times more capable than Hubble.

The 6.5-meter primary mirror consists of 18 actively controlled segments. A multilayer sunshield the size of a tennis court passively cools the mirror, telescope optics and instruments to about 40 kelvins. JWST will launch in 2018 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 allow 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, 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

Formulation	Development	Operations

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 onboard 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 2014

In FY 2014, 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:

- Completed the analysis of the first risk-reduction cryo-vacuum test of ISIM;
- Integrated the NIRCam and NIRSpec instruments into ISIM;
- Installed the new near-infrared detectors into NIRCam;
- Completed cryo-vacuum testing of the Optical Telescope Element (OTE) primary mirror backplane support structure;
- Completed delivery of the primary mirror segment assemblies to Goddard Space Flight Center (GSFC);
- Completed the Critical Design Review (CDR) of the spacecraft bus;
- Completed the system testing phase of the second cryo-vacuum ISIM test; and
- Fabricated and tested the five engineering model sunshield membranes. Started manufacturing the flight sunshield membranes.

WORK IN PROGRESS IN FY 2015

In FY 2015, the project plans to complete the following development and test efforts:

- Install new infrared detectors into the FGS/NIRISS and NIRSpec instruments and new microshutters into NIRSpec;
- Deliver the OTE flight structure, including primary mirror backplane support structure, backplane support fixture, and wings to 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;
- Initiate the third and final cryogenic vacuum test of ISIM, with all flight instruments and new detectors; and
- Deliver the flight cryo-cooling compressor components to JPL.

JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The President's FY 2016 budget request provides the full level of funding required to keep JWST on schedule for a 2018 launch. In FY 2016, the project plans to:

- Deliver ISIM for OTIS integration;
- Complete the integration of flight primary mirror subassemblies onto the flight primary mirror backplane;
- Complete the acceptance testing of the cryocooler compressor assembly;
- Complete the spacecraft bus structure; and
- Complete the sunshield structure manufacture and 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 2016 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

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($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

JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations

(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)
TOTAL:	**6,197.9**	**6,190.4**	**-7.5**
Aircraft/Spacecraft	2,955.0	3,142.6	187.6
Payloads	695.1	814.7	119.6
Systems I&T	288.4	358.3	69.9
Launch Vehicle	0.9	0.6	-0.3
Ground Systems	652.3	563.8	-88.5
Science/Technology	42.7	41.5	-1.2
Other Direct Project Costs	1,563.5	1,268.9	-294.6

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 is designed for at least a five-year lifetime. Northrop Grumman Aerospace Systems (NGAS) 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

JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations

Element	Description	Provider Details	Change from Baseline
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
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
NIRCam	Operates over the wavelength range of 0.6 to 5 micrometers, 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
NIRSpec	Operates over the wavelength range 0.6 to 5 micrometers with three observing modes	Provider: ESA Lead Center: ESA Performing Center(s): N/A Cost Share Partner(s): ESA	N/A
MIRI	Operates over the wavelength range 5 to 27 micrometers, providing imaging, coronagraphy, and spectroscopy	Provider: ESA, University of Arizona, JPL Lead Center: GSFC Performing Center(s): Cost Share Partner(s): ESA	N/A

Project Risks

Risk Statement	Mitigation
If: Cryogenic cooler component delivery changes to a later date Then: Changes to any or all of the following schedules and plans will be required; cooler acceptance testing, end-to-end cryocooler testing, spacecraft integration and test.	The Project will modify cryogenic cooler acceptance and end-to-end test plans, flow and schedules to reflect the estimated delivery dates for cryogenic cooler components. The Project would change the spacecraft integration and test plan schedule to reflect the later delivery dates for cryogenic cooler components.

JAMES WEBB SPACE TELESCOPE

Formulation	Development	Operations

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
Perform-ance	Standing Review Board (SRB)	Apr 2010	CDR	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 http://www.jwst.nasa.gov/publications.html	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	The Aerospace Corporation	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 the Agency	N/A
Perform-ance	NASA Headquarters Office of Evaluation	Jun 2012	Replan assessment review	A review assessed progress against replan	N/A
Perform-ance	SRB	N/A	OTIS Pre-Environmental Review		Jun 2016
Perform-ance	SRB	N/A	Spacecraft Element Readiness Review		Apr 2016
Perform-ance	SRB	N/A	Systems Integration Review (SIR)		Jul 2017
Perform-ance	SRB	N/A	Flight Readiness Review (FRR)		Sep 2018

HELIOPHYSICS

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Heliophysics Research	185.1	--	**158.5**	168.5	202.1	207.6	208.4
Living with a Star	212.5	--	**343.0**	387.3	399.9	212.6	103.3
Solar Terrestrial Probes	143.3	--	**50.5**	37.6	41.8	133.3	189.2
Heliophysics Explorer Program	100.2	--	**98.9**	91.9	54.1	154.5	221.3
Total Budget	**641.0**	**--**	**651.0**	**685.2**	**697.9**	**708.1**	**722.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Heliophysics

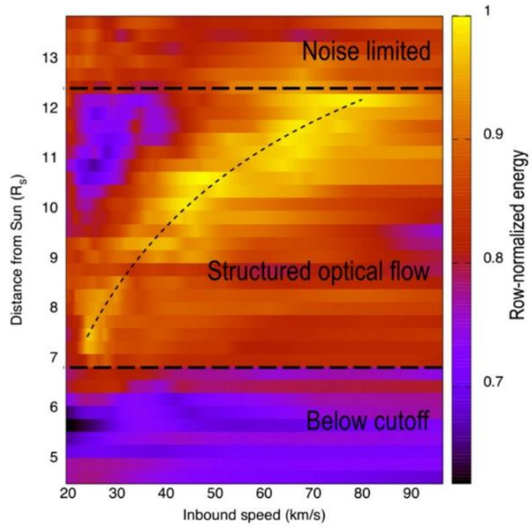
HELIOPHYSICS RESEARCH

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Research Range	21.8	--	**21.6**	21.7	21.7	21.7	21.7
Sounding Rockets	53.4	--	**48.3**	53.3	59.0	61.1	63.1
Heliophysics Research and Analysis	33.5	--	**34.0**	33.9	48.9	53.9	53.9
Other Missions and Data Analysis	76.4	--	**54.6**	59.6	72.5	71.0	69.7
Total Budget	**185.1**	**--**	**158.5**	**168.5**	**202.1**	**207.6**	**208.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Using data from NASA spacecraft, scientists confirmed the altitude in which solar material travels inward and outward in the solar atmosphere. This altitude is critical for understanding how the solar atmosphere is heated and the solar wind accelerated, key goals of the Solar Probe Plus (SPP) mission. The research shows that this altitude, known as the Alfven surface, is located between 12 and 13 solar radii above the Sun's photosphere, well within the boundaries where SPP will fly.

Heliophysics seeks to understand the Sun and its interactions with Earth and the solar system, including space weather. The goal of Heliophysics 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?

Heliophysics Research improves our understanding of fundamental physical processes throughout the solar system, and enables us to understand how the Sun, as the major driver of the energy throughout the solar system, impacts our technological society. The scope of heliophysics is vast, spanning from the Sun's interior to Earth's upper atmosphere, and throughout interplanetary space to the edges of the heliosphere, the bubble of charged particles surrounding the sun that reaches far beyond the outer planets. Heliophysics incorporates studies of the interconnected elements in a single system that produces dynamic space weather and evolves in response to solar, planetary, and interstellar conditions.

For more information, go to: http://science.nasa.gov/about-us/smd-programs/heliophysics-research.

HELIOPHYSICS RESEARCH

EXPLANATION OF MAJOR CHANGES IN FY 2016

NASA plans to terminate the Cluster II mission in FY 2016, per the recommendation of the 2013 Heliophysics Senior Review, with support limited to one instrument in FY 2014, with end of life closeout operations only in FY 2015 and termination by FY 2016.

ACHIEVEMENTS IN FY 2014

Geomagnetic storms are space weather events that affect Earth's space environment and can disrupt technological systems in space and on the ground. Scientists believe that conditions in the solar wind control the magnitude of these events. Recent research has shown that cold, dense gas at the very top of Earth's atmosphere forms a plume that stretches to the points where the solar wind or coronal mass ejections (CMEs) influence Earth's magnetosphere. This plume prevents solar energetic particles from entering into near-Earth space, creating an additional layer of protection that can diminish the intensity of some storms. Researchers combined data from NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission and GPS measurements to observe this interaction.

The Heliophysics Guest Investigator project resulted in a successful investigation of solar neutrons with the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft in orbit around Mercury. MESSENGER is close enough to the Sun to detect solar neutrons created in solar flares. The average lifetime for one of these neutrons is only 15 minutes. How far they travel into space depends on their speed, and slower neutrons do not travel far enough to reach particle detectors in orbit around Earth. We can decipher the complicated acceleration processes that are responsible for the creation of harmful solar energetic particles using the information carried by solar neutrons.

NASA completed a laboratory prototype of an instrument for the detection and analysis of nano-sized dust particles originating from the inner solar system. The Solar TErrestrial RElations Observatory (STEREO) spacecraft discovered nanodust traveling at speeds close to that of the solar wind, but scientists do not understand its origin and characteristics very well. Modeling of the dynamics of nanodust particles helped to assess the requirements and measurement strategies that future missions will use.

WORK IN PROGRESS IN FY 2015

In 2015, NASA will continue its recently restructured portfolio of competed research programs, a first step in implementing the Diversify, Realize, Integrate, Venture, Educate (DRIVE) initiative, outlined in the National Academies' 2013 Decadal Survey for Solar and Space Physics. The 2014 Research Opportunities in Space and Earth Sciences NASA Research Announcement (ROSES NRA), which solicits proposals for FY 2015 funding, reflects the restructured portfolio.

Heliophysics has implemented the CubeSat project. The project funded six new CubeSat missions: five Heliophysics missions and one Earth Science mission. One of the Heliophysics CubeSats will launch in FY 2015. Heliophysics is collaborating with NASA's Human Exploration and Operations Mission Directorate to investigate the possibility of a CubeSat launch on the Exploration Mission 1. A solicitation for this activity was developed and released in the ROSES call in 2014. If selected, the Exploration Mission 1 CubeSat will begin implementation in FY 2015.

HELIOPHYSICS RESEARCH

NASA solicited two ROSES-14 special program elements: one for the Interface Region Imaging Spectrograph (IRIS) to take advantage of critical new observations of the solar corona and the other for combined science data analysis of Van Allen Probes and the Balloon Array (BARREL) observations that will improve understanding of particle loss processes in Earth's radiation belts.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the Heliophysics Research program anticipates achieving significant science results from analysis of the data from 20 active space missions that make up the Heliophysics System Observatory with its 30 individual spacecraft. These include the Advanced Composition Explorer (ACE), Aeronomy of Ice in the Mesosphere (AIM), Coupled Ion Neutral Dynamic Investigation (CINDI), Geotail, Hinode, Interstellar Boundary Explorer (IBEX), IRIS, Magnetospheric Multiscale (MMS, 4 spacecraft), Ramaty High Energy Solar Spectroscopic Imager (RHESSI), Solar Dynamics Observatory (SDO), Space Environment Testbeds (SET), Solar and Heliospheric Observatory (SOHO), Solar Terrestrial Relations Observatory (STEREO, 2 spacecraft), Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED), Time History of Events and Macroscale Interactions during Substorms (THEMIS, 5 spacecraft), Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS, 2 spacecraft), Van Allen Probes (2 spacecraft), Voyager (2 spacecraft), and Wind. The anticipated awards of small research investigations will continue the science advancements.

In addition to operating mission data, the budget request supports a flight program of 16 to 20 sounding rocket flights, with one to two remote campaign deployments in Poker Flat, Norway, and/or Australia.

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 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 supports the NASA strategic vision and goals for Earth Science, Heliophysics, Planetary Science, and Astrophysics. The 16 to 20 suborbital missions flown annually by the Project provide researchers with unparalleled opportunities to build, test, and fly new instrument and sensor design concepts while simultaneously conducting world-class scientific research. Coupled with a hands-on approach to instrument design, integration, and flight, the short mission life cycle helps ensure that the next generation of space scientists receive the training and experience necessary to move on to NASA's larger, more complex space science missions.

HELIOPHYSICS RESEARCH

With the capability to fly higher than many low-Earth orbiting satellites and the ability to launch on demand, sounding rockets often offer the only means to study specific scientific phenomena of interest to many researchers. Unlike instruments on board most orbital spacecraft or in ground-based observatories, sounding rockets can place instruments directly into regions where and when the science is occurring to enable direct, in-situ measurements. The mobile nature of the project enables researchers to conduct missions from strategic vantage points worldwide. Telescopes and spectrometers to study solar and astrophysics phenomena fly on sounding rockets to collect unique science data and test prototype instruments for future satellite missions.

HELIOPHYSICS RESEARCH AND ANALYSIS

This project supports basic research, solicited through NASA's annual ROSES announcements. These research activities address understanding of the Sun and planetary space environments, including the origin, evolution, and interactions of space plasmas and electromagnetic fields throughout the heliosphere and in connection with the galaxy. Understanding the origin and nature of solar activity and its interaction with the space environment of the Earth is a particular focus. This project supports Heliophysics theory, Low Cost Access to Space investigations, and instrument development.

Theory investigations are the foundation of the Heliophysics Research and Analysis project. They lead the way to new understanding of previous investigations and drive science concepts for future missions. The Heliophysics Theory element supports large Principal Investigator (PI)-proposed team efforts that require a critical mass of expertise to make significant progress in understanding complex physical processes with broad importance.

Supporting research investigations guide the direction and content of future science missions. They employ a variety of fundamental research techniques (e.g., theory, numerical simulation, and modeling), analysis and interpretation of space data, development of new measurement concepts, and laboratory measurements of relevant atomic and plasma parameters.

Low Cost Access to Space investigations may use suborbital rockets, suborbital reusable launch vehicles, ISS payloads, CubeSats, or balloon flights of experimental instrumentation, and proof-testing new concepts in experimental techniques that may ultimately find application in free-flying Heliophysics space missions.

Instrument development investigations show promise for use in scientific investigations on future Heliophysics science missions, including the development of laboratory instrument prototypes, but not of flight hardware. The goal is to define and develop scientific instruments and/or components of such instruments to the point where complete instruments are ready for future Announcements of Opportunity (AOs) without significant additional technology development.

Program Schedule

NASA implements the Heliophysics Research program via a competitively selected process. NASA releases research solicitations each year through the ROSES NRA, aiming to initiate research for about one-third of the program, given the selected investigations are typically three-year awards. Therefore, NASA will allocate FY 2015 funds to ROSES-2014, ROSES-2013, and ROSES-2012 selections.

HELIOPHYSICS RESEARCH

Date	Significant Event
Q2 FY 2015	ROSES-2015 solicitation - February 2015
Q3/Q4 FY 2015	Review of all Proposals Submitted to Heliophysics ROSES Elements
Q3 FY 2015	Senior Review of All Operating Missions

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 projects. NASA previously selected the Heliophysics operating missions and instrument teams via NASA AOs. NASA evaluates the allocation of funding among the operating missions bi-annually through the Heliophysics Senior Review process.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Sounding Rocket Operations	Orbital Sciences Corp (OSC), Dulles VA	Various

HELIOPHYSICS RESEARCH

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Mission Senior Review Panel	Apr 2015	A comparative evaluation of Heliophysics operating missions	The report, released by July 2015, will assess missions individually, and as part of a system observatory	Apr 2017

OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Science Planning and Research Support	6.3	--	**6.6**	6.7	6.8	6.8	6.8
Directed Research & Technology	27.2	--	**2.9**	8.0	11.9	5.3	5.3
CubeSat	5.0	--	**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	3.1	--	**2.8**	2.8	2.8	3.0	3.0
Space Physics Data Archive	2.0	--	**2.0**	2.0	2.0	2.0	2.0
Guest Investigator Program	8.1	--	**10.5**	10.3	19.2	24.3	22.7
Community Coordinated Modeling Center	2.0	--	**2.0**	2.0	2.0	2.1	2.1
Space Science Mission Ops Services	10.9	--	**11.5**	11.5	11.5	11.6	11.9
Voyager	5.4	--	**5.7**	5.6	5.6	5.6	5.5
SOHO	2.2	--	**2.2**	2.2	2.2	2.2	2.2
WIND	2.2	--	**2.2**	2.2	2.2	2.0	2.0
GEOTAIL	0.5	--	**0.2**	0.2	0.2	0.2	0.2
CLUSTER-II	0.6	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**76.4**	--	54.6	**59.6**	**72.5**	**71.0**	**69.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

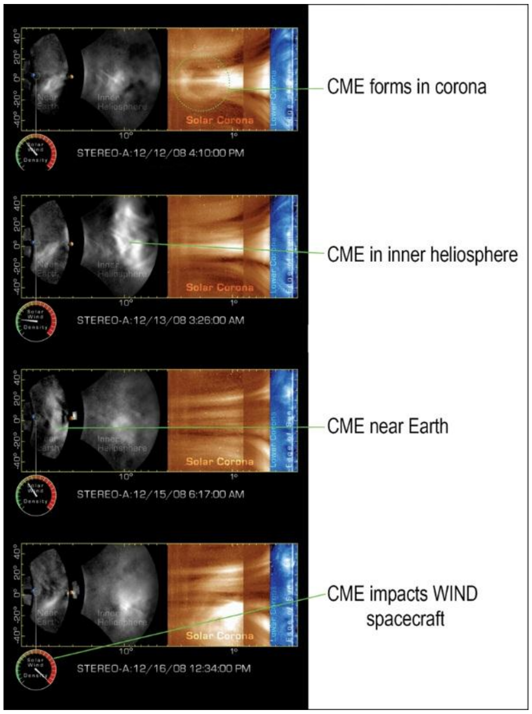
NASA accumulates, archives, and distributes data collected by the Heliophysics System Observatory, a fleet of operating spacecraft. Combining the measurements from all of these observing platforms enables interdisciplinary, connected systems science across the vast spatial scales of our solar system. 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 for NASA spacecraft and data analysis to advance the state of space science and space weather modeling. NASA conducts science community-based projects to evaluate research models containing space weather disturbance information that is of value to industry and government agencies. Heliophysics data centers archive and distribute the science data from operating missions in the Living With a Star (LWS), Solar Terrestrial Probes (STP), Research, and Explorer programs.

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 Academies studies.

OTHER MISSIONS AND DATA ANALYSIS



Images from NASA's STEREO-A spacecraft allow scientists to trace the anatomy of a coronal mass ejection (CME) as it moved and changed on its journey from the Sun to the Earth, identify the origin and structure of the material that affected Earth, and connect the image data directly with measurements at Earth at the time of impact.

DIRECTED RESEARCH AND TECHNOLOGY

This project funds the civil service staff that work on emerging flight projects, instruments, and research.

CUBESAT

Heliophysics implemented a CubeSat project in response to the 2013 Decadal Survey DRIVE initiative recommendation. The project offers a low-cost option for enabling scientific discovery across the various themes and disciplines within the Science Mission Directorate (SMD). CubeSats are very small spacecraft, as small as a few inches square, that can launch as secondary or “tag-along” payloads, on 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 address space technology and exploration systems development needs and 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 larger-scale missions.

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. The center also provides a repository for software used to analyze these data. The Virtual Solar Observatory is a software system that links together distributed archives of solar data into a unified whole, along with data search and analysis tools.

DATA AND 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. Elements of this project are competed through the annual ROSES competitive announcement.

OTHER MISSIONS AND DATA ANALYSIS

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.

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 competitive research investigations use data from multiple spacecraft, as appropriate. Investigations addressing global system science are strongly encouraged, as Heliophysics is, by its nature, the investigation of a large-scale, complex, connected system.

COMMUNITY COORDINATED MODELING CENTER (CCMC)

The CCMC 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 simulations to enable "runs on demand," using models to study space weather events in near-real time. This allows the comparison of observational data and model parameters during or shortly after solar activity, thereby improving the accuracy of the models.

SPACE SCIENCE MISSION OPERATIONS SERVICES

Space Science Mission Operations Services manages the on-orbit operations of GSFC Space Science missions. Services include consistent processes and infrastructure for missions operated at GSFC, Johns Hopkins University Applied Physics Laboratory (JHU-APL), OSC, 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 and the local interstellar medium. Voyager 1 is making the first in situ observations of the region outside the heliosphere from about 127 astronomical units (AU), or 127 times Earth's distance from the Sun, and is traveling at a speed of 3.6 AU per year. Voyager 2 is about 103 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.

Recent Achievements

Thirty-five years after launch, Voyager 1, at a distance of more than 11 billion miles from the Sun, became the first human-made object to cross the heliopause—the boundary that separates the stream of charged particles from the Sun from that of other stars. Surprisingly, the Plasma Wave instrument continues recording vibrations in the surrounding plasma caused by eruptions from the Sun. The plasma is now 40 times denser than that measured inside the heliopause by Voyager 2, matching all expectations of the plasma density of interstellar space. While scientists expected the plasma wave phenomena to cease with growing distance from the heliopause, they were surprised when additional "tsunami wave" signatures from the Sun arrived in mid-2014 at a much larger distance than expected from the heliopause. Scientists can now use the plasma wave information to better characterize and map the unknown medium surrounding the Sun.

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, located about one 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 CMEs, which are large bursts of plasma from the Sun that can collide with Earth's magnetosphere and cause disruptions to technological infrastructure in space and on the ground. SOHO also enables studies of CMEs and their effect on interplanetary space.

Recent Achievements

SOHO reached a milestone on December 2, 2013: it turned 18 years old. SOHO, a joint mission of the European Space Agency (ESA) and NASA, has been a dependable solar watchdog all the while, providing the only Earth-Sun line coronagraph images of solar storms. More than 4,600 scientific papers using data from SOHO have appeared in peer reviewed literature. Citizen scientists have used SOHO to discover more than 2,500 comets, a capability no one anticipated before launch. Over the 2013 Thanksgiving holiday, SOHO played a crucial role in tracking Comet ISON. Although some of its instruments no longer function, it still plays a unique role in monitoring solar and heliospheric activity.

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, evolution of solar activity in the heliosphere, and 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 delivers higher time resolution than available from any other mission.

Recent Achievements

Wind observations helped facilitate an international collaboration in the analysis of colliding CMEs, observed in September 2012, which led to a two-step space weather storm on Earth. A two-step storm refers to the quick succession of the arrival of two different CMEs. The first was still compressing the Earth's magnetosphere when the second one applied a second, larger compression and associated geomagnetic effects. The analysis showed that collisions between CMEs could lead to unusual behavior in the propagation speed from the Sun to Earth orbit. While usually fast, CMEs decelerate on the way to Earth. The collision of a slow leading CME with a faster CME behind it leads to a near-constant speed of the combined CMEs. Understanding CMEs and their impact on near-Earth space is a major goal of NASA Heliophysics.

OTHER MISSIONS AND DATA ANALYSIS

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 auroras 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.

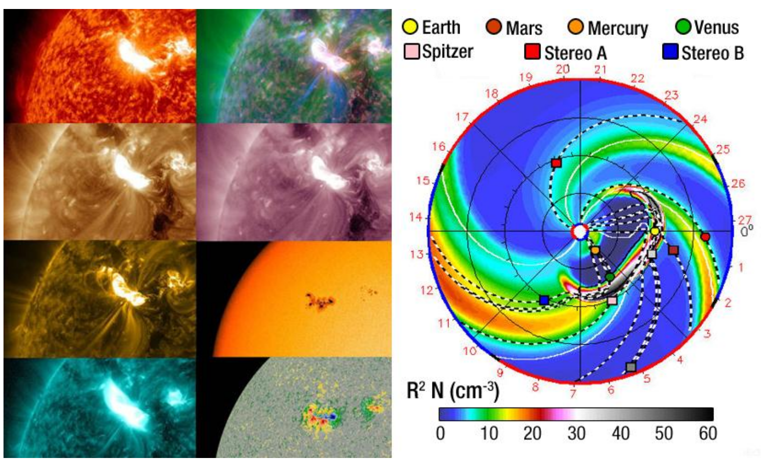
LIVING WITH A STAR

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Solar Probe Plus	121.4	179.2	**230.4**	226.5	323.7	100.4	25.2
Solar Orbiter Collaboration	39.4	31.5	**62.9**	112.2	19.3	42.8	2.3
Other Missions and Data Analysis	51.7	--	**49.7**	48.7	56.9	69.4	75.9
Total Budget	**212.5**	**--**	**343.0**	**387.3**	**399.9**	**212.6**	**103.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



Sunspot number AR1429 unleashed a powerful X5-class solar flare, starting the "St. Patrick Day Storms" of 2012. The blast also propelled a massive CME toward Earth. Left: SDO recorded the flare at multiple extreme ultraviolent wavelengths. Right: A "3D CME" model produced at the Goddard Space Weather Laboratory showed how the CME would propagate through the inner solar system.

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, linkages among the interconnected systems, and, specifically, space weather conditions at Earth and the interplanetary medium. Measurements and research from LWS missions may help prevent damage to spacecraft, communications and navigation systems, and power grids. LWS products improve our understanding of ionizing radiation, which has human health implications on the ISS and high-altitude aircraft flight, as well as operations of future space exploration with and without human presence. LWS 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 2016

None.

SOLAR PROBE PLUS

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	221.6	25.5	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	247.1
Development/Implementation	0.0	95.9	179.2	**230.4**	226.5	323.7	0.0	0.0	0.0	1055.7
Operations/Close-out	0.0	0.0	0.0	**0.0**	0.0	0.0	100.4	25.2	125.0	250.6
2015 MPAR LCC Estimate	**221.6**	**121.4**	**179.2**	**230.4**	**226.5**	**323.7**	**100.4**	**25.2**	**125.0**	**1553.4**
Total Budget	**246.6**	**121.4**	**179.2**	**230.4**	**226.5**	**323.7**	**100.4**	**25.2**	**125.0**	**1578.4**
Change from FY 2015				**51.2**						
Percentage change from FY 2015				**28.6%**						

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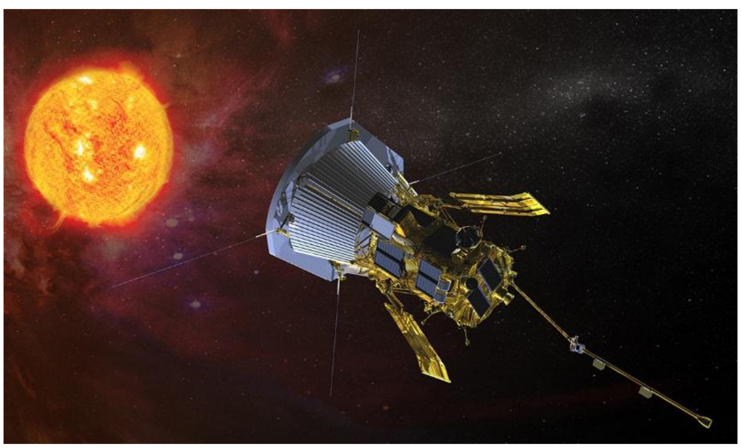


Artist's concept of the Solar Probe Plus spacecraft as it approaches the Sun.

PROJECT PURPOSE

SPP will explore the Sun's outer atmosphere, or corona, as it extends out into space. At a distance of less than five times the Sun's diameter from its surface, closer than any other spacecraft, SPP will repeatedly obtain direct in situ coronal magnetic field, plasma and white-light remote sensing observations in the region that heats the solar atmosphere and accelerates the solar wind. SPP's findings will revolutionize our knowledge and understanding of coronal heating and of the origin and evolution of the solar wind, answering critical questions posed in the 2003 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.

SOLAR PROBE PLUS

Formulation	Development	Operations

For more information, go to: http://nasascience.nasa.gov/missions/solar-probe.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The SPP budget profile reflects the requirements approved at the Key Decision Point-C (KDP-C) in March 2014.

PROJECT PARAMETERS

After launch in August 2018, SPP will orbit the Sun 24 times, gradually "walking in" toward the Sun with each pass. SPP's first close approach to the Sun occurs just three months after launch. Over a period of several years, seven Venus flybys will gradually shrink the spacecraft's orbit around the Sun. 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 3.8 million miles of the Sun's surface. That is about seven times closer than the Helios spacecraft, the current record holder for the closest solar pass. SPP will sample changes in the solar wind with increasing solar activity.

ACHIEVEMENTS IN FY 2014

SPP completed Technology Readiness Level (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 started its implementation phase. SPP also successfully completed cold temperature cycle testing on the TPS.

WORK IN PROGRESS IN FY 2015

In FY 2015, the project will conduct peer level Critical Design Reviews (CDRs) for system and subsystems, leading up to the mission level CDR. After completion of the CDR, the project will initiate the build of flight hardware and complete the launch vehicle procurement process.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the project will conduct the System Integration Review (SIR), which marks the end of Phase C design and fabrication and the beginning of system assembly, integration and testing. The SIR assesses the readiness of the subsystems and assemblies, software, and test procedures to begin final assembly. It evaluates the continuing compliance of the system against the applicable requirements and evaluates the readiness to proceed with system assembly and environmental testing.

SOLAR PROBE PLUS

Formulation	Development	Operations

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-C	Mar 2014	Mar 2014
CDR	Mar 2015	Mar 2015
SIR	Jun 2016	Jun 2016
Launch	Aug 2018	Aug 2018
Start of Phase E	Oct 2018	Oct 2018
End of Prime Mission	Sep 2025	Sep 2025

Development Cost and Schedule

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

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2015	1,055.7	70	2015	1,055.7	0	LRD	Aug 2018	Aug 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

NASA confirmed Solar Probe Plus to proceed into implementation phase in March 2014.

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**1,055.7**	**1,055.7**	**0.0**
Aircraft/Spacecraft	170.8	180.1	9.3

SOLAR PROBE PLUS

Formulation	Development	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
Payloads	143.4	143.4	0.0
Systems I&T	31.2	32.4	1.2
Launch Vehicle	430.5	430.4	-0.1
Ground Systems	17.8	17.8	0.0
Science/Technology	4.5	7.8	3.3
Other Direct Project Costs	257.5	243.8	-13.7

Project Management & Commitments

GSFC provides program management. JHU-APL manages the project.

Element	Description	Provider Details	Change from Baseline
Expendable Launch Vehicle	Deliver the spacecraft to operational orbit	Provider: TBD Lead Center: Kennedy Space Center (KSC) Participating Centers: KSC Cost Share Partners: N/A	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	N/A
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	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	N/A

SOLAR PROBE PLUS

Formulation	Development	Operations

Project Risks

Risk Statement	Mitigation
If: The spacecraft is unable to resolve time critical faults with sufficient speed, Then: Mission-ending exposure to the solar environment may occur.	The project will develop a system response for every manageable fault and perform extensive ground testing and simulation of system fault responses. Management will consider the risk mitigated after these activities are complete.
If: The magnetic field from the spacecraft is larger than anticipated, Then: It will affect SWEAP electron measurements.	The project will characterize permanent magnets and magnetic materials on the spacecraft, develop analytical magnetic model of spacecraft, and perform Magnetic Swing Test on the integrated Observatory. Management will consider the risk mitigated after these activities are complete.

Acquisition Strategy

PIs selected through the AO will build science instruments. JHU-APL will build the spacecraft, and will competitively procure the spacecraft subassemblies, components, and parts. The project will refine the ground system components and requirements during the development phase. GSFC will manage the operations contracts.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Prime Contract and Mission Management	JHU-APL	Laurel, MD
FIELDS magnetometers and 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
Heliophysics Origins Investigation	JPL	Pasadena, CA

SOLAR PROBE PLUS

Formulation	Development	Operations

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jan 2014	PDR to assess readiness for KDP-C	Successful, project ready to proceed to development	Mar 2015
Perform-ance	SRB	Mar 2015	CDR to assess readiness for KDP-D	TBD	Jun 2016
Perform-ance	SRB	Jun 2016	KDP-D	TBD	Mar 2018

SOLAR ORBITER COLLABORATION

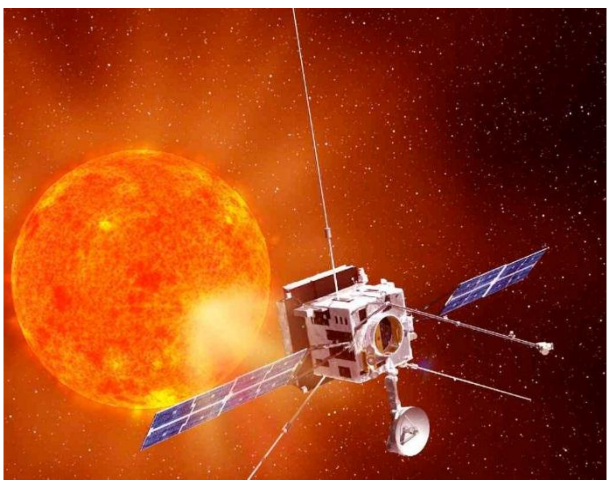
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	41.5	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	41.5
Development/Implementation	18.1	39.4	31.5	**62.9**	110.7	17.2	40.1	0.0	0.0	320.0
Operations/Close-out	0.0	0.0	0.0	**0.0**	1.4	2.1	2.6	2.3	9.0	17.4
2015 MPAR LCC Estimate	**59.6**	**39.4**	**31.5**	**62.9**	**112.1**	**19.3**	**42.8**	**2.3**	**9.0**	**378.9**
Total Budget	**59.6**	**39.4**	**31.5**	**62.9**	**112.2**	**19.3**	**42.8**	**2.3**	**9.0**	**378.9**
Change from FY 2015				**31.4**						
Percentage change from FY 2015				**99.7%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



This ESA-led mission will 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, 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. SOC will also make imaging/spectroscopic observations. SOC will provide close-up views of the Sun's polar-regions and 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 is currently possible.

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: the 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.

SOLAR ORBITER COLLABORATION

Formulation	Development	Operations

For more information, go to: http://nasascience.nasa.gov/missions/solar-orbiter.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The negotiated price for the launch vehicle was less than anticipated, enabling a savings without impact.

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 AU and the farthest distance from 0.73 to 0.88 AU. 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 maneuver between each rotation around the Sun. Each gravity assist maneuver will increase the SOC inclination 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 2014

The Heavy Ion Sensor (HIS) instrument successfully completed its CDR in March 2014. Both HIS and Solar Orbiter Heliospheric Imager (SoloHI) delivered shock thermal models, and HIS delivered its electrical model. NASA awarded the launch services contract to United Launch Alliance (ULA) in March 2014.

WORK IN PROGRESS IN FY 2015

The project will deliver the Electrical Model for SoloHI. Flight assets will be completed, tested and delivered. NASA will support the integration of the instruments into the spacecraft, and the integration of the spacecraft with the launch vehicle.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will continue to support the integration of the HIS and SoloHI instruments into the spacecraft.

SOLAR ORBITER COLLABORATION

Formulation	Development	Operations

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 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	Oct 2018
End of Prime Mission	Nov 2026	Nov 2026

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	376.9	N/A	2015	320.0	-15.1	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. 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 NASA approved the start of development (at KDP-C).

Development Cost Details

NASA confirmed Solar Orbiter to proceed into implementation phase in March 2013. The current year development cost reflects the award of the launch vehicle contract.

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**376.9**	**320.0**	**-56.9**
Aircraft/Spacecraft	0.0	0.0	0.0

SOLAR ORBITER COLLABORATION

Formulation	Development	Operations

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
Payloads	23.7	34.6	10.9
Systems I&T	0.0	0.0	0.0
Launch Vehicle	250.0	172.7	-77.3
Ground Systems	N/A	N/A	N/A
Science/Technology	1.3	1.5	0.2
Other Direct Project Costs	101.9	111.2	9.3

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 AO.

Element	Description	Provider Details	Change from Baseline
SoloHi	Measures the solar wind formations, shock disturbance, and turbulence	Provider: Naval Research Lab Lead Center: GSFC Performing Center: GSFC Cost Share Partner: N/A	N/A
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: N/A Cost Share Partner: N/A	N/A
Expendable Launch Vehicle	Launch vehicle	Provider: ULA Lead Center: KSC Performing Center: KSC Cost Share Partner: N/A	N/A

SOLAR ORBITER COLLABORATION

Formulation	Development	Operations

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 AO. NASA competitively selected the launch vehicle through the NLS-II 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

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Mar 2013	PDR to assess readiness for KDP-C	Successful, project ready to proceed to development	Jul 2015
Perform-ance	SRB	Oct 2013	SoloHI Instrument to assess readiness for CDR	Successful	Apr 2015
Perform-ance	SRB	Mar 2014	HIS Instrument to assess readiness for CDR	Successful	Apr 2015

SOLAR ORBITER COLLABORATION

Formulation	Development	Operations

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jun 2015	Pre-ship Review to assess readiness for shipment to ESA		
Perform-ance	SRB	Oct 2018	Operations Readiness Review/Mission Readiness Review to assess readiness for KDP-E.		

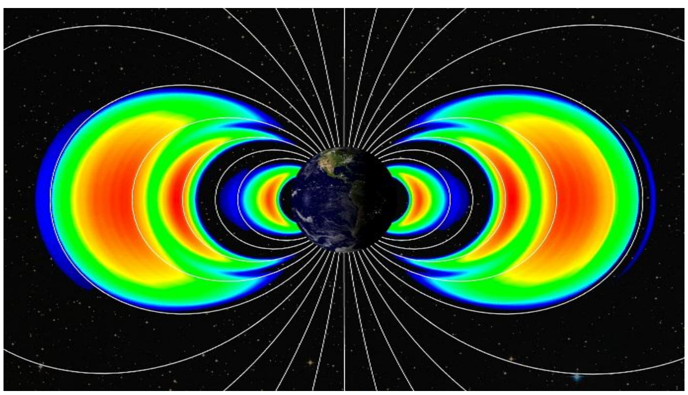
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Balloon Array for Radiation-belt Relativistic Electron Losses (BARREL)	1.5	--	**0.0**	0.0	0.0	0.0	0.0
LWS Space Environment Testbeds	0.6	--	**0.4**	0.4	0.0	0.0	0.0
LWS Science	18.2	--	**17.5**	17.5	25.5	30.5	29.5
LWS Program Management and Future Missions	5.9	--	**6.7**	6.9	7.8	15.3	26.8
Van Allen Probes (RBSP)	10.8	--	**15.5**	14.3	14.0	14.0	10.0
Solar Dynamics Observatory (SDO)	14.8	--	**9.5**	9.5	9.5	9.5	9.5
Total Budget	**51.7**	**--**	**49.7**	**48.7**	**56.9**	**69.4**	**75.9**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



The Earth's Van Allen radiation belts consist of donut-shaped distinct zones of trapped, highly energetic charged particles. The inner zone is primarily comprised of very energetic positive protons and is stable over years to decades. Novel energy-specific observations from NASA's Van Allen Probes show an 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 a powerful interplanetary shock wave passage virtually annihilated it.

The LWS Other Missions and Data Analysis budget includes operating LWS missions, a science research program, program management, and funding for missions to launch in the next decade.

For more information, go to: http://science.nasa.gov/about-us/smd-programs/living-with-a-star/.

Mission Planning and Other Projects

LWS SPACE ENVIRONMENT TESTBEDS

The SET project seeks to improve the accommodation and/or mitigation of the effects of solar variability on spacecraft. It addresses the identification and understanding of the mechanisms of space environment interactions, modeling of these interactions, and development and validation of 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 mid-2016.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

The Demonstration and Space Experiments spacecraft remains in storage with monthly battery charges, abbreviated functional tests, and minor hardware modifications.

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 (CMEs and solar flares), and will distribute the database 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 heliophysics, 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 through three main approaches:

- Builds infrastructure: The infrastructure component includes funding to train the next generation of heliophysics experts, conduct a heliophysics graduate-level summer school, develop graduate course content, and support a limited number of space weather postdoctoral positions at universities and government laboratories.
- Addresses scientific needs: The goal of the project is to develop the scientific understanding needed for the United States to address those aspects of Heliophysics science that may affect life and society. To ensure this, the Targeted Research & Testing (TR&T) element solicits large-scale problems that cross discipline and technique boundaries leading to a physics-based understanding of the integral system linking the Sun to the solar system both directly and via the heliosphere, planetary magnetospheres, and ionospheres. The proposals identify how this new understanding will have a direct impact on life and society. In addition, TR&T supports the Sun-Climate objective whose goal is to deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales. TR&T also supports the development of tools and methods needed to achieve the LWS goals.
- Addresses strategic capabilities. A primary goal of this project is the development of first-principles-based models for the coupled Sun-Earth and Sun-solar system, similar in spirit to the first-principles models for the lower terrestrial atmosphere. Such models can act as tools for science investigations, as prototypes and test beds for prediction and specification capabilities, as frameworks for linking disparate data sets at vantage points throughout the Sun-Solar System, and as strategic planning aids for enabling exploration of space and testing new mission concepts. Strategic capabilities are the development and integration of such models for all the various components of this system. These models have reached a level of maturity that enables integration into scientific and operational deliverables (e.g., models or tools) that are broadly useful to the larger community in universities, government laboratories, industry, and the military.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

In recent years, researchers have attempted to develop accurate solar cycle predictions. They have discovered that by following the motions of brightpoints, small magnetic regions on the Sun's surface, they can track the flow of material coursing underneath the Sun's surface. Tracking these movements provides a new way to watch how magnetic fields evolve and move through our closest star. Over the course of a solar cycle, sunspots migrate progressively lower in latitude, moving toward the equator. The new research shows that the brightpoints, which tend to cluster in bands tied to large magnetic fields deep below the surface, also moved steadily toward the equator over time along the same path as sunspots, but begin their migration at much higher latitudes. In addition, each hemisphere of the Sun usually has more than one of these bands present. Each band takes about 19-20 years from first appearance to disappearance at the equator. The interaction between these bands can explain the waxing and waning of the solar activity cycle. The overlap between two longer cycles may explain the 11-year solar cycle.

To learn more about the conditions that lead to severe space weather, researchers are using supercomputers to run simulations of the solar surface, interior, and atmosphere. These realistic computer models go a long way toward improving our understanding of the Sun's structure and dynamics beneath the visible surface. The simulation results show that the turbulent plasma flows can efficiently amplify initially weak magnetic fields in the Sun's interior by several orders of magnitude. This knowledge helps explain the dramatic changes that occur near the surface, providing a better understanding of the mechanisms that lead to the formation of sunspots and active regions. Understanding the magnetic and energetic interactions within these layers is key to learning how and why solar storms develop.

Researchers used a rare conjunction event between the THEMIS spacecraft and a ground-based all-sky imager at the South Pole during polar night to demonstrate that pulsating aurorae were highly correlated with the modulation of electron content of the magnetosphere above it. The researchers' model of luminous intensity matched the observed all-sky imager data. The ability to accurately model and predict the precipitation of electrons into the ionosphere has implications for mitigating the radiation dose experienced by polar flights, and limits high frequency communications.

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 support strategic planning for addressing the LWS 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 is helping scientists to 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 are providing 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

On March 26, 2014, NASA declared the Van Allen Probes mission, designed to explore and unlock the mysteries of Earth's radiation belts, an official success. This certification came just one year, six months, and 27 days into the two-year primary mission of the twin spacecraft, which orbit Earth roughly every nine hours. The Van Allen Probes mission has met and surpassed its requirements for scientific instrument performance, mission operations, and scientific progress needed to achieve mission success.

Observations from NASA's twin Van Allen Probes spacecraft have conclusively shown that particle acceleration can occur within Earth's radiation belts themselves. Researchers previously thought that the electrons pick up additional energy from elsewhere. The inner Van Allen radiation belt is fairly stable, but the outer belt changes shape, size, and composition. Some of the particles within this belt travel at close to light speed. Data from the Van Allen Probes suggests that this particle acceleration is a two-fold process. The first mechanism is based on time domain structures, which are very short-duration pulses of electric fields that run parallel to the magnetic fields that thread through the radiation belts. These magnetic field lines guide the movement of all the charged particles in the belts. During the early phase, the electric pulses push the particles faster forward in the direction parallel to the magnetic fields. Once the particles attain reasonably large energies, they interact with giant electromagnetic waves called "Whistler" waves, which increases the particles to extremely high speeds.

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. SDO collects data to help explain the creation of solar activity, which drives space weather. 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 SDO, called the Helioseismic and Magnetic Imager (HMI), researchers finally found elusive "giant convective cells" in the solar interior. Scientists theorized their existence over 40 years ago but data was not available to prove their existence until scientists were able to get continuous observations that are only available from space and, specifically, from the HMI instrument with its high resolution. Giant convective cells are 30 times the size of the earth, transport heat from the Sun's core, and play a role in originating the cycles of sunspot activity. The HMI observations may also help answer a question asked since the time of Galileo: Why does the Sun rotate faster at the equator than at the pole? The motion of giant cells can explain this rotation, which is a key part of how the solar cycle works, with implications to every star, not just the Sun.

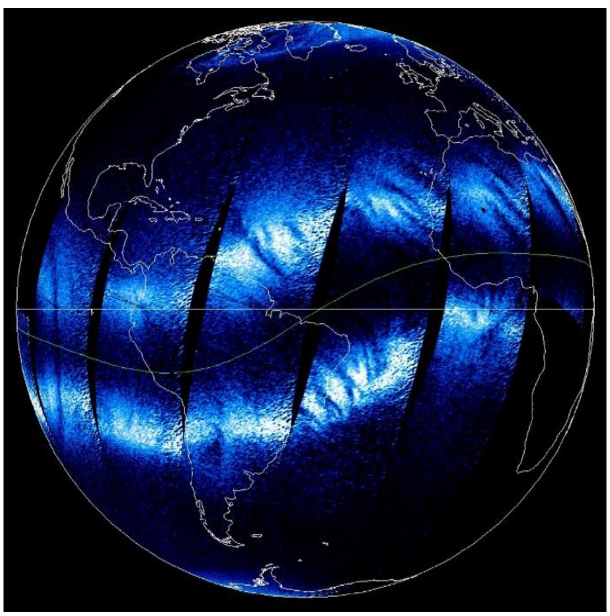
SOLAR TERRESTRIAL PROBES

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Magnetospheric Multiscale (MMS)	120.9	52.4	**30.1**	17.5	10.8	0.0	0.0
Other Missions and Data Analysis	22.4	--	**20.4**	20.1	31.0	133.3	189.2
Total Budget	**143.3**	--	**50.5**	**37.6**	**41.8**	**133.3**	**189.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



Observations from the STP mission TIMED of the Earth's nighttime ionosphere displaying spatial structures of various scales (caused by small and large-scale waves emanating upward from the troposphere). These plasma bubbles can cause dropouts in communication and navigation systems.

STP focuses on understanding the fundamental physical processes of the space environment, from the Sun to the Earth, other planets, and beyond to the interstellar medium. STP provides insight into the basic processes of plasmas (fluid of charged particles) inherent in all astrophysical systems. STP missions focus on processes such as the variability of the Sun, responses of the planets to those variations, and the interaction of the Sun and the 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: http://science.nasa.gov/about-us/smd-programs/solar-terrestrial-probes/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	172.9	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	172.9
Development/Implementation	712.6	120.9	51.0	**0.0**	0.0	0.0	0.0	0.0	0.0	884.5
Operations/Close-out	0.0	0.0	1.4	**30.1**	17.5	10.8	0.0	0.0	0.0	59.9
2015 MPAR LCC Estimate	**885.5**	**120.9**	**52.4**	**30.1**	**17.5**	**10.8**	**0.0**	**0.0**	**0.0**	**1117.3**
Total Budget	**885.5**	**120.9**	**52.4**	**30.1**	**17.5**	**10.8**	**0.0**	**0.0**	**0.0**	**1117.3**
Change from FY 2015				**-22.3**						
Percentage change from FY 2015				**-42.6%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

All four MMS spacecraft stacked for environmental testing.

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 natural laboratory to study the microphysics of magnetic reconnection, a fundamental plasma-physical process that converts magnetic energy into heat and charged particle kinetic energy. In addition to seeking to solve the mystery of the small-scale physics of the reconnection process, MMS will 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, go to: http://science.nasa.gov/missions/mms/.

MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations

EXPLANATION OF MAJOR CHANGES IN FY 2016

The budget reflects a potential overrun of about three percent.

PROJECT PARAMETERS

Scheduled for launch in April 2015, 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 highly elliptical 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 events. The separation between the observatories will be adjustable over a range of 6 to 250 miles during science operations in the area of interest. The mission design life is two years.

ACHIEVEMENTS IN FY 2014

The project completed testing of the spacecraft and scientific instruments, simulating the extreme conditions experienced during launch and in space during the mission. The project completed final spacecraft mass properties/spin balancing testing in preparation for shipment to the launch facility.

WORK IN PROGRESS IN FY 2015

The project will ship all four observatories to the Kennedy Space Center and complete launch processing. The project will complete extensive mission readiness testing prior to launch to ensure that the flight and ground operations work together as a system to support launch and on-orbit operations. NASA will launch, commission, and begin mission operation in FY 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will operate the spacecraft and process, analyze, and publish science mission results.

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 April 2015.

Milestone	Confirmation Baseline Date	FY 2016 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 2016 PB Request
Launch	Mar 2015	Apr 2015
Start of Phase E	Jul 2015	Sep 2015
End of Prime Mission	Jul 2017	Sep 2017

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2010	857.3	70	2015	884.5	3.2	LRD	Mar 2015	Apr 2015	1

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

The October 2013 government shutdown caused a launch delay. The new launch window is open through April 2014 and requires an increase in cost. Spacecraft costs increased due to increased personnel, parts costs, and environmental test costs. Payload costs 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, as well as 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 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 declined 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)
TOTAL:	**857.3**	**884.5**	**27.2**
Aircraft/Spacecraft	169.0	260.6	91.6
Payloads	131.9	228.43	96.5
Systems I&T	55.3	53.3	-2.0
Launch Vehicle	194.2	181.4	-12.8
Ground Systems	19.1	38.9	19.8
Science/Technology	19.9	27.3	7.4
Other Direct Project Costs	268.0	97.4	-173.2

Project Management & Commitments

Element	Description	Provider Details	Change from Baseline
Electric fields instrument	Provide measurements of electric fields (time resolution 1millisecond) and magnetic fields (time resolution 10 milliseconds)	Provider: University of New Hampshire Lead Center: GSFC Performing Center: GSFC Cost Share Partner: Austria	N/A
Fast Plasma Investigation	Provide high temporal resolution measurements of the 3D distributions of hot electrons and ions (30 milliseconds electrons, 150 milliseconds ions)	Provider: GSFC Lead Center: GSFC Performing Center: GSFC Cost Share Partner: Japan	N/A
Energetic Particle Detectors	Provide high-resolution measurement of energetic particles	Provider: JHU-APL Lead Center: GSFC Performing Center: GSFC Cost Share Partner: None	N/A
Hot Plasma Composition Analyzers	Three-dimensional measurements of hot plasma composition (time resolution 10 seconds)	Provider: Southwest Research Institute Lead Center: GSFC Performing Center: GSFC Cost Share Partner: None	N/A

MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations

Element	Description	Provider Details	Change from Baseline
Launch Vehicle	Deliver approximately 5,450 kilograms payload consisting of four observatories to a highly elliptical Earth orbit	Provider: ULA Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): None	N/A
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	N/A
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	N/A
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	N/A
Four Instrument Suites	Provide measurements of electric fields, plasma waves, energetic particles, and hot plasma	Provider: Southwest Research Institute Lead Center: GSFC Performing Centers: GSFC Cost Share Partners: Austria, France, Japan	N/A

Project Risks

Risk Statement	Mitigation
If: Latent FPI HV801 optocoupler anomalies and root cause are not fully mitigated, Then: There is the possibility that part dynamic failure leading to instrument degradation or part static failure leading to instrument spectrometer failure may occur.	The project screened all instruments for HV801 failures during FPI super suite testing. HV801 Mission Profile Risk Assessment Test (MPRAT) at the board and part level is ongoing. The project implemented operational changes to limit on orbit thermal cycling of FPI instruments.

MAGNETOSPHERIC MULTISCALE (MMS)

Formulation	Development	Operations

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	ULA	Cape Canaveral Air Force Station, Florida
Instrument Suite	Southwest Research Institute	San Antonio, TX

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
All	SRB	Nov 2014	Operations Readiness Review	Successful	N/A

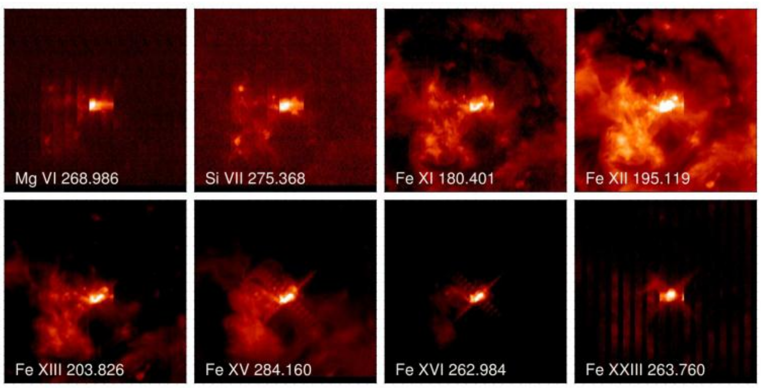
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
STP Program Management and Future Missions	2.0	--	**1.0**	1.0	12.0	114.4	170.2
Solar Terrestrial Relations Observatory (STEREO)	9.5	--	**9.5**	9.5	9.5	9.5	9.5
Hinode (Solar B)	8.0	--	**7.3**	7.0	7.0	7.0	7.0
TIMED	2.9	--	**2.7**	2.6	2.5	2.5	2.5
Total Budget	**22.4**	**--**	**20.4**	**20.1**	**31.0**	**133.3**	**189.2**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Each of these images from the Japan Aerospace Exploration Agency's and NASA's Hinode spacecraft shows a progressively hotter layer of the sun's atmosphere. The upper left corner shows material in a low part of the atmosphere, called the chromosphere. The images progress upward through the heart of the X-class solar flare that occurred on March 29, 2014 up to over 3,000 miles above the surface in the image on the lower ight. Each image shows a narrow swatch of the flare, which together are combined to create a 3-dimensional image.

The STP Other Missions and Data Analysis budget includes operating STP missions, program management, and funding for future missions launching in the next decade.

For more information, go to: 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

Operating Missions

SOLAR TERRESTRIAL RELATIONS OBSERVATORY (STEREO)

STEREO enables studies of the origin of the Sun's CMEs and their consequences for Earth, other planets, and interplanetary space. 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 events and developing predictive models. The models in turn help to identify and mitigate the risks associated with space weather events. Additionally, STEREO improves our space weather situational awareness not only for Earth and in low earth orbit, but also throughout the solar system.

Recent Achievements

Surrounding the Sun is a vast atmosphere of solar particles, through which magnetic fields swarm, solar flares erupt, and gigantic columns of material rise, fall, and jostle each other around. Now, using STEREO, scientists have found that this atmosphere, called the corona, is even larger than thought, extending out some five million miles above the Sun's surface, the equivalent of 12 solar radii. This information has implications for NASA's upcoming SPP mission, due to launch in 2018. Discovering that the corona extends much further than previously thought has important consequences for SPP because the spacecraft will travel to within 4 million miles of the Sun, closer than any man-made technology ever before. Scientists knew the mission would be gathering information closer to the Sun than ever before, but could not be sure it would travel through the corona proper. These STEREO observations provide the first direct measurements of the inner boundary of the heliosphere, the giant bubble sparsely filled with solar particles that surrounds the Sun and all the planets. Combined with measurements from Voyager 1 of the outer boundary of the heliosphere, we have now defined the extent of this entire local bubble.

HINODE

Hinode is a joint Japanese Institute of Space and Astronautical Science and NASA mission, operating as a follow-on to the highly successful Japan, United States, and United Kingdom 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

The current solar cycle (Cycle 24) has been unusual from its beginning, with the weakest polar magnetic field during the previous minimum since the beginning of the space age. The strength of the polar field is an important factor in predicting the onset and strength of future solar activity maxima. Hinode's Solar Optical Telescope (SOT) has been tracking in detail magnetic field changes at the poles since 2007. The observations show that the magnetic polarity reversed at the North Pole in 2012, while the South Pole has only changed in the last few months, if at all. SOT observations also reveal a "local dynamo" near the surface of the Sun that results in a large network of weak fields that evolve independently with time.

OTHER MISSIONS AND DATA ANALYSIS

Associated with the strong magnetic elements are polar faculae, which are patches of bright emission seen near the poles. The number of these faculae feed into many solar cycle prediction models. Surprisingly, however, an initial study by Hinode's SOT has concluded that the overall polar field strength may not directly result in the presence of polar faculae. Therefore, researchers must use this common marker for solar cycle predictions with more caution, especially for weak cycles, such as the current one. With extension of the observations over a complete solar cycle, we should be able to see how these relationships develop as the polar fields evolve towards the next minimum, thereby strengthening our ability to predict future solar activity.

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

TIMED observations show how global-scale waves forced by large-scale weather systems and modulated by the El Niño–Southern Oscillation in the tropical troposphere propagate upward and introduce strong variations in global mesospheric and lower thermospheric wind patterns 50 to 75 miles above the Earth's surface. TIMED has also observed that when a solar storm hits Earth, there is a sharp temperature rise followed by cooling. The temperature of earth's thermosphere is a balance between energy gained from the Sun and energy lost through infrared emission. In addition to solar effects, carbon dioxide increases in the atmosphere due to anthropogenic effects will lead to a long-term cooling trend in the thermosphere. TIMED data provide the first long-term observations for testing the radiative physics of upper atmosphere models to verify and quantify this behavior.

HELIOPHYSICS EXPLORER PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
ICON	59.8	61.0	**49.8**	48.0	9.0	4.5	1.3
Other Missions and Data Analysis	40.4	--	**49.2**	43.9	45.1	150.1	220.0
Total Budget	**100.2**	--	**98.9**	**91.9**	**54.1**	**154.5**	**221.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

In January 2014, a time of year when southern noctilucent clouds (NLCs) are usually abundant, NASA's AIM spacecraft observed a sudden and unexpected decline in the clouds. NLCs are Earth's highest clouds that form at the edge of space 83 km above our planet's polar regions in a layer of the atmosphere called the mesosphere. About two weeks before the NLCs disappeared, winds in the Arctic stratosphere were strongly perturbed, leading to the polar vortex that made headlines this winter when parts of the USA experienced crippling cold and ice. Scientists compared the AIM data to meteorological data and found there was a statistical link between winter weather in the USA and the decline in noctilucent clouds over Antarctica.

The Heliophysics Explorer 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 LWS and STP programs. Competitive selections ensure accomplishment of the most current and best science.

The Explorers Program provides several classes (Medium-MIDEX/Small-SMEX/University-UNEX) of flight opportunities to accomplish the goals of the science program. These mission classes enable NASA to increase the number of flight opportunities in response to recommendations from the scientific community.

The 2011 NASA AO for new missions introduced the Standard Explorers (EX) missions in response to the currently available expendable launch vehicles. EX missions fall between the SMEX and MIDEX class missions. Access to space will utilize one of the several, lower-cost expendable launch vehicles available through NASA's Launch Services Program.

Explorer Missions of Opportunity (MO) are smaller investigations, typically an instrument, characterized as being part of a host space mission, sub-orbital flight, small complete missions, and new science investigations using existing spacecraft or ISS-attached payloads.

HELIOPHYSICS EXPLORER PROGRAM

NASA implements the Heliophysics Explorers program via competitively selected 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.

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://science.nasa.gov/about-us/smd-programs/explorers/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

An increase in the notional out year budgets, if realized, would support the launch cadence recommended by the 2013 Heliophysics National Academies Decadal Survey for Explorers and associated Missions of Opportunity.

IONOSPHERIC CONNECTION EXPLORER

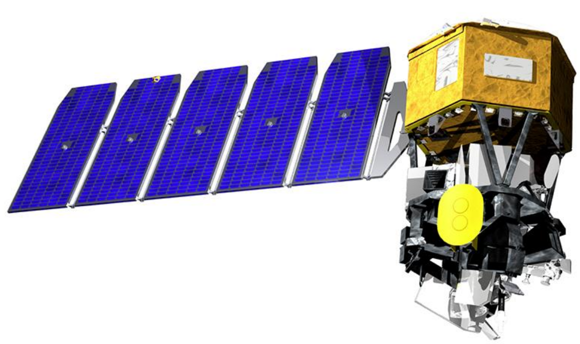
Formulation	Development	Operations

FY 2016 Budget

		Actual	Enacted	Request		Notional				
Budget Authority (in $ millions)	Prior	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	19.2	23.2	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	42.4
Development/Implementation	0.0	36.6	61.0	**49.8**	45.4	3.1	0.0	0.0	0.0	196.0
Operations/Close-out	0.0	0.0	0.0	**0.0**	2.6	5.9	4.5	1.3	0.0	14.3
2015 MPAR LCC Estimate	**19.2**	**59.8**	**61.0**	**49.8**	**48.0**	**9.0**	**4.5**	**1.3**	**0.0**	**252.7**
Total Budget	**19.2**	**59.8**	**61.0**	**49.8**	**48.0**	**9.0**	**4.5**	**1.3**	**0.0**	**252.7**
Change from FY 2015				**-11.2**						
Percentage change from FY 2015				**-18.4%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.



ICON will explore the boundary between Earth and space to understand the physical connection between our world and our space environment.

PROJECT PURPOSE

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 2016

The budget reflects the approved KDP-C cost and schedule baselines.

PROJECT 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 OSC ATK,LEOStar-2 spacecraft bus with heritage from Solar Radiation and Climate Experiment (SORCE), AIM, Orbiting Carbon Observatory

IONOSPHERIC CONNECTION EXPLORER

Formulation	Development	Operations

(OCO), Glory, and Nuclear Spectroscopic Telescope Array (NuSTAR). ICON will provide the data to "understand how neutral winds control ionospheric variability," which is a goal in the 2010 Science Plan for NASA's SMD.

ACHIEVEMENTS IN FY 2014

The project completed the SRR in January 2014 and PDR in July 2014.

WORK IN PROGRESS IN FY 2015

NASA confirmed ICON to proceed into implementation phase (Phase C/D) on October 29, 2014. ICON will also complete its CDR during FY 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The Project will complete the SIR and will proceed to observatory integration and test by the end of FY 2016.

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-C	Oct 2014	Oct 2014
CDR	Apr 2015	Apr 2015
SIR	Jun 2016	Jun 2016
Launch	Oct 2017	Oct 2017
Start of Phase E	Nov 2017	Nov 2017
End of Prime Mission	Dec 2019	Dec 2019

Development Cost and Schedule

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

IONOSPHERIC CONNECTION EXPLORER

Formulation	Development	Operations

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2015	196.0	70	2015	196.0	0	LRD	Oct 2017	Oct 2017	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

NASA confirmed ICON to proceed into implementation in October 2014.

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**196.0**	**196.0**	**0.0**
Aircraft/Spacecraft	29.8	29.8	0.0
Payloads	35.8	35.8	0.0
Systems I&T	9.4	9.4	0.0
Launch Vehicle	54.3	56.3	2.0
Ground Systems	2.9	2.9	0.0
Science/Technology	3.0	3.0	0.0
Other Direct Project Costs	60.8	58.8	-2.0

IONOSPHERIC CONNECTION EXPLORER

Formulation	Development	Operations

Project Management & Commitments

Element	Description	Provider Details	Change from Baseline
Expendable Launch Vehicle	Deliver the spacecraft to operational orbit	Provider: OSC Lead Center: KSC Performing Center: KSC Cost Share Partner: N/A	N/A
Spacecraft	Transport instruments to science destination	Provider: OSC Lead Center: N/A Performing Center: N/A Cost Share Partner: N/A	N/A
MIGHTI	High resolution imager instrument	Provider: NRL Lead Center: N/A Performing Center: N/A Cost Share Partner: N/A	N/A
EUV	Extreme UV instrument	Provider: University of California, Berkeley Lead Center: N/A Performing Center: N/A Cost Share Partner: N/A	N/A
FUV	Far UV instrument	Provider: UCB Lead Center: N/A Performing Center: N/A Cost Share Partners: Belgian Centre Spatial de Liège (CSL)	N/A
IVM	Ion velocity meter instrument	Provider: University of Texas, Dallas Lead Center: N/A Performing Center: N/A Cost Share Partner: N/A	N/A

IONOSPHERIC CONNECTION EXPLORER

Formulation	Development	Operations

Project Risks

Risk Statement	Mitigation
If: Problems occur in the flight unit build/test or software, Then: Flight Master Avionics Unit delivery will be delayed.	Utilize the Explorer Master Avionics Unit test program to meet ICON requirements

Acquisition Strategy

All acquisitions are in place. NASA selected ICON through the AO two-step process, and awarded the science investigation to the University of California Berkeley PI in April 2013.

MAJOR CONTRACTS/AWARDS

NASA awarded the mission Phase B through E (formulation through operations) procurement to the University of California at Berkeley for the PI-controlled mission. All major contracts are in place.

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	SRB	Jan 2014	SRR to evaluate ICON requirements	Successful	Jul 2014
Perform-ance	SRB	Jul 2014	PDR to assess readiness for KDP-C	Successful	Apr 2015
Perform-ance	SRB	Apr 2015	Critical Design Review to assess readiness for KDP-D		Aug 2016
Perform-ance	SRB	Aug 2016	Mission Pre-Environmental Review		Jan 2017
Perform-ance	SRB	Jan 2017	Observatory Pre-Ship Review		May 2017
Perform-ance	SRB	May 2017	Operations Readiness Review /Mission Readiness Review to assess readiness for KDP-E.		

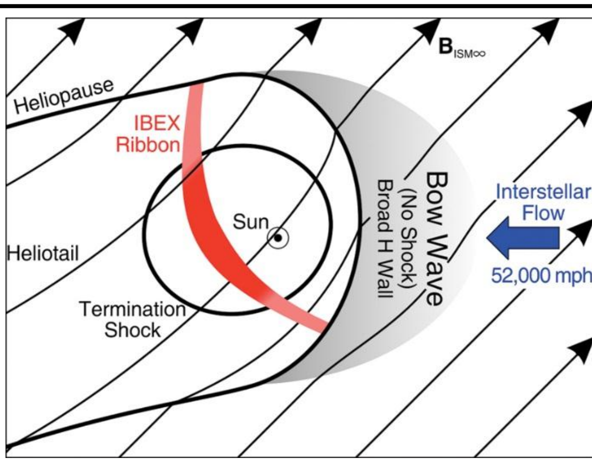
OTHER MISSIONS AND DATA ANALYSIS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Global-scale Observations of the Limb and Disk (GOLD)	9.4	--	**17.5**	14.8	8.6	2.8	0.7
Heliophysics Explorer Future Missions	0.0	--	**0.0**	0.0	4.0	115.2	187.2
Heliophysics Explorer Program Management	3.8	--	**6.8**	4.7	8.9	8.7	9.1
Interface Region Imaging Spectograph (IRIS)	8.6	--	**7.7**	7.7	7.0	7.0	6.5
Interstellar Boundary Explorer (IBEX)	3.6	--	**3.4**	3.4	3.4	3.4	3.4
TWINS	0.6	--	**0.6**	0.6	0.6	0.6	0.6
CINDI	0.9	--	**0.6**	0.3	0.2	0.0	0.0
Aeronomy of Ice in Mesophere (SMEX-9)	3.0	--	**3.0**	3.0	3.0	3.0	3.0
Time History of Events and Macroscale Interactions during Substorms (THEMIS)	5.4	--	**4.6**	4.5	4.5	4.5	4.5
ACE	3.0	--	**3.0**	3.0	3.0	3.0	3.0
RHESSI	2.1	--	**1.9**	1.9	1.9	1.9	1.9
Total Budget	**40.4**	**--**	**49.2**	**43.9**	**45.1**	**150.1**	**220.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



IBEX, a Small Explorer mission, provided unprecedented measurements of the interstellar flow speed and direction. The revised speeds indicate that the heliosphere, the bubble of solar wind surrounding the Sun and solar system, does not drive a bow shock. Instead, a bow wave precedes 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.

The Heliophysics Explorer 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: http://science.nasa.gov/about-us/smd-programs/explorers/.

Mission Planning and Other Projects

GLOBAL-SCALE OBSERVATIONS OF THE LIMB AND DISK (GOLD)

The GOLD investigation will perform unprecedented imaging of the Earth's thermosphere and ionosphere. For the first time, GOLD will answer fundamental scientific questions about how the

OTHER MISSIONS AND DATA ANALYSIS

thermosphere/ionosphere system responds to geomagnetic storms, solar radiation, and upward propagating waves and tides.

Recent Achievements

GOLD is proceeding towards PDR with excellent technical progress and is now preparing for 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.

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.

Recent Achievements

The Explorer Program Office successfully completed the Heliophysics Program Implementation Review in November 2014. This review is an independent assessment that validates the strategic direction and implementation of the Explorer, STP, and LWS flight programs.

Operating Missions

INTERFACE REGION IMAGING SPECTROGRAPH (IRIS)

IRIS is a Small Explorer 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 is enabling scientists to understand what energizes the solar atmosphere, providing significant new information to increase our understanding of energy transport into the corona and solar wind, which provides a model 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 provides key insights into all these processes, and thereby advances 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.

OTHER MISSIONS AND DATA ANALYSIS

Recent Achievements

Mounting evidence demonstrates that magnetic reconnection is the physical process responsible for much of the dynamics that forms and drives the Sun's atmosphere, from its deepest layer, the chromosphere, to the corona, and out to the solar wind that impacts our Earth. The IRIS satellite has shown that the dominant structure of the chromosphere is jets of relatively cool gas driven by magnetic reconnection and propelled upward at speeds of 100,000-200,000 miles per hour. IRIS's unparalleled spatial and temporal resolution has now revealed that these jets rapidly reach temperatures in excess of 100,000 Kelvin and carry strong magnetic waves that penetrate into the corona and solar wind. We believe these waves play a role in powering the high-velocity solar wind. Scientists believe that reconnection also plays a critical role in the corona, heating it through small-scale reconnection events termed nanoflares. The Extreme Ultraviolet Normal Incidence Spectrograph (EUNIS) sounding rocket obtained the first direct evidence of these nanoflares. The sounding rocket found the presence of pervasive faint high-temperature radiation, approximately 10 million degrees Kelvin, in the corona. This radiation can only be explained by small heating events, exactly as predicted by the nanoflare model and, hence, may well be the "smoking gun" that confirms this theory.

INTERSTELLAR BOUNDARY EXPLORER (IBEX)

IBEX is the first mission designed to image the edge of the solar system. As the solar wind from the Sun flows out beyond Neptune, 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 these 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.

Recent Achievements

IBEX observations of the energetic neutral atom ribbon at the edge of the heliospheric boundaries allowed scientists to build a new computer model of the orientation of the interstellar magnetic field draping around the heliosphere. This model accounted for the uneven distribution of cosmic rays observed at Earth and suggested that the boundary that separates solar and interstellar plasmas is very long, perhaps two trillion miles in the downwind direction away from the Sun. The direction of the magnetic field beyond this boundary is quite different when compared to that observed by Voyager 1. Though puzzling, these new results also provide important clues to the ways in which high-energy cosmic rays enter the solar system and reach Earth.

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 that contains 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

New global observations of magnetospheric ion temperature during Solar Cycle 24 have revealed a dramatic difference during geomagnetic storms driven by CMEs versus those driven by co-rotating interaction regions (CIRs), or rotating regions where fast and slow solar winds inter-act. Researchers obtained TWINS temperature maps for 48 geomagnetic storms that occurred between June 2008 and April 2012. Average ion temperature maps for each storm phase show how each type of storm driver (CME vs. CIR) yields different dynamics of storm evolution. Stronger convection during CME-driven storms transports higher-energy ions closer to the Earth, producing higher temperatures than for CIR-driven storms. During intense CME-driven storms, compression of the shocked magnetosphere yields the highest temperature at storm commencement, followed by a decrease during the storm main phase. Moderate CME storms have relatively steady temperatures from start to finish. These TWINS ion temperature maps are already helping to improve global geospace models and elucidate physical processes.

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 disruptions in 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 events. CINDI is in extended phase until September 2016. The mission consists of two instruments on the Communication/Navigation Outage Forecast System satellite, a project of the US Air Force.

Recent Achievements

CINDI has observed decreases in plasma densities over a wide range of longitudes over the same local time span. During solar minimum, these decreases extend beyond local midnight and over widely separated locations. This suggests that these decreases in the ionosphere may affect communications. Identifying the causes of these decreases, therefore, can aid in predicting future communications disruptions.

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 the 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

Arctic winter observations in 2013 by AIM show large amounts of nitric oxide-enriched air transported down through the atmosphere. Nitric oxide catalytically destroys ozone, a process in which a single nitric oxide molecule can wipe out thousands of ozone molecules. This downward transport has significant implications on the amount of ultraviolet sunlight reaching Earth’s surface. Since the bombardment of energetic particles from space onto our upper atmosphere produces thermospheric nitric oxide, the transport also provides an important link between space weather events and UV conditions at Earth’s surface. Evidence points to stratospheric temperature disturbances as a key trigger for processes that connect the upper atmosphere to the lower atmosphere, the northern hemisphere to the southern hemisphere, and space weather events to life here on Earth.

Additionally, recent AIM measurements show concentric curve images that align with very similar patterns in temperature simultaneously observed almost 30 miles below the clouds by the Aqua satellite. AIM results show that winter weather at the surface might be a harbinger of weather in the summer polar mesosphere in the other hemisphere of the globe because of two-way connections between the lower and upper atmosphere.

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 that can lead to 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, among others in the Heliophysics portfolio, are examples of missions offering important dynamics knowledge useful for future human spaceflight.

Recent Achievements

The solar wind and CMEs regularly bombard the Earth’s dayside magnetosphere. Normally blocked, in certain circumstances the solar wind may enter the magnetosphere via the process of magnetic reconnection. Researchers compared observations from the ground and in space, when a 2013 CME interacted with the magnetosphere for several hours. During this encounter, the THEMIS probes detected that magnetic reconnection allowed energy and solar material to cross the boundary into the magnetosphere. Simultaneous ground measurements using GPS signal strength showed that a region of plasma around the Earth, the plasmasphere, was expanding in response to the CME. A cold, dense plume of plasmasphere material extended sunward toward the magnetopause, where three THEMIS probes witnessed this interaction. The plasma plume had a dampening effect on magnetic reconnection, demonstrating the self-regulating capacity of the magnetosphere. These multipoint observations using ground and space sensors are critical to understanding and predicting the complex dynamics of our vast magnetosphere, which can lead to improved space weather forecasts.

OTHER MISSIONS AND DATA ANALYSIS

ADVANCED COMPOSITION EXPLORER (ACE)

The Advanced Composition Explorer observes particles of solar, interplanetary, interstellar, and galactic origins as they pass by its location near the L1 Lagrangian point, located about a million miles from Earth toward the Sun. Changing conditions over the solar cycle are presenting new opportunities, including providing new insights relevant to space weather events.

Recent Achievements

The intensity of the magnetic field embedded in the solar wind fluctuates with the solar cycle. During the recent extreme solar minimum, the magnetic field intensity fell to a record observed low. In addition, after the relatively small maximum of the current solar cycle, the magnetic and particle fluxes only made a partial recovery. Building on a 2010 study, researchers utilized long-term ACE magnetic field and other Heliophysics observations to show that the decreased flux levels at solar maximum will presumably lead to an even lower coming solar minimum. The similarities with the current solar conditions can help predict the coming solar minimum.

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

Many spacecraft observe the interplanetary consequences of solar eruptions. On March 29, 2014, an X-class flare erupted from the right side of the Sun and vaulted into history as the best-observed flare of all time. Many NASA spacecraft, including RHESSI, witnessed the flare. To have a record of such an intense flare from several spacecraft observing all the layers of the solar atmosphere is unprecedented. Such research can help scientists better understand what catalyst sets off these large explosions on the Sun.

AERONAUTICS

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Airspace Operations and Safety Program	0.0	--	**142.4**	153.2	159.6	160.0	163.0
Advanced Air Vehicles Program	0.0	--	**240.9**	243.2	241.2	231.0	232.8
Integrated Aviation Systems Program	0.0	--	**96.0**	85.6	89.0	101.6	104.8
Transformative Aeronautics Concepts Program	0.0	--	**92.1**	98.0	98.9	104.9	105.8
Aviation Safety	80.0	--	**0.0**	0.0	0.0	0.0	0.0
Airspace Systems	91.8	--	**0.0**	0.0	0.0	0.0	0.0
Fundamental Aeronautics	168.0	--	**0.0**	0.0	0.0	0.0	0.0
Aeronautics Test	77.0	--	**0.0**	0.0	0.0	0.0	0.0
Integrated Systems Research	126.5	--	**0.0**	0.0	0.0	0.0	0.0
Aeronautics Strategy and Management	22.7	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**566.0**	**651.0**	**571.4**	**580.0**	**588.7**	**597.5**	**606.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

AERONAUTICS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Airspace Operations and Safety Program	0.0	--	**142.4**	153.2	159.6	160.0	163.0
Advanced Air Vehicles Program	0.0	--	**240.9**	243.2	241.2	231.0	232.8
Integrated Aviation Systems Program	0.0	--	**96.0**	85.6	89.0	101.6	104.8
Transformative Aeronautics Concepts Program	0.0	--	**92.1**	98.0	98.9	104.9	105.8
Aviation Safety	80.0	--	**0.0**	0.0	0.0	0.0	0.0
Airspace Systems	91.8	--	**0.0**	0.0	0.0	0.0	0.0
Fundamental Aeronautics	168.0	--	**0.0**	0.0	0.0	0.0	0.0
Aeronautics Test	77.0	--	**0.0**	0.0	0.0	0.0	0.0
Integrated Systems Research	126.5	--	**0.0**	0.0	0.0	0.0	0.0
Aeronautics Strategy and Management	22.7	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**566.0**	**651.0**	**571.4**	**580.0**	**588.7**	**597.5**	**606.4**
Change from FY 2015			**-79.6**				
Percentage change from FY 2015			**-12.2%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Today's air transportation system is an integral part of the US 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 $1.5 trillion annually of total US economic activity[1] and is one of the few industries that generates a positive trade balance; $75.1 billion in 2013, alone[2]. The aviation industry supports more than 11.8 million direct and indirect jobs, including more than one million high-quality manufacturing jobs[1].

The overarching impacts of aviation and the air transportation system can be felt right down to the individual; just about every 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.[1] US airlines carried more than 741 million passengers in 2013 for both domestic and international flights.[1] Air travelers spend more than $670.8 billion per year for business and personal travel.[1] In short, the US aviation industry is critical to both the health of the economy and the functioning of our global society.

Research conducted by NASA's Aeronautics Research Mission Directorate (ARMD) has directly benefited today's air transportation system, aviation industry, and the passengers and businesses who rely on aviation every day. The tools and technologies that resulted from this research increased the capacity

[1] "The Economic Impact of Civil Aviation on the U.S. Economy," FAA June 2014
[2] "Bureau of Transportation Statistics http://www.transtats.bts.gov/Data_Elements.aspx?Data=2

AERONAUTICS

Successful Flight Test of Shape Changing Wing Surface

NASA is one step closer to developing technology that could make future airliners quieter and more fuel-efficient with the successful flight test of a wing surface that can change shape in flight. Researchers replaced an airplane's conventional aluminum flaps with advanced, shape-changing assemblies that form seamless bendable and twistable surfaces. Flight testing will determine whether flexible trailing-edge wing flaps are a viable approach to improve aerodynamic efficiency and reduce noise generated during take-offs and landings.

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 at NASA conduct cutting-edge research at both the fundamental and integrated systems levels to address national and global challenges.

NASA aeronautics guides its efforts with a strategic vision established in FY 2014. 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 major societal changes affecting mobility growth. The multi-year efforts indicated that NASA could best contribute to the Nation's future societal and economic vitality by focusing on efforts that are responsive to a growing demand for mobility, major challenges for energy efficiency and environmental sustainability, and convergence between traditional aeronautical disciplines and technology advances in information, communications, and automation technologies. The strategic vision identifies six research thrusts:

- Thrust 1: Safe, efficient growth in global operations;
- Thrust 2: Innovation in commercial supersonic aircraft;
- Thrust 3: Ultra-efficient commercial vehicles;
- Thrust 4: Transition to low-carbon propulsion;
- Thrust 5: Real-time, system-wide safety assurance; and
- Thrust 6: Assured autonomy for aviation transformation

NASA designed each strategic thrust to address an important area of research and technology development that will further US leadership in the aviation industry and enhance safe, sustainable global mobility. NASA's research is performed with an emphasis on multi-disciplinary collaboration focused on the critical, integrated challenges (aligned to the six research thrusts) referred to by NASA as convergent research. Together, these research thrusts combine to enable safe, sustainable growth in the overall global aviation system, while pioneering transformative capabilities that will create game-changing opportunities.

AERONAUTICS

EXPLANATION OF MAJOR CHANGES IN FY 2016

In FY 2016, the knowledge and promising technologies gained from the Environmentally Responsible Aviation (ERA) Project, which ends in FY 2015, will transition to the US aviation community. Flight testing will be increased to demonstrate promising vehicle technologies to enable additional efficiency and environmental benefits beyond ERA for future generations of aircraft. Also, NASA will add new activities to implement ARMD's strategic research thrusts, including small Unmanned Aircraft Systems (UAS) traffic management at low altitude; low-carbon propulsion concepts and technologies; methods for real-time, system-wide safety assurance; autonomous systems research; and rapid demonstrations of feasibility of new ideas that could solve big questions faced in the aviation community. Further, NASA will increase funding for fundamental hypersonics research to ensure sufficient NASA expertise and capabilities are available to support and complement the Department of Defense's efforts in this area.

ACHIEVEMENTS IN FY 2014

Thrust 1: Safe, efficient growth in global operations

The Airspace Systems Program continued progress toward Air Traffic Management (ATM) Technology Demonstration-1 (ATD-1), which will showcase an integrated set of technologies that provides an efficient arrival solution for managing an aircraft's descent from cruising altitude all the way down to the runway. In particular, NASA delivered one component of ATD-1, Terminal Sequencing and Spacing (TSS), to the FAA. TSS technology provides information to controllers about the speeds they should assign to aircraft as they follow more fuel-efficient, continuous-descent approaches into airports, saving time and fuel, and reducing emissions. TSS is another step in NASA's support of the development of a Next Generation Air Transportation System (NextGen), which is a joint multi-agency and industry initiative to modernize and upgrade the Nation's ATM system.

Thrust 3: Ultra-efficient commercial vehicles

NASA demonstrated, through analysis and testing, that ultra-high bypass (UHB) propulsion systems can be integrated with hybrid wing body concepts to meet fuel burn and noise goals. Advanced configurations, such as the hybrid wing body, hold the promise of significantly reducing the environmental impact for commercial transport aircraft, offering advantages in noise reduction and fuel burn reduction not available from today's standard tube-and-wing aircraft configurations. Additionally, the UHB engine offers the potential to dramatically reduce fuel burn and noise compared to state-of-the-art aircraft engines used today. NASA continued its investigation of UHB technologies by conducting a wind tunnel test of a second-generation UHB engine model with optimized fan exit guide vanes. The testing determined the effectiveness of those configurations to reduce noise and their impact on the performance of the engine. The wind tunnel results agreed with those predicted by state of the art analysis tools. Data from the test will contribute to a comprehensive performance database for modern UHB propulsor technologies that NASA and industry will use to update systems studies.

Thrust 4: Transition to low-carbon propulsion

NASA conducted alternative jet fuel flight tests with international partners over Palmdale, CA. Alternative Fuel Effects on Contrails and Cruise Emissions II (ACCESS II) flight testing is the latest in a series of ground and flight tests that began in 2009 to study emissions and contrail formation from new blends of aviation fuels that include biofuel from renewable sources. The ACCESS II experiment gathered additional data confirming the results of ACCESS I. This testing gathered information used to aid in developing theories about contrail formation. Understanding the impacts of alternative fuel use in aviation could enable widespread use of one or more substitutes to fossil fuels, as these new fuels become more readily available and cost-competitive with conventional jet fuels. This research supports ARMD's strategic vision, part of which is to enable the transition of the aviation industry to alternative fuels and low-carbon propulsion systems.

WORK IN PROGRESS IN FY 2015

Thrust 1: Safe, efficient growth in global operations

NASA will prepare for extensive testing of Spot and Runway Departure Advisor (SARDA) in operational field trials at the American Airlines Ramp Tower at Charlotte International Airport. SARDA improves the tower controller's ability to direct airport surface operations efficiently by allowing non-stop, continuous movement of aircraft on taxiways with resulting benefits of increased throughput and reduced fuel consumption. In the first half of FY 2015, a live data interface will be completed and extensive shadow testing of the SARDA system with subject matter experts will be conducted to assess the functional level validation and verification and system robustness. In the second half of FY 2015, SARDA will undergo a follow-on human-in-the-loop (HITL) simulation to address gaps discovered in the shadow testing.

Thrust 3: Ultra-efficient commercial vehicles

NASA's ERA Project, during its final year, will mature and demonstrate several high potential technologies in relevant environments. These technologies directly support NASA's strategic thrust to advance ultra-efficient commercial vehicles. Specifically, the ERA project plans to successfully complete eight Integrated Technology Demonstrations, which together could reduce fuel burn by 50 percent, community noise by 42 decibels below stage 4 noise standards, and nitrogen oxides emission by 75 percent during take-off and landing when they are implemented in the 2020–2025 timeframe. The US aviation industry has been coordinating and collaborating with NASA's ERA project throughout its project life, and NASA-developed technologies will significantly contribute to the aviation community's goal of achieving far more environmentally friendly aircraft without compromising performance.

Thrust 4: Transition to low-carbon propulsion

NASA plans to demonstrate the feasibility of a small filament made of a special material that will be an enabler for superconducting motors and useful for efficient transmission wires. If successful, this will greatly aid the development of future components that have the power-to-weight ratio needed for practical aviation hybrid electric propulsion systems. In addition, NASA plans to demonstrate other key components, such as a basic low-ac-loss coil system that are needed for the development of such systems. During FY 2015, NASA will ramp up its studies on hybrid electric system architectures and work on non-superconducting motors. Even though much of this work is still at very low technology readiness levels, it will pave the way for practical aviation hybrid electric propulsion systems that can achieve high levels of energy efficiency and substantially reduce carbon emissions in the future.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Thrust 1: Safe, efficient growth in global operations

NASA will develop and demonstrate air traffic controller-managed spacing of arriving flights, combined with flight deck interval management technologies, to enable precise and high-efficiency aircraft flows into the Nation's busiest airports. To demonstrate the 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, high-fidelity 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.

Thrust 3: Ultra-efficient commercial vehicles

NASA will validate the high-speed performance and aerodynamic design of a truss-braced wing (TBW) aircraft conceptual design to further advance this concept as a viable technology to reduce transport aircraft fuel use. High fidelity, Computational Fluid Dynamics (CFD)-based aerodynamic methods will be used to design the detailed novel aerodynamic shape of the configuration. One unique challenge for the TBW concept is achieving low drag with the integrated design of the truss structure with the wing and fuselage. A high-fidelity aerodynamic wind tunnel model will be tested in the 11x11-Foot Transonic Wind Tunnel at Ames Research Center (ARC) to validate the design, and contribute to an update of the integrated system assessment of this TBW concept.

Thrust 5: Real-time, system-wide safety assurance

NASA will work on real-time system monitoring and assurance through development and refinement of specialized data analytics that identify anomalies in operational data and provide information about precursors to safety risks. Tools to analyze heterogeneous data will be scaled to incorporate data from multiple sources within the aviation system, such as flight data, radar track data, and written safety reports. Prognostic and decision-making tools will also be refined and scaled to support development of a system that can predict emerging risks and provide decision support for mitigation strategies. Development of run-time monitoring capabilities for software and system assurance will enable progress toward continuous lifecycle assessment of aviation systems. Finally, continued research on operator state will work toward the goal of providing tools for continuous assessment of pilot and controller performance capabilities.

Thrust 6: Assured autonomy for aviation transformation

NASA will deliver data, analysis, and recommendations, based on two integrated flight test series with simulated traffic and live vehicles to the Radio Technical Commission for Aeronautics (RTCA) Special Committee on Minimum Operating Performance Standards for UASs. This effort is critical to the success of the RTCA Special Committee's effort and the standards necessary to achieve UAS integration into the National Airspace. This will be the last test flight series in the integrated campaign. The planned progression of the campaign will see high levels of technology integration and higher complexity of test conditions. The testing will integrate live flying unmanned aerial vehicle (UAV) and UAV surrogates (aircraft with pilots on board) with ground stations and air traffic data.

NASA will complete UAS Traffic Management (UTM) Build 1 which is a portable system focusing on small UAS flying at low altitude. UTM is a fundamentally enabling capability for safe operation of small UAS. The Build 1 system will include initial trajectory management by offering geo-fencing, initial wind/weather integration, rules of the road, and procedural separation. UTM is a system to support the development of autonomous concepts, technologies, and procedures, and demonstrate a prototype operational capability while safely enabling low-altitude operations of UAS and all other users. UTM Build 1 will be ideally suited for agriculture applications, FAA UAS test sites, or demonstrations of initial concepts. This build will allow a limited number of homogeneous vehicles to conduct delivery, search and rescue, photography, car following, surveillance, agriculture applications, humanitarian, or science missions. Future Builds will add additional capability for increased density and complexity of operations.

Programs

AIRSPACE OPERATIONS AND SAFETY PROGRAM

The Airspace Operations and Safety Program (AOSP) develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Airspace System (NAS) safely. The program works in close partnership with the FAA and the aviation community to enable and extend the benefits of NextGen, the Nation’s program for modernizing and transforming the NAS to meet evolving user needs. The program is on the leading edge of research into increasingly autonomous aviation systems, including innovation in the management of UAS traffic and other novel aviation vehicles and business models. The program is also pioneering the real-time integration and analysis of data to support system-wide safety assurance, enabling proactive and prognostic aviation safety assurance. The program takes lead responsibility for three of the Strategic Thrusts:

- Thrust 1: Safe, efficient growth in global operations;
- Thrust 5: Real-time, system-wide safety assurance; and
- Thrust 6: Assured autonomy for aviation transformation

ADVANCED AIR VEHICLES PROGRAM

The Advanced Air Vehicles (AAV) Program develops the tools, technologies, and concepts that enable new generations of civil aircraft that are safer, more highly energy efficient, and have a smaller environmental footprint. The program focus includes major leaps in the safety, efficiency, and environmental performance of subsonic fixed and rotary wing aircraft to meet challenging and growing long-term civil aviation needs; pioneering low-boom supersonic flight to achieve new levels of global mobility; and sustaining hypersonic competency for national needs. The program works in close partnership with academia and industry to pioneer the fundamental research and to mature the most promising technologies and concepts for transition to system application by the aviation industry. The program also works in partnership with the DoD to ensure both NASA and DoD vehicle-focused research is fully coordinated and leveraged. The program sustains and advances key national testing capabilities that support aeronautics research and development needs. The program takes lead responsibility for three of the Strategic Thrusts:

- Thrust 2: Innovation in commercial supersonic aircraft;
- Thrust 3: Ultra-efficient commercial vehicles; and,
- Thrust 4: Transition to low-carbon propulsion

INTEGRATED AVIATION SYSTEMS PROGRAM

The Integrated Aviation Systems Program (IASP) brings a focus on experimental flight research and the spirit of integrated, technological risk taking that can demonstrate transformative innovation. Therefore, the program complements both the Airspace Operations and Safety Program and the Advanced Air Vehicle Program by conducting research on the most 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 works in partnership with the other Aeronautics programs, academia, the aviation industry, and international partners as appropriate. The program supports the flight research and demonstration needs across all six ARMD Strategic Thrusts.

TRANSFORMATIVE AERONAUTICS CONCEPTS

The Transformative Aeronautics Concepts (TAC) 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 demonstrate initial feasibility of internally and externally originated concepts to support the discovery and initial development of new, transformative solutions for all six ARMD Strategic Thrusts. 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. The program also supports research and development of major advancements in cross-cutting computational tools, methods, and single discipline technologies to advance the research capabilities of all Aeronautics programs.

AIRSPACE OPERATIONS AND SAFETY PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	0.0	--	142.4	153.2	159.6	160.0	163.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Terminal Sequencing and Spacing (TSS) is designed to aid controllers in determining where each aircraft should be to maintain fuel efficiency in descent landing approaches and at what speed. Speed direction is issued to the aircraft by controllers to enable all of the descending aircraft to safely merge at a point in the sky. Controllers then hand aircraft off to an airport for final approach and clearance to land.

The Airspace Operations and Safety Program (AOSP) creates technologies that enable the Next Generation Air Transportation System (NextGen) fulfill its promise to transform the Nation's air traffic management (ATM) systems. AOSP seeks to directly benefit the flying public by moving key concepts and technologies from the laboratory into the field, ultimately increasing capacity and reducing the total cost of air transportation. The current US air transportation system is widely recognized to be among the safest in the world. Yet, while NextGen will meet this demand by enabling efficient passage through the increasingly crowded skies, it will come with increased operating complexity. Therefore, advanced automation technologies that work in harmony with human operators are critical for the United States to meet the public expectations for safety in this complex, dynamic domain.

AOSP, with the Federal Aviation Administration (FAA) and its other industry and academic partners, 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

AOSP will increase investment in assured autonomy and real-time system-wide safety, including both near-term concepts for UAS operations and critical long-term foundational research. AOSP will enhance the UAS Traffic Management (UTM) system enabling faster progress toward incremental system builds. The focus will also include development of simulation capability and conducting simulation studies to evaluate advanced autonomous operational architectures.

AIRSPACE OPERATIONS AND SAFETY PROGRAM

ACHIEVEMENTS IN FY 2014

Thrust 1: Safe, efficient growth in global operations

NASA completed a full-scale simulation of air traffic operations utilizing all technologies and procedures under development for ATM Technology Demonstration – 1 (ATD-1). This marked the end of the first phase of demonstration activities that involved development of prototype systems, integration of all of the technologies, and initial human-in-the-loop (HITL) simulations in NASA laboratories. Initiated in FY 2011, ATD-1 is planned to complete in FY 2017 with a final technology transfer to FAA of an integrated set of terminal arrival tools that will allow arrival aircraft to safely fly closer together on more fuel-efficient routes. This will increase capacity, reduce delay, and minimize fuel burn, noise, and greenhouse gas emissions.

NASA demonstrated an aerodynamic model that can improve stall recovery training for commercial airline pilots, surpassing the capabilities of current day simulators. The model was determined to be of sufficient fidelity for application to a flight training simulator environment, based on recommended simulator certification criteria for stalls being developed by relevant technical research and training organizations. Subscale aircraft flight tests, as well as other flight test and accident data validated the model data. Simulation of large transport airplanes in upset conditions remains a topic of high interest to commercial aviation as part of the effort to reduce the risk of fatal loss-of-control accidents.

NASA completed three in a series of six HITL experiments using the Agency's Future Flight Central facility to simulate Spot and Runway Departure Advisor (SARDA)-enabled operations at the American Airlines ramp tower at Charlotte International Airport. SARDA helps tower controllers improve the efficiency of airport surface operations. The next HITL simulation will incorporate a more advanced scheduler, providing new and enhanced advisories to ramp and tower controllers.

Thrust 5: Real-time, system-wide safety assurance

NASA awarded four different teams the task of developing an innovative NAS modeling architecture that will use a real-time, one-way feed of live aircraft traffic data and allow shadow-mode testing of advanced, gate-to-gate concepts in an integrated fashion to accelerate application of NextGen technologies. The tasks are a first step in the development of the Shadow Mode Assessments Using Realistic Technologies for the NAS (SMART NAS) capability. SMART NAS is a live, virtual, and constructive environment where alternative future concepts, technologies, air-ground, human-machine architectures can be examined in a system-wide, integrated fashion to assess NAS-level safety, performance, and benefits. The SMART NAS activities will accelerate safe transformation of the NAS.

NASA demonstrated the use of advanced software assurance techniques, compositional verification, through testing of an entire flight control system. Compositional verification enables a system-level software safety assessment by breaking down the system into component parts and examining the safety properties of each of those components. Formal methods such as compositional verification allow for more comprehensive and more efficient verification and validation of flight-critical systems. The verification and validation methods are essential to maintain the extremely high levels of safety required for flight critical systems.

NASA developed methods to improve the reliability of predicting future events through identification of specific precursors found in flight operating data. In particular, the program examined connections between overspeeds and underspeeds (potential safety events) and data patterns occurring earlier in the flight (precursors). The program also expanded its capability to identify unusual events (anomalies) in radar track data. This class of algorithms will be instrumental in developing broader system-wide safety capabilities that consider both onboard and air traffic data.

WORK IN PROGRESS IN FY 2015

Thrust 1: Safe, efficient growth in global operations

AOSP is assessing ATD-1 prototype software with Terminal Sequencing and Spacing (TSS) capabilities integrated with operational versions of FAA hardware at the FAA's William J. Hughes Technical Center. TSS technology provides information to controllers about the speeds they should assign to aircraft as they follow more fuel-efficient, continuous-descent approaches into airports, saving both time and fuel and reducing emissions. Successful integration, shadow testing and data collection simulations will reduce the deployment risk and facilitate flight testing. This assessment is part of the second phase of continued progress towards ATD-1, focused on the operational integration assessment conducted in partnership with the FAA.

NASA will prepare for extensive testing of SARDA in operational field trials at the American Airlines Ramp Tower at Charlotte International Airport. SARDA improves tower controller's ability to direct airport surface operations efficiently by allowing non-stop, continuous movement of aircraft on taxiways with resulting benefits of increased throughput and reduced fuel consumption. In the first half of FY 2015, a live data interface will be enabled and extensive shadow testing with the SARDA system and subject matter experts will be conducted to assess the functional level validation and verification and system robustness. In the second half of FY 2015, SARDA will undergo a follow-on human-in-the-loop simulation to address gaps discovered in the shadow testing.

Thrust 5: Real-time, system-wide safety assurance

AOSP is working with the FAA to address barriers to future systems safety assurance and will deliver two reports to the FAA in FY 2015. The first addresses the issue of assuring modern systems that are developed by a multi-tier network of suppliers and identifies issues in the practice, regulation, policy, or guidance material relative to safety and regulatory compliance. Recommendations for short-term and long-term solutions to achieving a higher level of confidence in the design of complex computer-based aircraft systems will be included. The second report will document new approaches to software assurance for the FAA. The report will outline results of a survey of alternative approaches to software assurance and knowledge obtained through preparation of a published guidebook considered the de facto standard for avionics equipment and software development worldwide.

AOSP is identifying alternative open architectures that will enable a plug-and-play capability of different technologies to operate in combined real, virtual, and constructive manners. These architectures support development of the SMART NAS capability that will allow integrated, real-time, and/or fast-time assessment of gate-to-gate operations and their operational and safety performance using real-world NAS inputs.

AIRSPACE OPERATIONS AND SAFETY PROGRAM

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Thrust 1: Safe, efficient growth in global operations

AOSP will develop tools to reduce take-off time variances, which will increase predictability of the airspace system and allows airlines to reduce schedule block-times for flights during high-demand periods, resulting in significant cost reduction to airlines. Development of such advanced departure tools will include maturity assessment of candidate technologies that support the integrated arrival/departure/surface concept of operations; benefit/cost analyses; feedback on concept of operations from key stakeholders; a schedule of simulations to support maturation of component technologies and their integration; and, development of requirements, processes, and procedures.

AOSP will develop and demonstrate air traffic controller managed spacing of arriving flights combined with flight deck interval management technologies to enable precise and high efficiency aircraft flows into the Nation's busiest airports. To demonstrate the 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, high-fidelity 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.

Following over two years of extensive HITL simulations of the SARDA system in operational scenarios, AOSP will evaluate the SARDA tool in operational training, shadow testing and live traffic evaluations at the American Airlines Ramp Tower at Charlotte International Airport throughout FY 2016. The evaluation will culminate in a technology licensing and transfer to airlines in late FY 2016 to early FY 2017.

Thrust 5: Real-time, system-wide safety assurance

AOSP will work on real-time system monitoring and assurance through development and refinement of specialized data analytics that identify anomalies in operational data and provide information about precursors to safety risks. Tools to analyze heterogeneous data will be scaled to incorporate data from multiple sources within the aviation system, such as flight data, radar track data, and written safety reports. Prognostic and decision-making tools will also be refined and scaled to support development or a system that can predict emerging risks and provide decision support for mitigation strategies. Development of run-time monitoring capabilities for software and system assurance will enable progress toward continuous lifecycle assessment of aviation systems. Finally, continued research on operator state will work toward the goal of providing tools for continuous assessment of pilot and controller performance capabilities.

Thrust 6: Assured autonomy for aviation transformation

NASA will also complete UTM Build 1, which is a portable system that focuses on small UAS flying at low altitude. UTM is a fundamentally enabling capability for safe operation of small UAS. The Build 1 system will include initial trajectory management by offering geo-fencing, initial wind/weather integration, rules of the road, and procedural separation. UTM is a system to support the development of autonomous concepts, technologies, and procedures, and demonstrate a prototype operational capability while safely enabling low-altitude operations of UAS and all other users. UTM Build 1 will be ideally suited for agriculture applications, FAA UAS test sites, or demonstrations of initial concepts. This build will allow a limited number of homogeneous vehicles to conduct delivery, search and rescue, photography, car following, surveillance, agriculture applications, humanitarian, or science missions. Future Builds will add additional capability.

Program Elements

AIRSPACE TECHNOLOGY DEMONSTRATIONS (ATD)

The Airspace Technology Demonstrations project is comprised of a suite of critical technology development and demonstration activities geared toward delivery of near-term benefits to the air transportation system stakeholders in support of the safe efficient growth in global operations strategic thrust.

The Interval Management/Terminal Area Precision Scheduling and Spacing 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.

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 trajectories. IADS 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. When traffic density is high, scheduling inefficiencies increase and result in lost slots and/or many stop-and-go operations between gates and runway threshold. Initial deliverables will include concept of operation, fast-time analysis to demonstrate the benefits, HITL 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 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. Overall, about 25 percent of aircraft are delayed (of which three quarters are 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; and
- Methodologies, tools, and procedures for en route pair-wise trajectory management concepts

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, which are the most common cause of fatal aviation accidents worldwide. 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. 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.

SHADOW MODE ASSESSMENT USING REALISTIC TECHNOLOGIES FOR THE NATIONAL AIRSPACE SYSTEM (SMART-NAS)

The SMART NAS Project will develop an ATM 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. This research primarily aligns with the Real-Time System-Wide Safety Assurance strategic thrust area as 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.

SAFE AUTONOMOUS SYSTEMS OPERATIONS (SASO)

In support of ARMD's strategic thrust toward assured autonomy in civil aviation, the Safe Autonomous Systems Operations (SASO) Project will conduct research and development activities to ensure that the future airspace management system will accommodate future needs. The needs are characterized by greater diversity of aircraft performance, user business models, and airspace requirements. The system must also ensure scalability of operations, and affordability for service providers and users. Combinations of increasingly autonomous technologies using automation (which follows scripted operational procedures), autonomy (which follows logic to make operational decisions), and autonomicity (which supports self-management of large-scale systems) will be considered to meet the next century of airspace operation's needs. The fundamental objective of the SASO Project is to identify justifiable combinations of automation, autonomy, and autonomicity to safely meet these future needs. The project has five sub-projects, each focused on a technical challenge, along with fundamental and cross-cutting research and development activities. The sub-projects focus on:

- The development of a UTM system to safely enable low-altitude UAS operations;
- Development of technologies, roles and responsibilities, and procedures to demonstrate technical feasibility of reduced crew operations;
- Development of technologies, roles and responsibilities, and procedures to demonstrate technical feasibility of autonomous aircraft operations in terminal areas; and
- Enabling autonomous traffic flow management to make Traffic Flow Management (TFM) related decision making much more robust in presence of weather forecast uncertainties, developing alternative plans and dynamically changing the plan as forecast changes, and using learning algorithms/automation based on historical analysis of performance.

Program Schedule

Date	Significant Event
Dec 2014	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
Jun 2015	ATD-1 simulation at the FAA William J. Hughes Technical Center
Sep 2015	SARDA operational field evaluation with an airline and airport partner and technology transfer to the FAA
Sep 2016	Initial evaluation of one future scenario in the shadow-mode NextGen simulator
Sep 2016	Develop initial automated traffic flow management strategies and algorithms for AutoMax to reduce delays under multiple weather possibilities
Dec 2016	Complete ATD-1 prototype avionics for use in airborne test of flight deck interval management capability
Sep 2017	Evaluate and Demonstrate Advanced flight deck technologies to improve attitude and energy state awareness in a relevant environment

AIRSPACE OPERATIONS AND SAFETY PROGRAM

Program Management & Commitments

Program Element	Provider
Airspace Technology Demonstrations	Provider: ARC, Langley Research Center (LaRC) , Armstrong Flight Research Center (AFRC), Glenn Research Center (GRC) Lead Center: ARC Performing Center(s): ARC, LaRC, AFRC, 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), DoD, ONERA (French Aerospace Lab)
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

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.

AIRSPACE OPERATIONS AND SAFETY PROGRAM

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	Expert Review	Dec 2014	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 the projects made satisfactory progress in meeting technical challenges and met all annual performance indicators.	Nov 2015

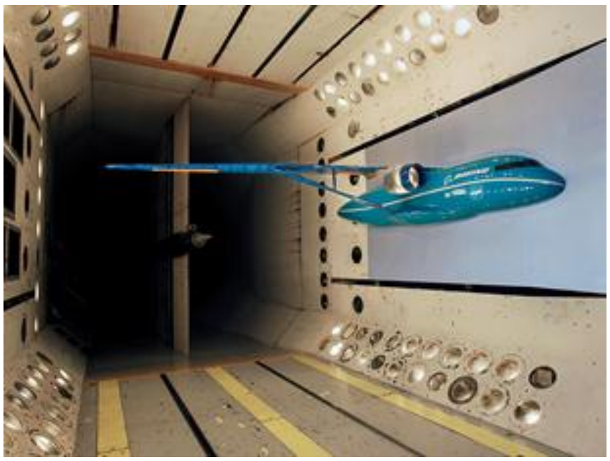
ADVANCED AIR VEHICLES PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	0.0	--	240.9	243.2	241.2	231.0	232.8

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



An aeroservoelastic wind tunnel model of a truss-braced wing concept was tested in the Transonic Dynamics Tunnel at NASA LaRC to validate wing weight benefits contributing to fuel burn reduction.

The Advanced Air Vehicles (AAV) Program develops knowledge, technologies, tools, and innovative concepts to enable safe, new aircraft that will fly faster, cleaner, 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 US aircraft, and the type of research performed by the AAV Program will prime the technology pipeline, enabling continued US 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. The AAV Program directly supports three of the ARMD Strategic Thrusts (Thrust 2: Innovation in Commercial Supersonic Aircraft, Thrust 3: Ultra-efficient Commercial Vehicles, and Thrust 4: Transition to Low-Carbon Propulsion.

EXPLANATION OF MAJOR CHANGES IN FY 2016

NASA will increase funding for research related to low-carbon propulsion. This research will explore new hybrid gas electric propulsion systems to better understand potential system benefits and limitations. Early systems configurations will be studied and advances in key components will take place. In addition, NASA will enhance research on turbine engine technologies that will be an important aspect of a hybrid system, but also could be applied to more traditional configurations. NASA will also increase funding for fundamental hypersonics research to ensure sufficient NASA expertise and capabilities are available to support and complement the Department of Defense's efforts in this area.

ADVANCED AIR VEHICLES PROGRAM

ACHIEVEMENTS IN FY 2014

Thrust 2: Innovation in Commercial Supersonic Aircraft

NASA completed a major milestone to "Complete Low Boom Flight Demonstrator Conceptual Design." The Low-Boom Flight Demonstration Concept Formulation Studies and final reports were completed along with NASA in-house configuration development and contractor assessment. Contractor and NASA teams identified feasible concepts for a specially shaped aircraft that could help prove the real viability of these aircraft designs for generating very low sonic booms. Additionally, completion of these conceptual designs helps to prove out the usefulness of the computer-based simulations and design codes for creating such designs that are expected to have low boom and that also meet other mission and operational requirements.

While developing a low-boom capability is a priority, there are other environmental barriers for the introduction of a commercial supersonic capability. Jet noise is one of these issues because supersonic aircraft will need to meet the same noise certification levels as similar sized subsonic aircraft. NASA tested an advanced design for a novel low-noise nozzle concept. This design was possible because NASA and the industry partner (General Electric) were able to effectively model the exhaust stream and analyze how to influence the noise signature. Not only did this test show that it is likely that supersonics-capable engines can be built that exceed the Project goal and meet new International noise standards, but the test also helped validate the analysis capability that can be applied to a wide variety of future designs.

Thrust 3: Ultra-efficient Commercial Vehicles

NASA completed high-fidelity experimental and computational simulations of a truss-braced wing (TBW) aircraft conceptual design to measure performance improvements that would lead to reduced fuel use; the TBW concept is a promising technology for improved performance in transport aircraft. This concept allows for thinner wings that are structurally sound, but weigh less than traditional wings and allows for a shaping concept that reduces drag. These effects combine for better overall efficiency. Initial conceptual studies showed the significant potential of this technology to contribute to meeting NASA "N+3" goals but also highlighted a significant uncertainty in estimating the wing weight. These N+3 goals target future designs (three generations beyond today) and include a variety of aggressive goals such as an efficiency improvement of up to 60 percent compared to today's aircraft. NASA created a detailed computer model (finite element model) to simulate the structure of the TBW concept including an estimate of the wing weight uncertainty. A complex, aeroservoelastic wind tunnel model was designed, fabricated, and tested at transonic conditions in NASA's Transonic Dynamics Tunnel (TDT) {see photo} to compare against the structural model. Test results indicated favorable lighter weight wing benefits contributing to the fuel burn reduction potential of the TBW concept for transport aircraft applications.

The ability to ensure that new material technologies can be efficiently incorporated into new designs will have a great impact on developing more efficient vehicles. NASA completed tests with the FAA at the China Lake Naval Air Warfare Center to study the feasibility of fuselage shielding for blade-out events in open rotor engines. Data from the tests provided a better understanding of damage mechanisms in composite structures. NASA will use this data to develop and validate advanced composite impact and progressive damage analysis (PDA) models.

NASA is also working to advance technologies for vertical lift vehicles, which perform critical missions such as emergency medical transportation, law enforcement, and specialized transport. NASA completed the successful evaluation of several different types of active rotor systems to assess the impact of the technology to reduce noise and vibration while improving efficiency of rotor systems. The data and analysis from these studies indicate that significant reduction in noise can be achieved using active rotors. Active rotor concepts are a more advanced form of design that include some form of mechanization, such as twisting or flaps embedded within the blades, to change the shape of the blade in order to achieve better efficiency, reduced noise, or reduced vibration. The evaluation identified concepts for new and continued development to achieve low noise, high-performance rotor systems. NASA also demonstrated the technology to improve helicopter transmissions for current and future vehicles by testing a NASA-patented transmission design in a unique new NASA facility designed specifically for this demonstration. The NASA two-speed transmission successfully demonstrated shifting where the rotor speed was changed by 50 percent at full operating speed while transmitting the high torque necessary for a rotary wing vehicle. This is a novel concept that has a potential to make a difference in a variety of vertical lift systems. The two-speed concept will enable significantly higher cruise speeds for all types of rotary wing vehicles and enable new missions for the vehicles.

Thrust 4: Transition to Low-Carbon Propulsion

NASA continued the exploration and development of concepts and enabling technologies for hybrid gas-electric propulsion systems for future transport applications with less noise, emissions, and energy use. One completed activity focused on the theoretical modeling and conceptual design of a fully superconducting electric generator/motor concept with high specific power (power to weight ratio) for novel aircraft propulsion applications such as distributed propulsion. This study produced a concept that may significantly exceed NASA’s target of 10 horsepower per pound for a flight-weight, fully superconducting generator/motor and identified the enabling technologies and system integration challenges to further advance the concept. NASA also competed and initiated new research activities with industry and academia to further study and develop technologies and concepts for non-superconducting, ambient temperature hybrid gas-electric propulsion systems.

Cross-Cutting Capabilities aligned with multiple thrusts

NASA aggressively addressed issues with data accuracy, data validation, and facility productivity at the National Transonic Facility at the LaRC and the 10x10-Foot Supersonic Wind Tunnel at the GRC. Through focused efforts, NASA scrutinized and improved data acquisition, facility measurement and control systems to provide high quality repeatable research and testing data quickly and without interruption. The improvements to these systems were critical to sustaining strategically important test capabilities needed to enable ARMD to meet technical challenge and national program objectives.

NASA demonstrated a new capability in the Propulsion Systems Laboratory (PSL) at the GRC that generates an ice crystal environment to evaluate full-scale engines at conditions known to cause engine-icing anomalies. An engine known to be susceptible to degraded performance under these conditions demonstrated this new capability. However, validating this capability requires an assessment of weather characterization data in the natural atmospheric environment. NASA partnered with the European High Altitude Ice Crystal Consortium in a flight weather characterization campaign in Darwin, Australia and preliminary data is now available on particle size and water content for initial assessment of the PSL ice crystal simulation capability and for engine simulation modeling.

ADVANCED AIR VEHICLES PROGRAM

WORK IN PROGRESS IN FY 2015

Thrust 2: Innovation in Commercial Supersonic Aircraft

Commercial Supersonics Technology Project: Experimental and analytical studies of jet engine exhaust plume and studies of the interactions of the plume with shock waves generated in supersonic flight will continue in order to complete the FY 2015 Technical Challenge for Low Sonic Boom Design Tools. Assessments of plume effects based on Computational Fluid Dynamics (CFD) analysis and comparison with the test data from the NASA GRC 1x1-Foot Supersonic Wind Tunnel will continue. Delivery of this Technical Challenge in FY 2015 will provide the tools and technologies to enable the design of supersonic aircraft that reduce sonic boom noise to levels that allow for supersonic overland flight rule change.

Thrust 3: Ultra-efficient Commercial Vehicles

NASA will complete the formation of the Advanced Composites Consortium (ACC) as a public-private partnership in FY 2015. NASA developed the foundational agreements for the ACC in FY 2014 and began execution in December 2014. The official formation of the ACC is a key milestone for the project and is essential to the project's ability to collaborate efficiently with its industry partners. The establishment of the ACC will provide a contractual mechanism for conducting project research through multiple industry/government partner teams with equal cost sharing and facilitates the handling of sensitive intellectual property and data rights between partners. The ACC will allow the industry/government team to efficiently conduct collaborative research and development tasks, to leverage resources and expertise, and to share research products between the partners.

NASA will accomplish another key milestone in FY 2015 with the creation of a Development to Certification Timeline (DCT) workbook for composite structures. This workbook is a tool that will represent the time associated with phases of product development, estimate reductions in time associated with technologies to be addressed by the project, and define performance measures for those technologies. The DCT will provide a framework for measuring system-level impacts of multiple technology advances, and will form the foundation for project operation and assessment of progress toward the project goal.

Revolutionary Vertical Lift Technology (RVLT) Project: NASA will complete acoustic flight testing of two helicopter configurations at three flight altitude conditions to validate a new acoustic prediction tool for rotorcraft noise. The data from the three different altitudes will be used to generate an altitude correction for noise models that is not currently included by acoustic prediction tools. The data will increase the accuracy of rotorcraft noise prediction tools, improving the ability to design quieter rotorcraft configurations.

NASA will complete the Transport Rotorcraft Airframe Crash Testbed research. This research evaluates the survivability of occupants in different seats, locations, and restraint systems during a controlled impact. Crashworthiness improvements of airframe structure by the addition of composite, energy-absorbing subfloors will be assessed using three different types of subfloor composite construction. The data will lead to improved safety and survivability for all types of vehicles with conventional and composite construction.

Thrust 4: Transition to Low-Carbon Propulsion

Advanced Air Transport Technology Project: NASA will complete analysis, documentation, and dissemination of test results from a flight campaign to characterize the gaseous and particulate cruise emissions of biofuel blended jet fuels, and effects of fuel sulfur during flight at cruise conditions. These results will enable improved emissions modeling and guide the development of international standards for drop-in alternative fuels. NASA leads a team including other US and international Government 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. Flight tests of a NASA DC-8 aircraft with CFM56-2C engines were completed at NASA's AFRC in FY 2014. In these tests, chase aircraft from NASA (Falcon HU-25), DLR (Falcon 20), and NRC-Canada (T-33) sampled the exhaust emissions (mono nitrogen oxide (NOx), carbon monoxide, and particulate matter mass and number) at cruise altitudes and acquired contrail characteristics data over a range of flight conditions and separation distances. Analysis of results from this internationally recognized data set will enable improved emissions modeling and guide the development of standards for drop-in alternative fuels.

Cross-Cutting Capabilities

Aeronautics Evaluation and Test Capabilities Project: NASA will enter the next phase in Test Section Optical Improvements in the ARC 11x11-Foot and 9x7-Foot Wind Tunnels laying the foundation for major advances in optical access, data gathering, and off-body measurements. Improvements in optical measurements using infrared thermography, pressure sensitive paint, advanced photogrammetry, and Schlieren techniques continue to enable major advancements in measurement accuracy, flow visualization, and model deformation. Next generation computational simulation development and validation need these improvements. The 11x11-Foot and the 9x7-Foot Wind Tunnels will be at the forefront of testing and optical data gathering with these techniques for the foreseeable future.

Aeronautics Evaluation and Test Capabilities Project: NASA will conduct a series of tests in the Glenn Research Center Icing Research Tunnel to validate a methodology to allow ice accretion testing of full-scale, swept-wing leading edge models that represent commercial transport aircraft by using a full-scale leading edge truncated wing approach. If successful, this methodology will enable the testing of transport aircraft size wing models in the Icing Research Tunnel without increasing the size of the current test section.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Thrust 2: Innovation in Commercial Supersonic Aircraft

Commercial Supersonics Technology Project: NASA will complete the Low Noise Propulsion for Low-Boom Aircraft technical challenge. This technical challenge addresses the development of computational design tools and innovative concepts for integrated low-noise supersonic propulsion systems and demonstrates these concepts through ground testing. Commercial supersonic vehicles will have to meet the same stringent airport noise regulations that govern the subsonic fleet in addition to having to overcome the sonic boom barrier. The planned activity addresses the challenge of meeting the current airport noise requirement and also anticipates an increase in the stringency of the noise requirement in the future.

Thrust 3: Ultra-efficient Commercial Vehicles

Advanced Air Transport Technology Project: NASA will validate the high-speed performance and aerodynamic design of a TBW aircraft conceptual design to further advance this concept as a viable technology to reduce transport aircraft fuel use. High fidelity, CFD-based aerodynamic methods will be used to design the detailed novel aerodynamic shape of the configuration. One unique challenge for the TBW concept is the design of a low drag integration of the truss structure with the wing and fuselage. To validate the design and contribute to an update of the integrated system assessment of this TBW concept, NASA will test a high-fidelity aerodynamic wind tunnel model in the 11x11-Foot Transonic Wind Tunnel at ARC.

Advanced Composites Project: NASA will downselect progressive damage analysis (PDA) technologies for further development in the second phase of the project. Specifically, characterization of PDA methods, non-destructive inspection technology, and manufacturing process models for composites (current capability and technology gaps) will be completed by comparing blind predictions with experimental results at the sub-element level of a representative building block. PDA models will provide damage progression methods that more accurately represent the failure mechanics for the composite structural component and applied loading. Blind predictions will validate the performance of a variety of PDA models and provide the necessary data to down select the best performing models for more detailed development and evaluation in Phase 2 of the project.

RVLT Project: NASA, in partnership with other Government agencies and industry, will demonstrate a new type of engine power turbine that will advance the efficiency of propulsion systems for vertical lift vehicles of the future. The Variable-Speed Power Turbine (VSPT) component tests will demonstrate the ability to operate the power turbine efficiently over a wide operating speed range of the engine. The VSPT concept will result in vehicles with higher performance and greater fuel efficiency.

Cross-Cutting Capabilities

Aeronautics Evaluation and Test Capabilities Project: NASA will complete the acoustical treatment of the Glenn Research Center 9x15-Foot Low Speed Wind Tunnel test section. This initiative will reduce the facility background noise to acceptable limits to enable testing of low noise propulsion system concepts.

Program Elements

ADVANCED AIR TRANSPORT TECHNOLOGY

NASA’s vision for advanced fixed wing subsonic transport aircraft is to enable revolutionary advances in energy efficiency and environmental compatibility of 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 major steps in energy efficiency and environmental compatibility resulting in less fuel burned, less direct impact on the atmosphere, and less noise around airports. This project 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

ADVANCED AIR VEHICLES PROGRAM

US 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 2025–2030 timeframe.

REVOLUTIONARY VERTICAL LIFT TECHNOLOGY

The NASA RVLT project develops and validates tools, technologies, and concepts to overcome key barriers to the expanded use of vertical lift configurations in the Nation's airspace. The unique ability of vertical lift vehicles to hover has great potential in the civil market for human and cargo transportation, delivery systems, inspection and surveillance missions, oil and gas exploration, disaster relief and many more critical operations. RVLT research advances technologies that will increase speed, range, payload, and safety as well as decrease noise, weight, and fuel burn. The research is accomplished through advanced computer-based multi-fidelity prediction methods, use of unique NASA facilities, and state-of-the art experimental techniques. RVLT considers current and future vertical lift vehicles of all classes and sizes, ranging from very small configurations to configurations that are viable commercial transports in the NAS. For example, in the future it is anticipated that the Project will incorporate ideas being developed in the Transformative Aeronautics Concepts Program that are exploring the potential to marry autonomy and hybrid/ full electric systems with a vertical lift capability to enable a variety of new civil missions.

COMMERCIAL SUPERSONIC TECHNOLOGY

Supersonic 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; supersonic aircraft fuel efficiency; airport community noise; high altitude emissions; vehicle aeroservoelastic design; supersonic operations and the ability to design future vehicles in an integrated, multidisciplinary manner. Research conducted will establish the necessary approaches and techniques for objectively measuring 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. The Project will also conduct research on key hypersonics technologies that support to this National capability. This work concentrates in areas such as development of new computational tools and key technologies that open the possibility for greater use of air-breathing hypersonic systems in the future.

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 rigorously validated results. 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 estimated 5 to 9 year timeline for composite structures development and certification by 30 percent, 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;
- 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 ground test capabilities (facilities, systems, workforce, and tools) 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 ground 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 ARC, GRC, and LaRC. These NASA-unique test facilities and capabilities may also serve the needs of the Nation. This integrated approach to asset planning, use, and management will consider the complementary computational tools, software, and related systems to effectively acquire and process research data and offer research customer's high-quality data that accurately reflects the test environment being simulated and the interactions of test articles in those test environments 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.

Program Schedule

Date	Significant Event
Sep 2016	Complete installation of the acoustic improvements to the GRC 9x15-Foot Low Speed Wind Tunnel test section to provide a reduced background noise environment to support aero-acoustic testing.
Sep 2016	Complete test section improvements of the optical access, physical access, and the related support infrastructures designed in previous phases, which will enable advanced optical test techniques such as Pressure Sensitive Paint, Infrared Thermography, High Speed Schlieren, Model Deformation and Particle Imaging Velocimetry to be routinely used in ARC Unitary Plan Wind Tunnel testing.
Sep 2016	Complete Phase I activities and create a plan for Phase II that enables the Advanced Composite Project to identify reductions in the timeline for development and certification of advanced composite structures through their use of the baseline Development to Certification Timeline (DCT) workbook.
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	Integrated analysis of advanced, candidate technologies contributing to a 1.5-2 times increase in the aspect ratio of a lightweight wing with safe flight controls and structures.
Sep 2017	Define the natural ice-crystal cloud environment in terms of altitude, temperature, ice water content, particle size and morphology to guide the engine ice crystal ingestion testing in the Propulsion Systems Laboratory at NASA GRC.
Sep 2017	Complete the replacement of the facility control system and steady state data acquisition systems at both the GRC 8x6-Foot Supersonic Wind Tunnel and 9x15-Foot Low Speed Wind Tunnel to enable world-class steady state data capabilities including higher reliability, channel count, processing rates, analyses, improved plotting, a higher reliability, and more versatile control system.

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Program Management & Commitments

Program Element	Provider
Advanced Air Transport Technology	Provider: ARC, AFRC, GRC, LaRC Lead Center: GRC Performing Center(s): ARC, AFRC, GRC, LaRC Cost Share Partner(s): US Air Force, Boeing, Pratt & Whitney, Northrop Grumman, General Electric Aviation, Aurora, United Technologies Corporation, Rolls Royce/Liberty Works, Honeywell, FAA, ONERA, DLR, JAXA, Lockheed Martin, Cessna, US Navy, US small business and universities
Revolutionary Vertical Lift Technology	Provider: ARC, GRC, LaRC Lead Center: LaRC Performing Center(s): ARC, GRC, LaRC Cost Share Partner(s): United Technologies Research Center, US Army Sikorsky Aircraft, GE, Pratt and Whitney, ONERA, DLR, NLR, US Navy, US small businesses and universities
Commercial Supersonic Technology	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): ARC, GRC, LaRC Cost Share Partner(s): Boeing, General Electric Aviation, Lockheed Martin, Northrop-Grumman, United Technologies Corporation, FAA, DOD
Aeronautics Evaluation and Test Capabilities	Provider: ARC, GRC, LaRC, AFRC Lead Center: N/A Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): DoD, FAA, European High Altitude Ice Crystal (HAIC) Consortium

Acquisition Strategy

NASA’s AAV 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.

ADVANCED AIR VEHICLES PROGRAM

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
Perform-ance	Expert Review	Nov 2014	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 the projects made satisfactory progress in meeting technical challenges and met or justifiably eliminated annual performance indicators.	Nov 2015

INTEGRATED AVIATION SYSTEMS PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	0.0	--	96.0	85.6	89.0	101.6	104.8

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

An MQ-1B Predator pilot participates as a test subject for integrated HITL simulation, which measured pilot acceptability of UAS integration into the NAS concepts. Detect and Avoid systems were utilized with NASA-developed self-separation algorithms and the Air Force Research Lab's Vigilant Spirit Control Station advanced display.

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 objective of IASP is to conduct flight oriented, integrated, system-level research and technology development that supports the flight research needs across the ARMD Strategic Thrusts, the programs and their projects. IASP focuses on the rigorous execution of highly complex flight tests and related experiments. These flight tests support all phases of the ARMD Program's research, not just the culmination of research activities. For technologies at low Technology Readiness Levels, IASP's flight research accelerates the development and/or determines the feasibility of those technologies. For more mature technologies, flight research will reduce risks and accelerate transition of those technologies to industry.

NASA will make significant technology advancements contributing to national aviation challenges through the IASP portfolio. IASP consists of two projects, the UAS Integration in the NAS Project and the Flight Demonstrations and Capabilities (FDC) Project.

One of the national challenges 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. Other public uses of UAS include US 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. However, significant 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 routinely 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 become more important than ever. NASA's UAS Integration in the NAS Project will contribute flight validated data and 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 (FDC) Project will identify, design, and conduct integrated, system-level flight tests that support the flight research needs across the ARMD Strategic Thrusts, the programs and their projects. FDC will focus on innovation and flexibility. During FY 2015, FDC will assess various technologies and down select the most appropriate to be included as part of the project's portfolio, which is consistent with the ARMD strategic plan. An example would be the flight validation of a drag reduction concept referred to as discrete roughness elements focused on reducing aircraft drag by controlling boundary layer instability. In order to accomplish the technology demonstrations, the FDC will select the most appropriate assets (NASA, other Government agencies, industry, or international partners) available to support the chosen technology demonstrations.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The ERA Project will end in FY 2015, then complete its closeout transition of technical knowledge and progress gained throughout the Project's six-year effort to stakeholders both internal to NASA and the aeronautics community during the first quarter of FY 2016. The Flight Demonstrations and Capabilities Project will add a series of integrated, complex technology demonstrations of the most promising concepts and technologies.

ACHIEVEMENTS IN FY 2014

NASA demonstrated, through analysis and testing, that ultrahigh bypass (UHB) propulsion systems can be integrated with hybrid wing body concepts to meet fuel burn and noise goals. Advanced configurations such as the hybrid wing body hold the promise of significantly reducing the environmental impact for commercial transport aircraft, offering advantages in noise reduction and fuel burn reduction not available from today's more standard tube-and-wing aircraft configurations. Additionally, the UHB engine offers the potential to dramatically reduce fuel burn and noise compared to state-of-the-art aircraft engines used today. NASA continued its investigation of UHB technologies by conducting a wind tunnel test of a second-generation UHB engine model with optimized fan exit guide vanes. The testing determined the effectiveness of those configurations to reduce noise and their impact on the performance of the engine. The wind tunnel results agreed with those predicted by state-of-the-art analysis tools. Data from the test will contribute to a comprehensive performance database for modern UHB propulsor technologies that NASA and industry will use to update systems studies.

Integration of compliant structures in next generation aircraft will reduce weight and drag contributing to a reduction of fuel burn. In FY 2014, NASA began flight tests on its G-III aircraft of a wing design equipped with adaptive compliant trailing-edge technology (ACTE). The ACTE flaps were delivered to

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NASA this year and NASA began the process of integrating them onto the vehicle. One of the critical steps in this process was to ensure that the as-built installed aircraft flaps were within the required tolerance of the Computational Fluid Dynamic Computer-aided design model that provided pre-flight predictions. The experimental flaps met this narrow tolerance helping set the stage for successful flight testing. Supporting this work, the ERA project conducted a successful Flight Readiness Review. The flight test demonstrates and establishes airworthiness for a compliant structure used as a large primary control surface in a relevant flight environment and accelerates the infusion of this technology.

In its effort to support the integration of UAS into the NAS, NASA conducted an integrated human-in-the-loop simulation as a precursor to a series of flight test campaigns, which will progressively increase the complexity of UAS integration testing that will occur over the next two years. The test campaign had three objectives. The first was to evaluate air traffic controllers' acceptance of UAS maneuvers performed in order to remain well clear of other traffic. The second objective was to examine the effects of advanced traffic displays and tools on the ability of UAS pilots to maintain well clear of traffic. Finally, the test collected performance metrics to determine the interoperability of the UAS sense-and-avoid algorithms, and current-collision-avoidance algorithms. This testing featured use of the project's operationally relevant environment called Live Virtual Constructive-Distributed Environment (LVC-DE). For this test campaign, the LVC-DE included a proof-of-concept UAS ground control station and virtual traffic. UAS pilots and air traffic controllers participated as test subjects. This was a significant step in the development of findings and data associated with the sense-and-avoid, communications, and human system integration performance requirements and guidelines.

NASA successfully conducted a formulation review that approved the implementation of the Advanced Composites Project. The goal of this five-year project is to significantly reduce the time required for certification of innovative composite materials and structures.

WORK IN PROGRESS IN FY 2015

NASA's ERA Project, during its final year, will mature and demonstrate several high potential technologies in relevant environments. These technologies directly support NASA's goal to advance ultra-efficient commercial vehicles. Specifically, the ERA project plans to successfully complete eight Integrated Technology Demonstrations. Together they could reduce fuel burn by 50 percent, community noise by 42 decibels below stage 4 noise standards, and nitrogen oxides emission by 75 percent during take-off and landing once implemented in the 2020–2025 timeframe. The US aviation industry has been coordinating and collaborating with NASA's ERA project throughout its project life and NASA developed technologies will significantly contribute to the aviation community's goal of achieving far more environmentally friendly aircraft without compromising performance.

For UAS integration into the NAS, NASA will deliver data, analyses, and recommendations based on an integrated flight test series using simulated airspace/traffic, and a live vehicle to inform development of preliminary minimum operational performance standards by the RTCA Special Committee on UAS integration into the NAS.

Also in FY 2015, NASA's goal is to embed flight research throughout all research phases based on the aeronautics research community strategic needs. To this end, 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. In addition,

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NASA will begin working with ARMD Programs in defining a series of small flight demonstrations that will begin execution in FY 2016.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Automation will continue to transform the civil aviation industry and is a rich area for continued research. NASA seeks to forge applications of automation in aircraft operations and air traffic management, generate validated data through testing for by regulatory bodies, and develop technologies and concepts that promote safety, reliability, and future economic development. The integration of UAS in the NAS for commercial, science, security and other users will be furthered through analysis, simulation, and flight testing.

In FY 2016, NASA will deliver data, analysis, and recommendations, based on two integrated flight test series with simulated traffic and live vehicles which will follow the integrated flight test series in FY 2015, to the RTCA Special Committee on Minimum Operating Performance Standards for unmanned aircraft systems. This effort is critical to the success of the RTCA Special Committee's effort and the standards necessary to achieve UAS integration into the National Airspace. This will be the last test flight series in the integrated campaign. The planned progression of the campaign will see high levels of technology integration and higher complexity of test conditions. The testing will integrate live flying UAV and UAV surrogates (aircraft with pilots on board) with ground stations and air traffic data.

NASA will develop integrated system-level flight demonstrations focused on the most promising technologies to assess feasibility of integrated benefits and/or to advance technology readiness levels. The Flight Demonstrations and Capabilities project will support all six ARMD strategic thrusts with an early focus on reducing environmental impact. The project will further capitalize on technologies from the ERA Project and increasing autonomy in support of the UAS Integration to NAS Project.

Program Elements

UNMANNED AIRCRAFT SYSTEMS (UAS) INTEGRATION IN THE NATIONAL AIRSPACE SYSTEM (NAS)

NASA's UAS Integration in the NAS Project focuses on technologies to enable routine civil operations for UAS of all sizes and capabilities in the NAS. This research aligns with ARMD's Assured Autonomy for Aviation Transformation strategic thrust area. 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 safety and operational challenges. The technical barriers include:

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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 (e.g., where a human is part of the simulation and influences the outcome) and flight tests conducted in a relevant environment. The project will conduct integrated test and evaluation 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.

FLIGHT DEMONSTRATIONS AND CAPABILITIES (FDC)

NASA's FDC Project will validate benefits associated with critical technologies through focused flight experiments. As part of the FDC Project, NASA will demonstrate the feasibility and maturity of new technologies through flight tests, utilizing collaborative partnerships from across the aeronautical industry, and include international partners as appropriate. These demonstrations will typically address technologies that have proven their potential merit through ground based or subscale testing and require results from a realistic flight environment for validation of the benefits.

Through the integrated use of appropriate flight test capabilities and assets, regardless of whether the capabilities and assets are available from NASA, through other Government agencies or industry, the FDC Project will validate benefits associated with critical selected technologies. The flight experiments are focused campaigns that will be accomplished on aggressive, success-oriented schedules utilizing the most appropriate set of assets available to accomplish the experimental objectives. While many of the technologies will be at relatively high Technology Readiness Levels, the FDC Project will support all phases of technology maturation.

The FDC Project will utilize specific flight research and test capabilities residing within NASA, including the Dryden Aeronautical Test Range and Simulation and Flight Loads Laboratories at the AFRC, necessary to address and achieve the ARMD Strategic Plan, ARMD Program/Project activities. The Project will also utilize flight research and test capabilities across the US aeronautical industry and international partners as appropriate.

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Program Schedule

Date	Significant Event
Dec 2015	Conduct close-out activities for the ERA Project.
Mar 2016	FDC begins support of Program small flight demos.
Apr 2016	Complete Flight Test Series 4 for Detect and Avoid.
Aug 2016	Provide data, analysis, and recommendations based on two fully completed integrated flight test series with simulated traffic and live vehicles to support development of final Minimum Operational Performance Standards.
Dec 2016	Conduct close-out activities for the UAS-NAS activities.

Program Management & Commitments

Program Element	Provider
UAS Integration in the NAS	Provider: ARC, AFRC, GRC, LaRC Lead Center: AFRC Performing Center(s): ARC, AFRC, GRC, LaRC Cost Share Partner(s): Rockwell Collins, FAA
FDC	Provider: AFRC, LaRC Lead Center: AFRC Performing Center(s): AFRC, LaRC Cost Share Partner(s): DoD

Acquisition Strategy

NASA’s IASP 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.

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INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	Expert Review	Oct 2014	The 12-month review is a formal independent peer review. Experts from other government agencies report on their assessment of technical and project risk and/or weaknesses.	Received expert feedback on project improvement from the panel members. Rating comments were in the very good to excellent range.	Oct 2015

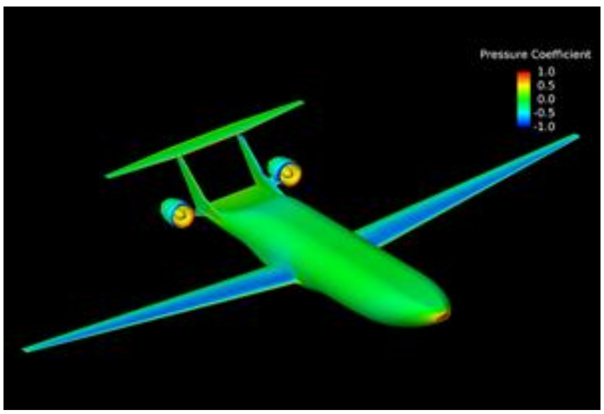
TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**0.0**	**--**	**92.1**	**98.0**	**98.9**	**104.9**	**105.8**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



The ability to simulate airflow over aircraft that look different from what we see today is a key challenge for aeronautical innovators.

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 challenges, and ongoing affordability issues, for which technology can be a key part of the solutions. The TAC Program fosters innovative solutions to these problems, capitalizing on advancements in aeronautics and non-aeronautics sectors 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. Also performing ground and small-scale flight tests allows failures, 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. Thereby, investments are 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 non-traditional partners.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

NASA demonstrated a wireless sensor, which provides lightning protection, and can detect and diagnose damage in composite structures. This sensor was added to an aircraft's external surface forming a "smart skin" layer to provide lightning strike protection, as well as perform damage detection and diagnosis. NASA conducted post-strike damage assessment comparisons between metal mesh (the current accepted solution) and the wireless sensor system to show compliance for an acceptable level of protection.

NASA aeronautics researchers worked with government and industrial partners to push the envelope on ceramic matrix composites material's ability to withstand higher temperatures in aircraft engines and to accelerate the introduction of their performance benefits into the fleet. NASA demonstrated the feasibility to handle several hundred degrees more than state-of-the-art materials at coupon levels. By advancing the capabilities of ceramic matrix composites, which can withstand high temperatures while being strong and lightweight, the design of propulsion systems with up to 6 percent less fuel burn will be enabled.

WORK IN PROGRESS IN FY 2015

NASA is completing specific activities in the Convergent Aeronautics Solutions (CAS) Project that started in the previous Aviation Safety Program. 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 supporting algorithms used in ground-based sensors systems for the aviation community to provide terminal area icing weather information. NASA will also complete a conceptual design for an advanced sensing system that provides not only the required lightning protection, but also can provide damage diagnosis in composite structures. Finally, NASA, in cooperation with its community partners, will demonstrate diagnostics systems to detect faults between major inspections in an engine test.

NASA will explore collaborative program/center processes to incubate and select the best cross-center, multi-disciplinary research activities, leading to the establishment of initial feasibility of the technologies and concepts. During FY 2015, NASA is researching an initial set of ideas for feasibility, including a distributed electric propulsion concept that is being explored for performance and scalability. It has the promise of significant reductions in emissions and noise that can support the application of lower-carbon propulsion technologies. Also, NASA is developing a low-cost, fast-turnaround method for obtaining realistic vehicle performance and flying quality data in flight research by towing an X-plane. This test method could support future advanced vehicle development with increased probability of success during early design, fabrication, and flight research.

NASA is developing next-generation, high-performance, computational methods and tools that have the potential to dramatically reduce the cost and error in simulating complex turbulent flows. The Transformational Tools and Technologies Project will document turbulence prediction results obtained using advanced models for standard test cases involving flow separation.

NASA is funding new challenging research ideas through the external Leading Edge Aeronautics Research for NASA (LEARN) fund as well as completing follow-on phases of the most promising research awards by NASA in-house and selected external LEARN teams. Industry and university teams are continuing several phase two awards, three of which include:

- Plasma-assisted combustor dynamics control to enable ultra-compact, low emission combustors;
- Sensor fusion and cooperative strategy for gust sensing and suppression within formation flight; and

- Innovative nanotube technology to enable practical, multifunctional structure composites with superior mechanical performance. Upon completion, NASA will evaluate the results for incorporation into the existing programs.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

During FY 2015, NASA will develop a process for incubation and selection of proposals for multiple cross-center, and multi-disciplinary research activities that advance the NASA Aeronautics Strategy. This process will be utilized during FY 2016 for selecting and investing in those ideas, concepts, and technologies that could transform aviation. Research on ideas selected by this process will be used to establish initial feasibility, and prepare a path for transitioning the knowledge to other NASA Aeronautics research programs and external customers.

NASA will advance state-of-the-art aeronautics modeling and simulation capability through improved physics-based tools and methods development. These multidisciplinary tools and methods will enhance the ability to predict and design air vehicles and propulsion systems. Improvements in aerodynamics, combustion, acoustics, and materials modeling capability, and experimental validation of these methods against community-wide standard test cases will also improve prediction capabilities.

NASA will mature new, innovative technologies in materials, sensors, actuators, and measurement techniques to address the needs of future air vehicles and propulsion systems. To facilitate improved vehicle performance and measurement accuracy, higher-temperature application of ceramic matrix composite materials, and measurement techniques that can withstand higher temperature environments will be developed in addition to the next generation of concepts.

NASA will continue funding new research ideas through LEARN fund via competitive awards to industry and universities, as well as follow-on phases of promising research from previous selected external LEARN awards. NASA will also utilize challenges and prizes to engage non-aerospace communities of interest as well as traditional partners. NASA will evaluate the most promising ideas to incorporate into existing programs.

Program Elements

CONVERGENT AERONAUTICS SOLUTIONS

The 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 project considers the most promising capabilities for continued development 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 in activities that do not proceed.

TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

TRANSFORMATIVE TOOLS AND TECHNOLOGIES

The Transformative Tools and Technologies Project advances state-of-the-art computational and experimental tools and technologies 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. Applying these revolutionary tools will accelerate NASA's research and the community's design and introduction of advanced concepts. Examples include the development and validation of new computational tools used to predict complex turbulent airflow around vehicles and within propulsion systems, ultimately leading to greater abilities to predict future vehicle performance in flight. The Project also explores technologies that are broadly critical to advancing ARMD strategic outcomes, such as:

- Understanding new types of strong and lightweight materials;
- Innovative controls techniques; and
- Experimental methods.

Such technologies will 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 the external community including university and industry teams. The LEARN Project incorporates a competitive review process of the external teams' proposals to develop integrated solutions for complex technical problems captured in the ARMD strategic thrusts, followed by short duration activities for feasibility assessment. For the most promising ideas, LEARN will fund follow-on phases. LEARN also plans to utilize challenges and prizes to the external community. With these processes, NASA funds also help catalyze investments from the aerospace and non-aerospace communities 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—is a critical part of NASA Aeronautics' approach to enabling transformation in aviation.

TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

Program Schedule

Date	Significant Event
Dec 2014	Initial call for CAS proposals from internal teams on large-scale aeronautics problems important to ARMD
Mar 2015	LEARN, Round 2 Further Study Awards
Jun 2015	LEARN, Round 4 Awards
Dec 2015	Call for CAS proposals from internal teams on large-scale aeronautics problems important to ARMD
Mar 2016	LEARN, Round 3 Further Study Awards
Jun 2016	LEARN, Round 5 Awards

Program Management & Commitments

Program Element	Provider
CAS	Provider: ARC, GRC, LaRC, AFRC Lead Center: LaRC Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): TBD
TTT	Provider: ARC, GRC, LaRC, AFRC Lead Center: GRC Performing Center(s): ARC, GRC, LaRC, AFRC Cost Share Partner(s): TBD
LEARN	Provider: ARC Lead Center: N/A Performing Center(s): ARC Cost Share Partner(s): TBD

Acquisition Strategy

The research conducted through TAC activities will use a wide array of acquisition tools relevant to the research objectives including external solicitations through full and open competitions including challenges and prizes.

MAJOR CONTRACTS/AWARDS

The TAC Program awards smaller contracts, which are generally less than $1 million.

TRANSFORMATIVE AERONAUTICS CONCEPTS PROGRAM

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	ARMD Mission Program and External Expert	No previous review	Review of LEARN 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.	Feb 2015
Perform-ance	ARMD Mission Program Directors	No previous review	Review of initial 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 2015
Perform-ance	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

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Agency Technology and Innovation	30.6	--	**33.0**	33.0	33.2	33.2	33.2
SBIR and STTR	175.0	--	**200.9**	213.0	213.2	213.5	213.8
Space Technology Research & Development	370.4	--	**491.0**	489.7	500.3	511.2	522.4
Total Budget	**576.0**	**596.0**	**724.8**	**735.7**	**746.7**	**757.9**	**769.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

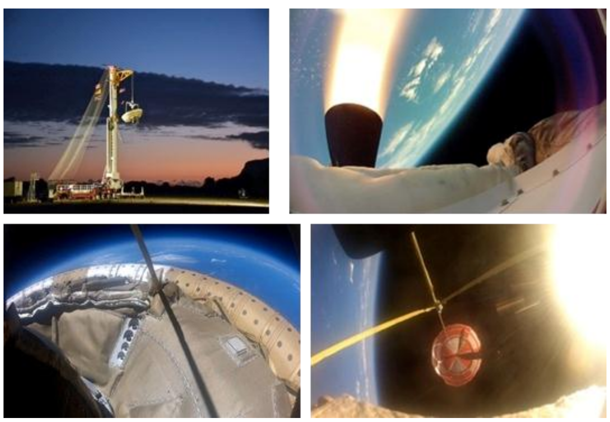
SPACE TECHNOLOGY

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Agency Technology and Innovation	30.6	--	**33.0**	33.0	33.2	33.2	33.2
SBIR and STTR	175.0	--	**200.9**	213.0	213.2	213.5	213.8
Space Technology Research & Development	370.4	--	**491.0**	489.7	500.3	511.2	522.4
Total Budget	**576.0**	**596.0**	**724.8**	**735.7**	**746.7**	**757.9**	**769.3**
Change from FY 2015			**128.8**				
Percentage change from FY 2015			**21.6%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Space Technology conducted its first high altitude test of NASA's Low-Density Supersonic Decelerator over the US Navy's Pacific Missile Range, validating the test vehicle's performance in advance of 2015 demonstrations. NASA's LDSD mission is led by the Jet Propulsion Laboratory in Pasadena, California to conduct a near-space test flight to evaluate new landing technologies for future Mars missions.

Space Technology conducts rapid development and infusion of transformative space technologies that increase the Nation's capabilities in space and enable NASA's missions. Space Technology improves our ability to access and travel through space; operate satellites in earth orbit and far beyond; land more mass, more accurately in more locations throughout the solar system; live and work in deep space and on planetary bodies; and transform the ability for the research community to observe the universe and answer profound questions in earth and space sciences.

NASA leverages common interests from stakeholders, customers, and partners to develop technology that dramatically enhances current US space capabilities by increasing performance, reducing technological risk, and increasing affordability and reliability. This includes technologies that advance the US space industry, other government agencies, NASA's future science missions, and human spaceflight endeavors beyond low Earth orbit. To advance these critical technologies, NASA sources technology from the entire pool of potential technology suppliers: industry, academia, small businesses, other government agencies, individual entrepreneurs, and NASA Centers. By engaging the brightest minds on the toughest technological challenges, NASA spurs innovation throughout the aerospace enterprise.

The Space Technology account also supports NASA's Office of the Chief Technologist, which coordinates the Agency's overall technology portfolio to identify needs. The Chief Technologist also ensures that programs work together when appropriate and minimizes duplication of effort. NASA prioritizes technology development using the Agency's Technology Roadmaps. This office enhances technology transfer and partnership opportunities through a wide range of users to ensure the Nation realizes the full value of these development efforts and leads the Agency's Asteroid Grand Challenge.

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 2016

NASA merges Crosscutting Space Technology Development and Exploration Technology Development to form Space Technology Research and Development. No projects will be impacted as a result of this merger. In addition, NASA will rename the Partnership Development and Strategic Integration program to the Agency Technology and Innovation program to better align the program's title to work performed by the Office of the Chief Technologist. Other adjustments influencing Space Technology's budget profile are driven by upcoming project milestones of on-going development efforts, and support of required increases in Small Business Innovation Research and Small Business Technology Transfer.

ACHIEVEMENTS IN FY 2014

Space Technology is improving the Nation's capabilities to more efficiently access and travel through space. In collaboration with Boeing, NASA completed fabrication and ground demonstration of the world's largest composite cryogenic propellant tank, verifying the ability to develop large-scale cryogenic propellant tanks that are 30 percent lighter than the state of the art metallic tanks and providing a 25 percent reduction in production costs using efficient manufacturing techniques and a structurally efficient design. Opportunities to infuse this technology into the Space Launch System, commercial launch vehicles, and other aerospace applications that require large-scale composite structures are currently being explored by both NASA and the aerospace industry. In addition, Space Technology worked with ATK and Deployable Space Systems to conduct thermal vacuum and performance tests for two competing approaches for large-scale, high-power, deployable solar array systems. This technology development effort enabled manufacturing advances, weight savings, and packing efficiencies that dramatically improve the affordability of commercial satellites. In addition to solar arrays, Space Technology continued maturation of enabling technologies including advanced thermal protection system materials, green propellant, deep space optical communications, and an advanced atomic clock that support deep space navigation as well as enhanced gravitational science for outer planetary icy moon missions. These technologies were incentivized in the Science Discovery 2014 solicitation which will enable infusion once the technology development phase is complete.

In order to land more mass with increased accuracy, in more locations, throughout the solar system, Space Technology is advancing the entry, decent and landing technologies for the Agency. With the Jet Propulsion Laboratory, Space Technology successfully conducted the first supersonic level flight demonstration of an inflatable aerodynamic decelerator and largest ever supersonic parachute. In addition, the Ames Research Center completed development and arc jet testing of a Woven Thermal Protection System (TPS) material for a first infusion into critical structural components on all future heat shields.

To live and work in deep space, Space Technology fabricated and delivered to Exploration a new variable oxygen regulator and carbon dioxide removal system for next generation portable life support systems. This will be demonstrated as a part of an integrated systems test in FY 2015. With small business partner Sunpower, Inc. (Athens, Ohio), Space Technology developed a Stirling cycle power conversion unit that will be integrated into a terrestrial (non-nuclear) demonstration of a space-based fission power system at Glenn Research Center (GRC). These technologies are necessary building blocks for human missions beyond low Earth orbit where power and consumables such as oxygen and water are not readily available.

NASA is taking an active role in fostering emerging industries. For example, Space Technology completed the assembly of 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.

In FY 2014, the Space Technology Mission Directorate (STMD) collaborated on 45 activities with 43 other government agencies, and 10 activities with 14 international organizations. It evaluated over 2,400 proposals and made over 600 new awards in 46 states investing over $240 million with small businesses, academia, and entrepreneurs.

WORK IN PROGRESS IN FY 2015

The Low Density Supersonic Decelerator (LDSD) project will conduct the second in a series of 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 applications such as human missions.

Space Technology initiated technology development of an oxygen production instrument for demonstration on the Mars 2020 mission that aims to convert carbon dioxide from the Mars surface to oxygen with 99.6 percent purity. This precursor effort, being conducted in collaboration with Exploration and Science, will verify that in situ resource utilization technologies can produce enough oxygen at Mars to supply both human breathing needs as well as propellant oxidizer for Mars ascent rockets used to send people, science and equipment back into space for their trip back to earth.

To enable more capable spacecraft, Space Technology is completing flight hardware for a variety of small scale, in-space technology demonstrations including laser communications and navigation using CubeSats, and a suborbital demonstration of a small Earth return capsule. Improvements gained from these technology efforts will be shared widely across the aerospace industry to ensure infusion into future spacecraft designs.

Space Technology will release several technology solicitations targeted at improving the Nation's capabilities for access and travel through space. Technologies sought in these solicitations include: high power solar electric propulsion components, including demonstration thrusters, power-processing units, and flight solar arrays that could utilize a common design that allows for a standalone demonstration or one on the International Space Station (ISS). In addition, NASA continues to invest in the Nation's small businesses and ensure relevance within the Small Business Innovation Research (SBIR) and Small

Business Technology Transfer (STTR) programs by leveraging technology solutions from small businesses to meet critical Agency and industry needs in areas such as robotics, propulsion, and avionics.

NASA expects to release the draft Technology Roadmaps for public review and comment. These roadmaps will serve as the foundation for the Strategic Technology Investment Plan (STIP) which will be finalized in FY 2016.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Space Technology will continue to develop critical technologies to improve access to and travel through space to benefit both NASA and commercial space endeavors. This includes completing high-power solar electric propulsion subsystems in progress toward a full system demonstration. Space Technology will be making awards for flight-ready solar arrays, and conducting the Preliminary Design Review of those arrays as well as thruster subsystems. In addition to high-power solar electric propulsion, technologies developed by Space Technology will continue to benefit the broader aerospace industry and other government Agency needs. Examples include further progress of high performance spaceflight computing hardware, robotics for extreme environments and advanced manufacturing capabilities with government and industry partners. Furthermore, Space Technology will conduct the first flight demonstration of the AF-M315E propellant in the Green Propellant Infusion Mission (GPIM) with partners Aerojet and Ball Aerospace. This mission will validate this new propellant formula as well as compatible thrusters, and integrated propulsion system. On successful demonstration, the propellant and propulsion system will provide industry with a safe and better-performing alternative to highly toxic hydrazine for use on future space missions. This mission also includes first-time flight for a novel thermal insulation material developed by Aspen Aerogels, a small business located in Massachusetts. In order to develop and demonstrate fast transit in-space propulsion capabilities, Space Technology will release a competitive opportunity seeking propulsion technologies that will make deep space exploration more efficient and affordable.

Space Technology will conduct an in-space demonstration of its new Deep Space Atomic Clock. This new atomic clock provides enhanced navigation accuracy, increased science data bandwidth, and improved gravitational measurements, necessary for future planetary science and exploration missions. As one example, this technology will enable understanding Europa’s under-ice, liquid water oceans, where precise gravitational measurements are essential to understanding the make-up of Europa’s surface. Additionally, the new atomic clock will provide next-generation GPS satellites with dramatically improved navigational accuracy and time-keeping stability. Space Technology will also initiate development of foundational technologies to support future outer planets icy moons missions with emphasis on landing and mobility, navigation and communications, radiation protection, and accommodation of power requirements.

Based on the recommendation of the National Academies, Space Technology will continue to prioritize “tipping point” technologies and early-stage innovation with approximately 500 awards to small businesses, private innovators, and academia to spark new ideas for the benefit of US aerospace and high tech industries and to fuel the space technology pipeline. Space Technology will solicit the aerospace community for technologies at the “tipping point” and support demonstrations on the ground or in-space of selected technologies.

SPACE TECHNOLOGY

Programs

AGENCY TECHNOLOGY AND INNOVATION

This program supports the Office of the Chief Technologist (OCT), which provides the strategy, leadership, and coordination that guide NASA's technology and innovation activities. The 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. This ensures that NASA technologies energize the commercial space sector and provide the greatest benefit to the United States.

SBIR AND STTR

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (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.

EXPLORATION AND CROSSCUTTING TECHNOLOGY DEVELOPMENT

Space Technology Research and Development develops and demonstrates near-term and far reaching technological solutions and enhancements, making NASA's missions more capable, affordable, and reliable. Through activities within this program, Space Technology develops transformative, broadly applicable technologies necessary for NASA's future science and exploration missions while supporting the space technology needs of other US Government agencies and the commercial space sector.

AGENCY TECHNOLOGY AND INNOVATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	30.6	--	33.0	33.0	33.2	33.2	33.2

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A Rollins College business student speaks with a NASA scientist about a sensor technology, originally created to inspect the space shuttle windows. Students from the Winter Park, FL college formed Juntura Group and licensed the technology, resulting in a commercial sensor poised to disrupt the market.

The Office of the Chief Technologist (OCT) serves as the NASA Administrator's principal advisor on matters concerning Agency-wide technology policies and programs. Agency Technology and Innovation supports OCT's efforts, which provide the strategy and leadership that guide NASA's technology and associated open innovation activities. The office performs an agency-level technology coordination role, working with the NASA Mission Directorates and field centers to align the Agency's technology investments to meet mission requirements while filling technology gaps, anticipating future needs, and minimizing duplication of effort.

Through OCT, NASA responds to the legislative requirements and Administration priorities to promote technology transfer, including commercialization of technologies that emerge from NASA's research and development activities. As part of this work, OCT documents and communicates the benefits of NASA technology investments to the Nation through various mechanisms, including the media and publications, such as Spinoff. NASA's technologies provide advanced capabilities, new tools, equipment, and solutions for industry. This spurs economic growth, creates new markets, increases competition in US industry, and maintains global technological leadership.

EXPLANATION OF MAJOR CHANGES IN FY 2016

In FY 2016, NASA plans to rename the Partnership Development and Strategic Integration program to the Agency Technology and Innovation program to better align the program title to work performed by the OCT.

ACHIEVEMENTS IN FY 2014

NASA's Technology Transfer Program published an Agency-wide software catalog that contains over 1,000 technologies from all NASA field centers. The catalog is available both online and in hardcopy at no cost to the public, and NASA is the first federal agency to produce such a comprehensive offering. The

AGENCY TECHNOLOGY AND INNOVATION

Technology Transfer Program also developed new and modernized Agency technology transfer polices and piloted the Quick Launch Licensing project. This project is an innovative approach to technology transfer, providing a simplified license application and license agreement process that offers non-exclusive licenses that feature modest, pre-established, upfront licensing fees and fixed annual royalty payments, as well as a pre-determined licensed field of use. The Technology Transfer Program was the recipient of several major awards, most notably, from the Federal Laboratory Consortium and R&D Magazine. Through this program's efforts, NASA saw significant increases in the quantitative metrics used to measure federal technology transfer. Invention capture increased four percent, the volume of software transfer increased 18 percent, and patent licenses increased by an astounding 38 percent.

The Asteroid Grand Challenge announced several new partnerships, including Space Act Agreements with Planetary Resources, SpaceGAMBIT, Maui Makers, and Slooh. These partnerships have led to a dramatic increase in participation by new members of interested citizen scientists looking to contribute to the detection, tracking, and characterization of potentially hazardous asteroids.

WORK IN PROGRESS IN FY 2015

NASA will release the Draft NASA Technology Roadmaps for public review and comment and prepare them for an independent review. The roadmaps are a foundational element of the Strategic Technology Investment Plan (STIP), an actionable plan that lays out the strategy for developing those technologies essential to the pursuit of NASA's mission and achievement of national goals. The updated STIP will include the prioritization and guiding principles for NASA's technology portfolio, and as done in FY 2012, the NASA Advisory Council, other government Agencies, OMB, and OSTP will review the portfolio. NASA completed the development of the public facing portion of TechPort, and will release it to the public in 2015, making available information about technology programs and projects easy to search and analyze. TechPort is a web-based software system that serves as NASA's integrated technology data source and decision support tool. Using TechPort, internal NASA users generated more than 7,500 reports to track and analyze the Agency's portfolio, and provided information to other Government agencies.

Technology Transfer offices at the NASA Centers engage with university business schools for technology marketing assessments in order to discover new ways that industry can apply for NASA technologies, and receive draft business plans on how to adopt NASA technologies within industry. This activity benefits NASA by providing business and marketing insights into its technology portfolio while the business schools will benefit from the "real world" experience of working with licensable technologies and NASA technology transfer personnel to understand the breadth of federal technologies and resources available to industry. NASA will also develop new guidelines to increase access for students to use NASA technologies by allowing simple non-negotiated licenses with no upfront fees, should students choose to pursue commercial applications.

The Asteroid Grand Challenge continues to explore partnership opportunities to expand the potential for citizens to contribute to the Challenge, and begin at least two "mission proofs" or pilot projects for measurable contribution. These "mission proofs" will be designed with global scaling in mind for future year activities. NASA will conduct research on the best mechanism(s) for easy implementation of large-scale citizen science activities to inform follow-on approaches and new procurement activities. The Expert and Citizen Assessment of Science and Technology (ECAST) will conduct two facilitated in-person forums and one online forum to gather general public value around asteroids, thereby pioneering a new method for meaningful public engagement.

AGENCY TECHNOLOGY AND INNOVATION

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will work with an external organization to complete the independent review of the 2014 Draft Technology Roadmaps, and finalize the updated NASA STIP. NASA will also develop and implement a new initiative to track infusion of NASA-developed technology into NASA missions and ground activities. This will enable NASA to verify the number of NASA-developed technologies that are used by NASA and to determine what types of new technologies are used for more than one NASA purpose.

Program Elements

OFFICE OF THE CHIEF TECHNOLOGIST

OCT provides the strategy, leadership, and coordination that guide NASA's technology and associated innovation activities. OCT accomplishes this through four primary functions:

- **Strategic Technology Integration** develops policy, requirements, and strategy for NASA's technology development activities in support of the Chief Technologist. Coordinate Strategic Technology integration 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.
- Enable **Technology Transfer** by providing Agency-level management and oversight of NASA-developed and NASA-owned intellectual property, and manage 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 metrics related to these activities (i.e. numbers of new inventions, patents, licenses, cooperative research and development agreements, and software use agreements).
- **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. This activity includes leadership of the Asteroid Grand Challenge, which focuses on finding all asteroid threats to human populations and knowing what to do about them.
- **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 in the emerging space sector. 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. As a part of this effort, NASA supports research grants in economic analysis related to emerging space activities in order to strengthen optimizing technology investments.

SBIR AND STTR

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	175.0	--	200.9	213.0	213.2	213.5	213.8

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Bally Ribbon Mills of Bally, PA is working with Space Technology to deliver flight hardware for the Orion EM1 flight test by developing multi-layer materials that will withstand extreme entry environments. In addition, they are working on a space vehicle entry system concept consisting of a series of deployable ribs and struts, connected with a flexible fabric skin which, when deployed, will function as a semi rigid aeroshell entry system. The small business was awarded an SBIR Phase III for their work.

NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs leverage the Nation's innovative small business community to support early-stage research and development. These 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. The Agency actively works to facilitate the infusion of NASA-funded SBIR and STTR technologies into its missions and projects. Research and technologies funded by SBIR and STTR contracts have made important contributions to the Agency's work.

Examples of these activities include 3D printing to support in-space manufacturing, adaptive bio-inspired navigation to support exploration of planetary environments, and gravity mapping of asteroids. 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 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 SBIR and STTR program solicitations, setting forth a substantial number of topic areas open to qualified small businesses. Both the list and description of topics are sufficiently comprehensive to provide a wide range of opportunities for small business concerns, research institutions, and universities to participate in NASA's research and development programs. SBIR and STTR funding awards are divided 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 process, based on scientific and technical merit, expected value to NASA, and commercialization potential. Phase III is the commercialization of innovative technologies, products, and services resulting from a Phase I or 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 2016

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 SBIR/STTR Reauthorization Act of 2011 (Public Law 112-81), NASA will increase the SBIR investment by 0.1 percent to 3.0 percent of Agency extramural R&D. In addition, STTR funding will increase 0.05 percent to 0.45 percent of Agency extramural R&D.

ACHIEVEMENTS IN FY 2014

- Awarded 348 SBIR Phase I and 119 SBIR Phase II contracts, with 293 firms in 35 states participating in NASA's missions. Awards included technologies to advance life support and resource utilization systems, manipulation subsystems and human-system interaction for robots, air traffic management research and development, and deep space CubeSat operations.
- Awarded 32 STTR Phase I and 23 STTR Phase II contracts with 50 firms in 20 States, collaborating with universities and research institutions to develop technologies for future NASA missions.
- Participated in 30 technical exchanges and face-to-face summits. These summits support companies as they look to transition beyond Phase II funding.
- NASA saw growth in its Phase II-E participation with small businesses, leveraging nearly $4 million in matching funds from NASA to enable additional maturation of their technologies, enabling more rapid utilization by potential stakeholders.
- The Small Business Administration approved NASA's implementation plan for the Commercialization Readiness Program (CRP), which identifies pathways from the SBIR/STTR Program to the other technology development programs in NASA. Through this initiative, Space Technology will facilitate direct infusion of SBIR/STTR-developed technology into NASA's broader programs, enabling new science and demonstrating new exploration capabilities.

WORK IN PROGRESS IN FY 2015

- After working with Mission Directorates and Centers to identify subtopics for annual solicitations, Space Technology released the annual SBIR and STTR solicitations in November 2014 and expects to award new Phase I selections in the third quarter. Phase II selections, as a follow-on from Phase I awards made in FY 2014, will occur in the second quarter. Topics from these solicitations include solid and liquid waste management for human spacecraft, spectroscopy technology and instrumentation, and launch and in-space propulsion technologies.
- Space Technology will expand its CRP funding allocation for post Phase II technologies following evaluation of the pilot effort, conducted in FY 2014. Agency participation is underway with preliminary applications released. SBIR firms will be invited to engage with NASA Programs at all 10 Centers to identify NASA program sponsors for Phase II follow-on efforts.

SBIR AND STTR

- During the first quarter, SBIR/STTR introduced new initiatives to increase the overall efficiency with which the program interacts with their customer and stakeholder base. The first initiative (In-Reach) will promote program visibility and value within NASA by connecting awardee firms with Agency missions and projects. The Outreach initiative will build better external awareness of the features of NASA's SBIR and STTR programs. The Integrated Investment initiative will ensure future topic areas and awards have the greatest impact on future missions and programs. The teams will work to develop strategic plans through the remainder of FY 2015.
- SBIR and STTR technologies continue to support numerous Space Technology projects, including providing critical self-supporting multi-layer insulation into the Green Propellant Infusion Mission (Aspen Aerogels), providing a cryocooler design for eCryo (Madison CryoGroup LLC.), and providing a compact Iodine Hall Thrusters (Busek Company Inc.).
- Innovations from small businesses address critical challenges faced by the Agency. Under an SBIR Phase III, Bally Ribbon Mills developed advanced thermal protection system materials that solved a critical challenge on the Orion spacecraft and will fly on the EM-1.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The SBIR and STTR Programs will complete the implementation of recommendations received from the In-Reach, Outreach, and Integrated Investment teams. In FY 2016, the In-Reach Team will facilitate greater access to post-Phase II funding resources, and support the infusion of innovative technologies developed under SBIR/STTR. The Outreach Team will work to effectively communicate the program needs, benefits, and resources to the external SBIR/STTR community. The Integrated Investment Team will demonstrate NASA's portfolio end-to-end, optimize selections to provide high impact on current missions and programs, and support continuity of reporting throughout.

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 US 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. In FY 2016, the SBIR program is supported at a level of 3.0 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. NASA also supports Phase II Enhancement (II-E) contract options with incentivizes for cost sharing to extend the research and development efforts of the current Phase II contract. In addition, Phase II eXpanded (II-X) contract options further mature innovations developed under Phase II via an extension of research and development efforts to current Phase II contracts.

SBIR AND STTR

STTR

The STTR program was 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 0.45 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. Phase II-E and II-X contract options are also available to STTR participants.

Program Schedule

SBIR and STTR Program Year 2015 solicitation and award schedule is below.

Date	Significant Event
Nov 2014	FY 2015 SBIR and STTR Phase I Solicitation Opens
Jan 2015	FY 2015 SBIR and STTR Phase I Solicitation Closes
Mar 2015	FY 2015 Mission Directorates Complete Evaluations of Phase I proposals
Mar 2015	FY 2016 Topics Requested from Mission Directorates and Centers
Mar 2015	FY 2015 Phase I Awards Selected (Dependent on Appropriations)
Mar 2015	FY 2015 SBIR Phase II Awards Selected (from 2012 Awards)
May 2015	FY 2015 STTR Phase II Awards Selected (from 2012 Awards)
Aug 2015	FY 2016 Final Topics and Subtopics Reviewed and Concurred on by Mission Directorates and Centers
Nov 2015	FY 2016 Solicitation Open
Jan 2016	FY 2016 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: Ames Research Center (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 $125,000 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. SBIR Phase II-X matches, on a two for one basis, up to $250,000 of NASA program or project funding, thus enabling a maximum of $500,000 of SBIR/STTR award funds from the NASA SBIR/STTR Program. The total cumulative award for the Phase II contract plus the Phase II-X match is not expected to exceed $1,250,000 of SBIR/STTR funding.

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 through proposal review and ranking) in support of final selection. Mission Directorates 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.

SBIR AND STTR

MAJOR CONTRACTS/AWARDS

The Commercialization Readiness Program (CRP) awarded 9 Phase III CRP contracts at the centers for $3.6M in its FY 2014 pilot year, to further develop and commercialize technologies. These companies are listed below:

Vendor	Location (of work performance)
Mezzo Technologies	Baton Rouge, LA
AO Sense, Inc.	Sunnyvale, CA
Colorado Power Electronics	Fort Collins, CO
San Diego Composites, Inc.	San Diego, CA
GSE Inc.	Incline Village, NV
Bally Ribbon Mills	Bally, PA
Carbon-Carbon Advanced Technologies (C-CAT)	Kennedale, TX
Creare, Inc.	Hanover, NH
Fiber Materials, Inc.	Biddeford, ME

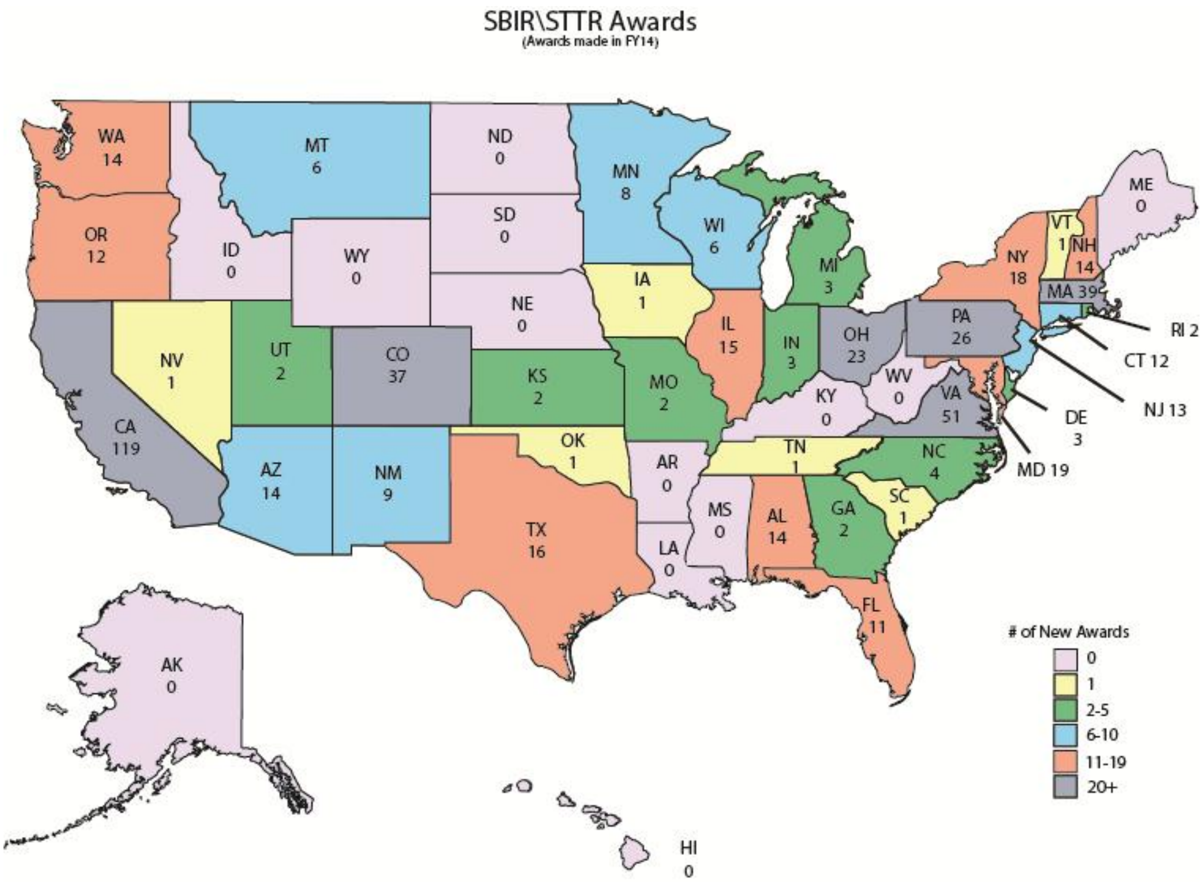
INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	National Academies	Ongoing	Assessment of the SBIR program.	TBD	Ongoing
Perform-ance	GAO	Ongoing	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

The map below represents SBIR and STTR Phase I, Phase II, Phase II-E, and Select Awards made in FY 2014, represented by geographic location.



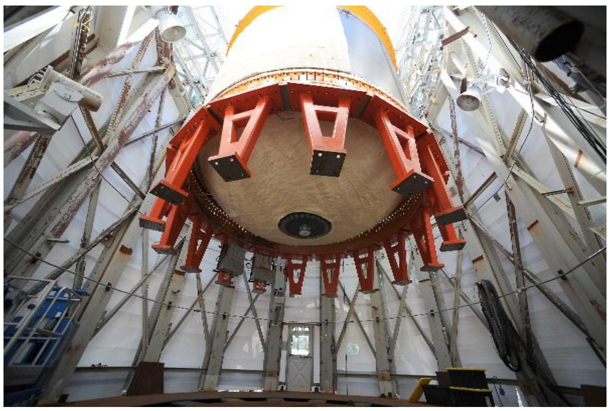
SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	370.4	--	491.0	489.7	500.3	511.2	522.4

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



The largest composite cryotank ever built recently completed a battery of tests at NASA's Marshall Space Flight Center (MSFC) in Huntsville, AL. The tank was lowered into a structural test stand where it was tested with cryogenic hydrogen and structural loads were applied to simulate stresses the tank would experience during launch.

NASA invests in space technologies with the objective of enabling or significantly advancing relevant capabilities for NASA missions while simultaneously providing for a more capable aerospace sector. 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 US Government agencies and the larger aerospace industry.

The Space Technology Research and Development portfolio supports a combination of early stage conceptual studies that focus on discovering entirely new technologies rapid competitive development and ground-based testing to determine feasibility; and flight demonstrations in relevant environments to complete the final step prior to mission utilization. By supporting projects at all technology readiness levels, Space Technology creates a technology pipeline, starting with innovation and early stage technology investigations, and eventually resulting in mature, ready-to-utilize 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.

Technology investments in robotics, automation, structures, materials, manufacturing, communications, and computing also have broad application within US technology and aerospace industries. As a result, Space Technology represents NASA in the National Nanotechnology Initiative, the Advanced Manufacturing Partnership, the National Robotics Initiative and the Materials Genome Initiative. These initiatives enable NASA to take advantage of and contribute knowledge toward common challenges across a network of government, academia, and industry experts. In addition, strategic investments supported within these initiatives bring new technological solutions to NASA and private industry through an expansion of the Nation's technology-base. By demonstrating new manufacturing techniques and developing new materials using nanotechnology, materials genomics, and synthetic biology, NASA contributes to the growth of the Nation's innovation economy. Space Technology conducts virtual workshops, creates technology infusion plans and uses unfunded and funded Space Act Agreements to share expertise with industry and academia and improve the probability of infusion into the user community.

Technologies advanced within Space Technology Research and Development target key technology thrust areas both within and outside of NASA, including: high-power solar electric propulsion; life support and resource utilization; entry, descent, and landing; space robotic systems; optical communications; deep space navigation; lightweight structures; and space observatories. In addition, the Agency looks to Space Technology to address the challenges of far-reaching missions. For example, because the transit times, distances, radiation environment and surface environments of the Outer Planets differ significantly from vistas that we have visited often (Earth, Mars, Moon), technology investment is a required component of any credible plan for exploration of these worlds. Technology development in a small number of critical areas will begin in FY 2015 to enable a broad set of Outer Planet Exploration Missions in the decade of the 2020s. Technology investments in power (solar and nuclear), radiation protection, sensing, landing, navigation, and deep-space communications made over the next four years could enable a broad set of small missions to compelling planetary science targets. Space Technology will also invest in a number of targeted technologies to enable low-cost, frequent access space. 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

Crosscutting Space Technology Development and Exploration Technology Development will be merged to form Space Technology Research and Development. This merger will not impact any projects.

ACHIEVEMENTS IN FY 2014

- To support more efficient travel through space, space technology completed fabrication and integration of a 12.5 kilowatt-class Hall thruster capable of providing more than twice the power of the current state-of-the-art designs. Completed integration and testing of a 300-Volt power processing unit in an effort to more efficiently convert energy on a Solar Electric Propulsion spacecraft. In addition, NASA completed testing and validation two solar array designs: ATK's MegaFlex, which folds out like a fan, and Deployable Space Systems' Roll Out Solar Array (ROSA), which rolls out like a carpet.
- NASA and Boeing collaborated to successfully design and fabricate the largest, out-of-autoclave composite cryogenic propellant tank ever manufactured. The 5.5-meter diameter tank endured a rigorous series of tests to replicate the physical stresses launch vehicles experience during flight.
- Space Technology is supporting the Science Mission Directorate (SMD) by infusing five groundbreaking technologies for the Discovery 2014 mission, which promises to significantly improve the performance of future human and robotic exploration missions beyond Low Earth Orbit (Heat shield for Extreme Entry Environment Technology (HEEET)), Deep Space Optical Communication (DSOC), advanced solar arrays, Deep Space Atomic Clock and Green Propellant).
- To better understand the utility of supersonic retrorocket propulsion (SRP) under Mars entry conditions, Space Technology imaged a SpaceX Falcon 9 first stage SRP demonstration and will conduct further imaging in 2015 to validate the capability for future Mars landings.

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

- To provide propulsion for the Nation's CubeSat community, Space Technology invested in and successfully completed a hot-fire test of Aerojet Rocketdyne's MPS-120™ CubeSat High-Impulse Adaptable Modular Propulsion System™ (CHAMPS™). The MPS-120 is the first 3D-printed hydrazine integrated propulsion system and is designed to provide propulsion for CubeSats, enabling missions not previously available to these tiny satellites.
- Space Technology broke a new world record in conductivity by substantially improving the electrical conductivity of carbon nanotube power cables by using carbon nanotube yarns as conductors. This technology has the potential to reduce the power and data cable mass by more than fifty percent.
- To assist astronauts who live and work in space, a Space X resupply mission delivered robotic legs to provide mobility for Robonaut 2, and a 3D printer to demonstrate the feasibility of on-demand additive manufacturing in microgravity (in collaboration with Exploration). Station astronauts also supported a demonstration of the Synchronized Position Hold, Engage, Reorient, and Experimental Satellites (SPHERES) to give NASA a greater understanding for how fluids behave in space.
- To support increased data demands required for future missions, Space Technology completed development of a prototype deep space optical communication system with the potential to achieve a tenfold increase data transmission rates.

WORK IN PROGRESS IN FY 2015

- Continue breakthrough development of a three-dimensional layer-to-layer woven thermal protection system, which has applications for extreme entry environments. Using a densely woven approach, the promising materials will be utilized on the Orion crew vehicle flight EM-1 and support Science for their potential application on future planetary science missions.
- Develop the second generation Mars Entry, Descent, and Landing Instrumentation (MEDLI) sensor suite for incorporation into the Mars 2020 mission heat shield.
- Conduct a non-nuclear terrestrial demonstration of a power system to convert heat into energy to be used anywhere, regardless of available sunlight in partnership with the Department of Energy and small businesses (Sunpower, Inc. and Material Innovations, Inc).
- Deliver three microfluidic-electrospray propulsion thruster designs that have the potential to transform small spacecraft propulsion. These thrusters, designed by the Jet Propulsion Laboratory (JPL), Busek Company (Natick, MA), and the Massachusetts Institute of Technology, will each also offer a highly reliable alternative to reaction wheels for fine pointing capability on large satellites. These technologies will be further developed through propulsion pathfinder missions on small spacecraft platforms.
- Conduct suborbital demonstrations of new low cost, high performance avionics with Up Aerospace, through a non-reimbursable Space Act Agreement.
- Finalize the design of a soft airlock hatch system that will be tested on inflatable structures and spacecraft modules to support an emerging space industry and future spacecraft designs. In addition to substantial mass savings, soft hatches will reduce spacecraft packaging volume by eliminating rigid hatch designs currently limiting the utility of inflatable space structures.
- Announced several new Centennial Challenges including the Cube Quest Challenge for deep space CubeSat exploration with a $5 million prize purse, and an additive manufacturing challenge in partnership with America Makes, and in partnership with NSF, a robotics automation challenge as a follow on the DARPA robotics challenge.

- Release several Requests for Information to explore non-reimbursable partnerships that provide access to NASA expertise in areas such as suborbital and nano-launch capability development, low mass data cables and wires, composite structures, wireless power beaming, and laser communications.
- Continue a steady cadence of early stage grants to academia, industry, entrepreneurs, and NASA innovators.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

- To enable scientific discovery, Space Technology will complete software development of Station Explorer X-ray Timing and Navigation Technology (SEXTANT) at the Goddard Space Flight Center which will evaluate real-time X-Ray data from known regular pulsars to demonstrate deep space navigation. This ISS demonstration will use pulsars for navigation similar to the way we use GPS on the Earth today.
- In addition to launching the Deep Space Atomic Clock and Green Propellant Infusion Mission, the Composite Exploration Upper Stage project will conduct its critical design review and begin fabrication of full scale composite panels for applicability toward launch vehicle components.
- With application to both commercial and NASA operations, Space Technology will complete the integration and testing of all components for the Laser Communications Relay Demonstration mission. Set to fly as a hosted payload on a Space Systems Loral-built communications satellite in geosynchronous orbit, this technology will provide an order of magnitude leap in communications capability for future TDRS satellites as well as commercial space communications providers.
- With Mezzo Technologies located in Baton Rouge, LA, Space Technology will develop two phase change material heat exchangers, one using wax and one using water to disburse heat. The microgravity performance of these heat exchangers will be assessed on the ground and potentially on the International Space Station. If the water-based unit proves successful, NASA will incorporate the technology into Orion’s vehicle thermal control system, giving it the ability to work at full power levels during all portions of lunar orbits.
- Space Technology will conduct two flight demonstrations (CubeSat Proximity Operations Demonstration and Integrated Solar Array and Reflectarray Antenna) to demonstrate rendezvous and docking and radio communications.

Program Elements

EARLY STAGE INNOVATION

Space Technology invests in early stage space technology research and development sourced from academia, industry, entrepreneurs and from the NASA workforce to bring pioneering approaches to the Agency’s difficult and far reaching challenges. Over 427 early-stage activities span the 14 Technology Roadmap Areas with over seventy percent focused on the eight Space Technology thrust areas. More than seventy percent of the early-stage work supports Science, sixty percent supports Exploration and ten percent focuses on Aeronautics challenges. As an example of the progress in the early-stage portfolio, Space Technology Research Grants researcher Jaemi Herzberger from the University of Maryland has developed an acoustic NDE technique that, for the first time, will provide a screening process for the indication of dielectric cracks in multi-layer ceramic capacitors – MLCCs - after they have been assembled in space flight hardware; Greydon Foil from Carnegie Mellon University led the development of autonomous science and navigation software, which operated autonomously for over 40km during field testing; Shannon Zirbel from Brigham Young University utilized origami concepts to optimize deployment of satellite solar arrays to increase performance, reduce or eliminate assembly, eliminate friction and wear, and reduce the cost and weight of space structures; and Arizona State University's Mary Laura Lind developed, characterized, and tested membranes to recover water from urine and urine brines through osmosis; this research has the potential to advance waste management capabilities needed on NASA's future long duration missions. Using a steady cadence of competitive solicitations, Space Technology maintains ongoing access to these new, innovative technological solutions to drive more high-risk/high-payoff space technologies into the NASA technology pipeline. Space Technology invests in early-stage innovations through the following opportunities:

- Space Technology Research Grants annually conducts a series of competitive solicitations targeting high-priority technology areas that challenge the entire spectrum of academic researchers, from graduate students to early career and senior faculty members, to make science, space travel, and exploration more effective, affordable, and sustainable. These grants harness the unique innovative environment that resides with academia to solve space technology most difficult long-term challenges. In the process, Space Technology fortifies the close collaborations between US universities and NASA. In FY 2014, Space Technology awarded 54 fellowships, seven Early Career Faculty awards and solicited Early Stage Innovations proposals that resulted in 11 selections in early FY 2015. In addition, Space Technology continued 220 previous fellowships and grants awards.
- NASA Innovative Advanced Concepts (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. NIAC annual issues both Phase I and continuation Phase II solicitations, open to NASA Centers, other government agencies, universities, industry and individual entrepreneurs. In 2014, NIAC made 12 Phase I and 5 Phase II awards across industry, academia, and NASA Centers, while completing 12 Phase I and 10 Phase II studies.
- 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 academia, private industry, individual innovators, as well as other NASA Centers and Government labs are encouraged. Space Technology at NASA HQ reviews the Center selections to ensure a customer relevant, non-duplicative, and technically credible portfolio. In FY 2014, the Center Innovation Fund completed approximately 150 studies, and competitively awarded 120 new studies to kick off FY 2015.

Space Technology continues to enhance its involvement with academia and NASA Centers to access unique ideas with breakthrough potential. In FY 2016, 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 capabilities important to the Nation. With Exploration, Space Technology will initiate an In-Space Manufacturing and Resource Utilization Institute to nurture capabilities and technologies that enable in-space systems development and allow space explorers to replenish resources such as oxygen, food and propellant while living and working space. This effort will encourage a deeper collaboration between NASA, industry, and academia with a common goal to greatly reduce the cargo needed from Earth by reusing and extracting resources from the space environment. Key ideas explored under the Institute include in situ resource utilization, automated in-space manufacturing and assembly, closed loop biological systems, and digital designs for materials, structures, and systems.

CENTENNIAL CHALLENGES

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 often collaborates with private non-profit entities to manage the competitions at no cost to NASA. The following challenges are underway:

- 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. Among the 18 competitors that competed in the third year of the challenge, West Virginia University won a $5,000 Level 1 prize and is expected to join Team Survey (California) to compete for a Level 2 prize in the 2015 event.
- The Mars Ascent Vehicle Challenge opened for registration in FY 2014. Teams are challenged to develop an autonomous robotic system that can load a sample into a rocket, launch to a predetermined altitude of 3,000 feet and return the sample container to the earth surface safely.
- Space Technology announced the Cube Quest Challenge to design, build, and launch flight-qualified, small satellites capable of advanced operations near and beyond the moon, to demonstrate communications and propulsion technologies. Teams will have the opportunity to compete for a future secondary payload spot on the first integrated flight of NASA's Orion spacecraft and SLS rocket.
- NASA is formulating a manufacturing challenge with America Makes to demonstrate on-demand, low cost shelter production using resources on the planet. This challenge aligns with NASA mission and goals for deep space exploration and planetary surface construction of infrastructure and will encourage the acceleration of technology in the area of additive manufacturing between industry, academia, and government.
- Additional future challenges will address NASA's efforts in robotics for human exploration and planetary science missions, and improve University involvement through targeted challenges. For example, Space Technology is working with the National Science Foundation (NSF) to formulate the Space Robotics Challenge where NASA and NSF developed robots will be awarded to qualified institutions. The selected teams will have three years to improve the software and automation aspects of the Robonaut series robots.

GAME-CHANGING DEVELOPMENT

Within Game Changing Development, NASA focuses on maturing transformational technologies across the critical gap between early stage innovation and flight demonstration. Technologies are primarily selected through competitive solicitations emphasizing capabilities most likely to be infused in to the known user community. Space Technology favors technology investments that offer direct partnerships and co-funding from NASA, industry, and/or other government agencies, to advance specific technologies needed by those customers. For example, key technology developments will address long-term challenges identified for outer planetary science missions by SMD, such as Deep Space Optical

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

Communications, advanced radiation tolerant spaceflight computing and woven Thermal Protection System materials. In partnership with the SMD, Space Technology has incentivized technology development and demonstration through they recently released Discovery 2014 solicitation. In addition, Space Technology partners with the Human Exploration and Operations Directorate to address challenges for human missions to Mars, such as converting carbon dioxide from the Mars atmosphere to oxygen, development of an upgrade of the SPHERES robots on ISS and development high capacity batteries for next generation space suits. Game Changing also partners with other government agencies to explore solutions to common challenges in areas such as robotics, manufacturing, and materials. Game Changing Development makes fixed duration investments typically categorized within the investment areas described below.

Landing Accurately: Advanced Entry Descent and Landing (AEDL)

In order for NASA to land more mass, more accurately on planetary bodies, the Agency must develop more capable entry, descent, and landing systems and materials. This includes the development of new aeroshell concepts and thermal protection system materials for Orion, Mars 2020, and future exploration vehicles. Space Technology designs, analyzes, and tests technologies, materials, and aeroshell architectures required for future planetary entry missions. Much of the work in this theme involves developing efficient ways to reduce spacecraft re-entry speed while providing protection from extreme heating. One such remarkable breakthrough is the first utilization of a three-dimensional layer-to-layer woven thermal protection system developed by Bally Ribbon Mills, a small business, which has applications for extreme entry environments. Using a densely woven approach, the promising materials will integrate onto the heat shield of the Orion crew vehicle for EM-1; and also support Science for their potential application on future planetary science missions.

In partnership with Exploration and Science, Space Technology will develop the second generation Mars Entry, Descent, and Landing Instrumentation (MEDLI) sensor suite for incorporation into the Mars 2020 mission heat shield. This effort builds on the success of Curiosity’s MEDLI instrumentation, and will further improve our understanding of entry system performance. To better understand the utility of supersonic retrorocket propulsion under Mars entry conditions, Space Technology is evaluating flight data from SpaceX Falcon 9 first stage landing demonstrations. The Falcon 9 is using SRP to conduct precision landing of the first stage, allowing them to reuse the stage and to validate the capability for future Mars landings. Space Technology also conducts advanced analytics and modeling for hypersonic flight including aerothermodynamics and material thermal response analyses. This improved modeling capability will result in lower mass entry systems due to a better understanding of the thermal protection system thickness margins.

Access and Travel through Space: Future Propulsion and Energy Systems

Space Technology supports the development of lightweight microfluidic-electrospray propulsion technologies using a parallel development path. Following a down-select and successful demonstration, these propulsion systems will also offer fine pointing and directional control capability for larger spacecraft, possibly providing an alternative or redundancy to the reaction wheels currently used and potentially address a common failure mode seen on many spacecraft.

Space technology personnel are also developing a Hall iodine electric propulsion thruster at the Marshall Space Flight Center. The use of solid iodine as a propellant is beneficial because it significantly reduces the required storage volume while simultaneously eliminating the need for the expensive, high pressure tanks required to store gaseous propellants.

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

In addition, Space Technology is making critical advancements in power generation, storage, and transmission technologies with a focus on Outer Planetary exploration. This includes development of a power processing unit that can operate at high temperatures, and power conversion and thermal management technologies being tested for future in-space nuclear power applications, targeting the development of a small and scalable (1- to 10-kilowatt) fission power system. This approach offers tremendous potential for more capable outer planetary science missions. Space Technology also supports advanced in-space power storage by investigating and maturing advanced alternate chemistry and lithium-ion batteries with a goal to double to quadruple the specific energy of the best commercially available rechargeable batteries. Four Phase I battery designs selected in late FY 2014 will be evaluated in the spring of 2015. Two of these designs will be down selected for further development, and single battery prototype will be delivered to Exploration for validation in FY 2017.

Enabling Scientific Discovery: Revolutionary Robotics and Autonomous Systems

Robotics and autonomous systems are critical when exploring or operating in an extreme environment, on Earth or in space, especially critical in the exploration of the Outer Planets. Human Robotics Systems technology also supports the Agency's role in the National Robotics Initiative by issuing grants for robotics technologies that benefit space exploration and also support manufacturers, businesses and other entities. Specific technology efforts include the development:

- An icy moons lander testbed (analogous to the JPL Mars yard) would allow advancement of the broad range of landing architectures, technologies and capabilities required for safe access of the new and diverse surface and subsurface environments found on the icy moons. This laboratory testbed is critical because of the fundamentally different icy moon terrain than any encountered in planetary exploration to date. Planetary landing has become an important measuring stick of US scientific and technological readiness. An icy moon landing testbed would also enable development of icy moon surface and subsurface mobility systems.
- A new freeflyer robot for use inside ISS as a follow-on to SPHERES. This robotic system will improve the crew's efficiency by autonomously performing the more mundane and monotonous tasks such as inventory management and air quality assessments. In addition, with its open source software platform, it will continue to be available for use by Universities and for telerobotics challenges on ISS.
- Continued maturation of humanoid robots through a collaboration with Centennial Challenges and the National Science Foundation. NASA will leverage the DARPA robotics challenge as an on ramp to initiate a NASA robotic challenge and to form partnerships with private and university organizations that show potential to dramatically improve NASA's future robotic capabilities. Space Technology is maturing the Robonaut software to improve the robot's efficiency and autonomy further freeing up the crew's valuable time.
- Rover development for the Resource Prospector Mission with Exploration. A prototype rover will be developed to demonstrate nighttime operations and inform the Resource Prospector Mission rover design.

Enabling Industry: Lightweight Materials and Advanced Manufacturing

Space Technology 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. These collective 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. NASA's participation has plugged the Agency into a network focused on cutting edge manufacturing methods and technologies. Included within this portfolio:

- Using cutting-edge materials and emerging capabilities to design, develop, and test an additively manufactured upper stage class rocket engine combustion chamber and nozzle.
- Developing and testing airlocks that utilize soft goods as opposed to metallic closure rings and hatches to drastically reduce the mass of a complete inflatable airlock system and allow for highly compact launch packaging.
- Exploring nanotechnology research and applications for aeronautics and space, with a focus on reducing vehicle mass and improving reliability through the development of carbon nanotube-based materials. This includes investments in nano-manufacturing through the development of carbon nanotube structural materials, carbon nanotube reinforced composite overwrapped pressure vessel elements, lightweight carbon nanotube/aerogel wires, and cables.
- In addition, Game Changing is reviewing proposals received from a late 2014 solicitation to develop and manufacture ultra-lightweight materials for aerospace vehicles and structures of the future to demonstrate lower-mass alternatives to honeycomb or foam cores currently used in composite sandwich structures.

Enabling Scientific Discovery: Affordable Destination Systems and Instruments

Space Technology will fundamentally transform spacecraft systems through investment in high payoff technologies that increase data rate communications, increase the sensitivity of scientific instruments and sensors, advance navigation and flight avionics, advance thermal control systems and in-situ resource utilization technologies, advance closed-loop life support systems, and develop capabilities to mitigate space radiation. Included within this portfolio:

- With both SCaN and Planetary Science, technologies that enable deep space optical communication to provide 100 times increase in data rates available on NASA's exploration 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.
- With the Air Force Research Laboratory, a high performance flight computing system. This development effort will lead to vastly improved in-space computing performance, energy management, and increased radiation fault tolerance. The new radiation tolerant microprocessor will offer a 100 times improvement in performance relative to the current state of the art RAD750 processor while requiring the same roughly 5 watts of power.
- With Exploration, Space Technology selected four partners to develop technologies that will increase the oxygen recovery rate aboard human spacecraft to at least 75 percent while achieving high reliability. These systems are critical when oxygen resupply from Earth isn't available. Technologies will be delivered to NASA at the end of the year for evaluation. Future maturation of these technologies may use the International Space Station National Laboratory as a proving ground to retire risk and gain experience with capabilities needed for deep-space exploration.
- With Science, advancing coronagraph technologies for the Wide Field InfraRed Survey Telescope/Astrophysics Focused Telescope Assets (WFIRST/AFTA) mission to dramatically improve our ability to directly observe exo-planets, and interrogate the atmospheric properties of

these distant worlds allowing humanity to discover habitable planets within our galaxy for the first time.

- Space Synthetic Biology investments will focus on the development of a "biomembrane." This synthetic-biology enabled, lipid-based membrane will be engineered to remove contaminants, self-repair, and have extended lifetimes far beyond the state-of-the-art membranes. This will be the first-ever demonstration of a self-repairing synthetic membrane.

TECHNOLOGY DEMONSTRATION MISSIONS

To bridge the gap between early development and mission utilization, Technology Demonstration Missions (TDM) matures system-level space technologies that can benefit multiple NASA Missions and aerospace industry stakeholders by demonstrating prototypes and demonstration units in relevant environments. To remain affordable, flight demonstrations of technologies that have passed feasibility ground testing are supported primarily through hosted payloads, rideshares and secondary payloads. The current portfolio for TDM is described below:

Enabling Industry and Travel through Space: Solar Electric Propulsion

Space Technology, working with Glenn Research Center, will continue development of high-powered solar electric propulsion. Once proven, high-powered solar electric propulsion will enable more efficient orbit transfer for satellites and accommodate increasing power demands for government and commercial satellites. Recent NASA investments in Solar Electric Propulsion (SEP) subsystems have already begun to revolutionize the commercial satellite industry. Furthermore, solar electric propulsion can efficiently propel NASA's future robotic science and human exploration missions beyond the Earth-moon system. NASA will leverage internal and external expertise and industry partners to develop a cost effective, high-powered solar electric propulsion demonstration system. This system will utilize 30 to 50 kilowatt deployable solar arrays using advanced deployable structures with half the mass and one third the packaging volume compared to the best current arrays. Hall Effect thrusters designed to operate at up to 15 kilowatts each are under development with magnetic shielding to permit several years of continuous operations without degradation. High-voltage advanced power processing units will supply power from the solar arrays to the thruster to complete the system. The Asteroid Redirect Mission expects to provide a deep-space demonstration of the solar electric propulsion system, but space technology is also exploring additional demonstration paths such as using the ISS as a test bed for the arrays or supporting science missions with a complete SEP system.

Enabling Industry and Scientific Discovery: Laser Communications Relay Demonstration

The goal of Laser Communications Relay Demonstration is to demonstrate bi-directional optical communications relay services between geosynchronous orbit and Earth. The outcome of this demonstration will prove optical communications technology in an operational setting, providing data rates up to 100-times faster than today's radio frequency based communication systems. The demonstration will measure and characterize the system performance over a variety of conditions, develop operational procedures, assess applicability for future missions, and provide an on orbit capability for test and demonstration of standards for optical relay communications. This will have major implications for NASA, other agencies, and the US satellite manufacturers and operators. In FY 2014, Space Technology released a Request for Information to gauge industry interest in this technology and ensure that the planned design specifications will permit utilization into the commercial communications industry. The responses received indicated that this technology has great value to industry in responding to the rising demand for bandwidth. After the in-space technology demonstration becomes operational, NASA will provide access to the system for the communications industry to test the capabilities for their needs. On completion, NASA will transfer laser communication technology to industry for future missions.

Landing Accurately: Low Density Supersonic Decelerators

Space Technology, working with the Jet Propulsion Laboratory, is developing and demonstrating new entry, descent, and landing (EDL) technologies capable of increasing the landed mass and landing accuracy over current baseline systems. NASA has utilized Viking era parachutes for decades to perform supersonic deceleration for its ever heavier Mars science landers. These descent parachutes along with the rest of Mars EDL systems have reached the upper limit of their capacity (one metric ton). Space Technology is developing and testing a variety of supersonic decelerator systems to support future larger Mars missions. The project is designing, developing, and testing a supersonic 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 (180,000 feet) supersonic (Mach 2 to 4) flight demonstrations. This effort is funded, in part, through a partnership with NASA's Planetary Science Division. Once proven, these technologies will enable future robotic science missions to Mars that increase the landed mass capability to between three and four metric tons. In addition, this EDL approach has potential to scale up to 15-metric tons landed mass to accommodate requirements for applications such as human missions to Mars. Building off the incredible success of the successful flight in FY 2014, which proved the inflatable decelerator and ability to achieve Mars-like environment and speed, subsequent flights in FY 2015 and FY 2016 will continue to prove the capability of inflatable technology as well as large-scale, supersonic parachutes.

Access and Travel through Space: 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. The accurate timing and navigation provided by the clock will also dramatically improve gravitational measurements planned for a future Europa (and other icy moons) mission to characterize the under ice liquid water oceans. Precision timing and navigation provided by the new clock will 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 2016, and is funded in a partnership with SCaN.

Access and Travel through Space: Green Propellant Infusion Mission

Space Technology and partners Ball Aerospace and Aerojet designed, built, tested, and is launching a dedicated spacecraft to demonstrate green propellant propulsion with the goal to provide an alternate to hydrazine propellant. Hydrazine extensively used since the 1960s 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 have actively sought 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 AF-M315E as an innovative, low-toxicity mono-propellant alternative with improved performance over hydrazine. The overall AF-M315E propulsion system is expected to improve overall vehicle performance and processing efficiency while decreasing 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. The green propellant formula, thrusters, and related systems will perform a series of in-space demonstration tests over a 13 month period. NASA has secured a rideshare opportunity for a FY 2016 technology demonstration via the STP-2 launch of a SpaceX Falcon Heavy.

Enabling Industry: Composite Exploration Upper Stage

Reducing the mass of launch vehicles will allow for greater payload capacity. Existing human space flight vehicles do not utilize composites for primary structures since validation of the critical technologies have occurred at scale and in a relevant environment. Building on the success of the Composite Cryotank Technologies & Demonstration and on advanced composites integrated modeling conducted by Space Technology, the Composite Exploration Upper Stage project, working with the MSFC, will develop and demonstrate additional composite structures for application on launch vehicles. This project will design, build, and test composite forward and/or aft skirts to demonstrate the performance of composite structures under relevant environments. The resulting composite structures developed through this effort, at 8.2 meters in diameter will be significantly wider than the fuselage of the Boeing 787 and will have broad applicability across the aerospace industry. The objective is to provide validated alternative structural materials for designers to use in future versions of commercial and government launch vehicles. While the initial target application is the SLS Exploration Upper Stage, this effort will develop, design, and validate manufacturing processes for using composites that can be applied to other large space structures and science platforms developed across the aerospace industry. The project is a cooperative effort between Space Technology and Exploration, involving multiple NASA Centers. The project will also leverage collaborations with the Department of Defense, industry and academia to provide the most innovative and affordable ideas.

Access and Travel through Space: Evolvable Cryogenics (eCryo)

Managing the cryogenic fluids and minimizing boil-off of cryogenic propellants on long duration missions is a critical capability needed to enable high-performance in-space propulsion stages, a key component of future human spaceflight architectures. Advancements in cryogenic fluid management will address challenges experienced by NASA and commercial launch providers by demonstrating the capability of in-space long-term storage and transfer of cryogenic propellants (i.e. liquid oxygen and liquid hydrogen). With eCryo, Space Technology will conduct a series of ground demonstrations at the MSFC and the GRC to validate the performance of propellant storage tanks designed for long-term storage. In addition to managing the propellant boil-off by validating the effectiveness of advanced multi-layer insulation, the team will look to reduce ancillary system weights and complexity. The project will also investigate the utilization of remaining boil-off gases to replace existing pressurization and attitude control systems and to provide electrical power for the SLS Exploration Upper Stage. In addition, the team will develop new cryogenic monitoring instrumentation and analytical models to assist in determining cryogenic health during in space operations. For NASA, these technologies enable beyond low Earth Orbit exploration missions. However, industry will likely infuse the technologies on next generation launch vehicles – particularly upper stages – making them more efficient and capable. By taking an incremental ground test approach, Space Technology will prioritize technologies needed by SLS upper stage development and the long term needs of the aerospace industry as a whole. The project will build on the knowledge gained from previous investments and utilize existing Agency assets and test facilities capable of maturing cryogenic propellant technologies. Currently, the project is completing the design and analysis phase for the ground demonstration and will procure and develop the test hardware to support test operations beginning in FY 2016.

Landing Accurately: Terrestrial HIAD Orbital Reentry (THOR)

The Terrestrial HIAD Orbital Reentry project will conduct an orbital demonstration of an inflatable braking system that, if successful, could increase the Agency's capability to land mass on the Mars surface. Entry mass at Mars is presently limited by the size of the aeroshell that can fit into the launch vehicle shroud. Inflatable technologies would allow for the utilization of a larger aeroshell while still fitting within the constraints of the launch vehicle shroud (see image). This project will build on previous suborbital demonstrations with the Hypersonic Inflatable Aeroshell Decelerator (HIAD) by conducting a high-energy reentry flight test on sub-scale heat shield. This demonstration would significantly advance the second generation HIAD, enabling ISS down mass capability in the near term and more affordable human missions to Mars in the far term. The orbital demonstration will utilize existing flight hardware from the 2012 test to develop a follow-on hosted payload, taking advantage of available mass and usable volume capability in Antares launch vehicle to further the technology. The goal of this demonstration is to verify the heat shield capabilities and obtain data in Mars or low Earth Orbit return class flight environment (heat rate, heat load, and deceleration).

SMALL SPACECRAFT TECHNOLOGY

Small Spacecraft Technology develops and demonstrates technologies to enhance and enable new small spacecraft capabilities. NASA invests in small spacecraft to provide a low-cost platform for rapid in-space demonstration of new technologies and innovations that are applicable across the space sector. Small Spacecraft are most often delivered to space using a rideshare approach, where the spacecraft uses launch vehicle volume that would otherwise go unused by a primary payload. 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. Small Spacecraft Technology is supporting the following development projects:

- To demonstrate the ability of coordinated communication in a scientific satellite constellation, the 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 cross-linked network communications between the individual satellites to relay science data. The flight hardware development for this project is complete and the mission is planned for mid-2015.

- The Nodes mission will employ two satellites of the same design as EDSN, but with enhanced software capabilities for an orbital demonstration in early 2015, after deployment from the ISS.
- To demonstrate laser communication capability for small spacecraft, the Optical Communications and Sensor Demonstration will send large amounts of information from a small satellite to Earth using laser communications and demonstrate low-cost optical sensors to enable formation flight with two small satellites. The mission is scheduled for launch in mid-2015.
- To demonstrate affordable Earth-entry return, the Johnson Space Center (JSC) will conduct a suborbital flight demonstration of a small Earth-return capsule called Maraia in 2015.
- To demonstrate flight, rendezvous, and docking in orbit, the CubeSat Proximity Operations Demonstration will fly two satellites by the end of 2015.
- To demonstrate multi-purpose structures, the JPL will develop the 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 a small satellite can transmit by using the back of its solar array as a reflector for the antenna. The mission is planned for late 2015.
- Propulsion Pathfinder will conduct a series of flight demonstrations beginning in 2016 to expand propulsion system capabilities for CubeSat-scale and other small spacecraft to support greater maneuverability and access to destinations beyond low Earth orbit. This project will demonstrate miniaturized electrospray propulsion systems, electric thrusters, and other innovative propulsion systems. One specific mission, known as Isat, is in development to demonstrate a 200-watt Hall Iodine thruster and is working toward a flight demonstration by 2017.
- The Smallsat Technology Partnerships continue with eleven projects involving collaborations between 13 universities and seven NASA Centers. An opportunity to propose a new round of projects will be offered in 2015.

FLIGHT OPPORTUNITIES

Flight Opportunities enables the maturation of technologies by providing affordable access to space environments using commercially available suborbital flights. This helps fulfill the overall goal of advancing space technology to meet future mission needs while simultaneously fostering the growth of the commercial spaceflight market. The program achieves these objectives by selecting promising technologies from industry, academia, and government, and testing them on commercial suborbital launch vehicles. This approach takes technologies from a laboratory environment and gives them flight heritage, while also feeding the development of the spaceflight technologies and infrastructure created by the companies Flight Opportunities flight providers. The program supports flights for both externally funded payloads and NASA-funded technology payloads selected though NASA Research Announcements. Space Technology also collaborates with other NASA programs to provide suborbital platform flights for research and/or technology demonstrations.

In support of NASA’s overall mission, Flight Opportunities has facilitated the testing of technologies for exploration and the commercial utilization of space. To date, the program has selected over 150 technology payloads, over which 50 percent are led by universities. Technologies include ones that will: guide the next generation of spacecraft to safe landings on the moon, Mars, and back on Earth; track spacecraft though the national airspace; facilitate in situ repair and construction of spacecraft; and enable on-orbit refueling and spacecraft servicing. In FY 2014 commercial partners flew 38 technologies on four different commercial platforms, with an additional 19 payload flights spanning 10 flight campaigns planned for early FY 2015. Among the technologies supported in FY 2014, Masten Space Systems conducted three flights of Astrobotic Technology's optical and Light Detection and Ranging (LIDAR) based system that they plan to use to perform a lunar soft landing in 2015 for the Google X-Prize. Near Space Corporation (NSC) successfully flew a small balloon from Madras, Oregon for the University of Central Florida's Planetary Atmosphere Minor Species Sensor (PAMSS) payload. Additionally, UP Aerospace Corporation successfully launched SpaceLoft-8 (SL-8) with six program-sponsored technology payloads from Spaceport America in New Mexico. NASA selected Masten Space Systems, Up Aerospace, Paragon Space Development Corporation and Virgin Galactic in its recent vendor solicitation to integrate and fly technology payloads on commercial suborbital reusable platforms. In FY 2015 and FY 2016, Flight Opportunities will explore partnerships to spur the development of nano-launch orbital capabilities development to spur development of small spacecraft launch systems. The aim of the effort is to enable emerging companies by sharing NASA expertise and relevant technologies to provide the nation with frequent, reliable, and cost effective access to space for small payloads.

Program Schedule

Specific timelines for deliverables and achievement major milestones vary from project to project, and depend on successful demonstration of experimental capabilities and the results of design, development, fabrication, analyses, and testing. Both Game Changing Development and Technology Demonstration Missions are composed of sets of uncoupled project elements. See more in the historic performance graphic below.

Program Management & Commitments

Program Element	Provider
Space Technology Research Grants	Provider: US 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

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

Program Element	Provider
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
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, GRC, LaRC, JSC, JPL, KSC Cost Share Partner(s): Air Force Research Laboratory, Various universities
Flight Opportunities	Provider: Various Lead Center: NASA HQ program executive Performing Center(s): AFRC Cost Share Partner(s): Various

Acquisition Strategy

Space Technology Research and Development uses a blended acquisition approach. Solicitations are open to the broad aerospace community to ensure engagement with the best sources of new and innovative technology. As such, projects 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 Technology will endeavor to use unfunded and funded Space Act agreements where these approaches are likely to yield acquisitions that are more efficient. The focus of these agreements will be to increase the level of public / private partnerships to perform future space technology development.

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
	Technology Demonstration Missions	
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
Low Density Supersonic Decelerator	Mark Adler, Project Manager, California Institute of Technology, JPL; Wallops Flight Facility (WFF); ARC; LaRC	California Institute of Technology, JPL
Solar Electric Propulsion	Mike Barrett, Project Manager, GRC; GSFC; JPL; Deployable Space Systems and ATK	Cleveland, OH Pasadena, CA
THOR	Kurt Detweiler, Project Manager, LaRC; WFF, ARC, Aberdeen Proving Ground, Orbital Sciences	Hampton, VA; Wallops, VA; Pasadena, CA; Aberdeen, MD
eCryo	Carol Ginty, Project Manager, GRC; MSFC, GSFC, KSC, ARC	Cleveland, OH; Huntsville, AL, Greenbelt, MD; Cape Canaveral, FL, Moffett Field, CA
Composite Exploration Upper Stage	John Vickers, Project Manager, MSFC; LaRC, GRC	Huntsville, AL; Hampton, VA; Cleveland, OH;
Green Propellant	Ball Aerospace (Prime); Aerojet Rocketdyne Corporation; US Air Force Research Laboratory; US Air Force Space and Missile Systems Center; GRC; LaRC; KSC	Boulder, CO; Redmond, WA; Edwards, CA; Albuquerque, NM; Cleveland, OH; Cape Canaveral, FL
	Small Spacecraft Technology	
Integrated Solar Array and Reflectarray Antenna (ISARA)	Richard Hodges, JPL Aerospace Corporation Pumpkin Inc.	Pasadena, CA El Segundo, CA San Francisco, CA
Optical Communications and Sensor Demonstration (OCSD)	Siegfried Janson, Aerospace Corporation	El Segundo, CA
CubeSat Proximity Operations Demonstration (CPOD)	Marco Villa, 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

SPACE TECHNOLOGY RESEARCH & DEVELOPMENT

Element	Vendor	Location (of work performance)
Edison Demonstration of Smallsat Networks and Nodes	Deborah Westley, ARC MSFC Montana State University Santa Clara University	Moffett Field, CA Huntsville, AL Bozeman , MT Santa Clara, CA

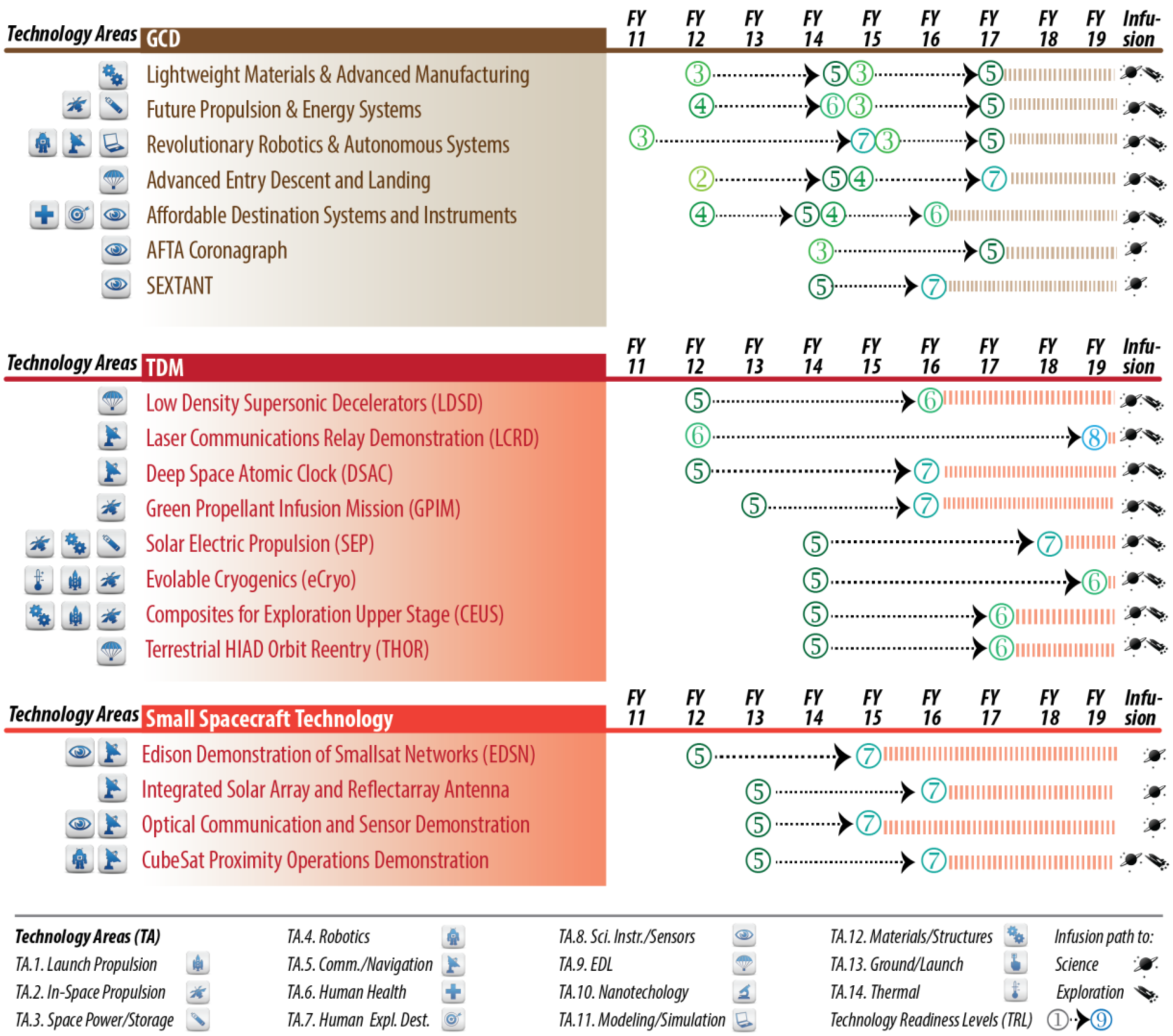
INDEPENDENT REVIEWS

Space Technology conducts Directorate Program Management Council reviews, and representatives from the Office of Chief Engineer, the Office of Safety and Mission Assurance, and the Office of Chief Financial Officer will assess performance during Agency-level Baseline Performance Reviews.

SPACE TECHNOLOGY RESEARCH & 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.



HUMAN EXPLORATION AND OPERATIONS

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Exploration	4113.2	4356.7	**4505.9**	4455.9	4297.7	4263.7	4204.3
Space Operations	3774.0	3827.8	**4003.7**	4217.5	4505.9	4671.8	4865.4
Total Budget	**7887.2**	**8184.5**	**8509.6**	**8673.4**	**8803.6**	**8935.5**	**9069.7**
Change from FY 2015			**325.1**				
Percentage change from FY 2015			**3.8%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

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NASA is working to expand human presence into the solar system, including eventually to the surface of Mars. The first steps to human deep-space exploration are well underway, with research into long-duration spaceflight continuing aboard the International Space Station (ISS), and the successful flight test of NASA's next generation crew vehicle, Orion.

To enable this effort, NASA has shifted to a new paradigm for access to low Earth orbit by engaging US commercial providers. To date, Space Exploration Technologies Company (SpaceX) and Orbital Sciences Corporation (Orbital) have flown a combined total of eight successful cargo delivery flights to ISS, including their two demonstration flights. By having two commercial partners for cargo, NASA minimized the impacts from the Orb-3 mission mishap. ISS was able to absorb the loss of the Orbital Cargo Resupply mission 3 vehicle without any immediate impacts to ISS operations and utilization. The lost cargo was not irreplaceable, but will need to be re-flown over the next couple of years. The SpX-5 flight which launched in January flew some replacement hardware lost on Orb-3. This hardware was necessary for the revised increment plan, and to provide consumables to adjust logistics stored on-board. ISS's ability to tolerate this loss was the direct result of planning by the ISS team, the structure of the program that maintains margin for crew, maintenance and utilization equipment, and the commercial approach that has resulted in multiple providers for cargo transportation services. NASA has also entered into contracts with two industry partners to develop a US commercial capability to transport crew to and from the station; building on the successful cargo transportation model.

Exploring deep space requires the capability to transport crew and large masses of cargo beyond low Earth orbit. To accomplish this, NASA is developing a crew capsule, a heavy-lift launch vehicle, and supporting ground facilities and systems. The Space Launch System (SLS) leverages NASA heritage systems, therefore reducing risk. The Orion crew capsule 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.

Before we can use these systems to send humans safely into deep space for extended missions, we must also complete the vital human health research already in work, develop key technologies, and enhance the supporting capabilities that NASA requires for mission success. The Human Exploration and Operations

Mission Directorate (HEOMD) budget funds near-term objectives with a portfolio of development and operational programs to extend the boundaries of human space exploration and generate new scientific and technical knowledge. HEOMD utilizes a mix of government-led contracts, milestone-based private-sector agreements, and international and US commercial partnerships.

Capability Driven Exploration: Enabling Multiple Destinations

Unlike previous human spaceflight missions driven by a specific destination, NASA's current mission is to develop the capability for people to live and work safely beyond the Earth for extended periods of time. In this new era, NASA is implementing a multiple destination exploration strategy, using a capability driven approach. This strategy leverages compelling near-term mission opportunities that enable incremental buildup of capabilities for more complex missions in the future, such as exploring Mars and its moons.

The cornerstone of our current efforts is the ISS, which has provided opportunities to explore the future of human spaceflight. What capabilities do we need for long-duration missions? What effects does the harsh environment of space have on the crew? How can we maximize the crew’s health and performance on future deep-space missions? Research continues on the ISS to answer these questions and to validate exploration capabilities in an in-space environment, while maintaining reliance on the station's proximity to Earth.

To advance our ability to conduct a sustainable campaign of progressively more complex exploration missions, NASA will exploit the opportunities afforded by other locations such as cis-lunar space. From the volume of space around the Earth-Moon system, we can establish a proving ground to validate new technologies, hardware and operations in deep space and microgravity environments. There, crews can assess mitigation techniques for health and performance, perform test operations of Space Launch System and Orion, and demonstrate prototype systems.

As NASA incrementally lessens human reliance on Earth, cis-lunar space will provide a location from which we can mount missions to the more distant reaches of space, including expeditions to Mars. The distance and duration of these future missions requires that crew and transportation systems be completely independent of Earth. Logistics, power and propulsion systems, human factors, habitat, and operations, all these factors must be capable of supporting the autonomous operations necessary to travel millions of miles and spend many months in space. Our strategy is to move from Earth-reliant research and technology development to the proving ground of cis-lunar space to achieve Earth-independent exploration capability for human mission durations that enable us to reach Mars and other destinations in the solar system.

Earth Reliant Activity

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 capabilities required for future long-duration missions. NASA is making technological advances aboard ISS in autonomous rendezvous and docking, advanced communications systems, human health and behavior in space, habitat and space suit systems, as well as basic research in biological and physical sciences. NASA has partnered with the Center for the Advancement of Science in Space (CASIS) to exploit the National Lab portion of the ISS for commercial and other government agency research, allowing researchers and entrepreneurs representing a wide range of disciplines to develop groundbreaking technologies and products in a microgravity environment.

HUMAN EXPLORATION AND OPERATIONS

NASA and the US 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 US commercial industry now providing cargo resupply services to the ISS, NASA is funding development activities for commercial crew systems. As with cargo, the Agency will purchase commercial crew transportation services.

Proving Ground Activity

As part of extensive development efforts, NASA successfully completed the Orion crew capsule’s initial flight test on December 5, 2014; when an uncrewed Orion vehicle launched from Cape Canaveral atop a Delta IV Heavy launch vehicle. The test flight checked aerodynamic and thermal performance, structure, and systems during a four-hour, two-orbit flight 3,600 miles above the Earth. The environment experienced in orbit and during reentry were close to those we will encounter returning from missions beyond low Earth orbit. NASA is working toward a capability to launch the first Exploration Mission (EM-1) 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 (EM-2) is scheduled to launch in FY 2021-2022.

To travel beyond low Earth orbit, NASA requires enhanced research and technological capabilities; 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 being infused into systems and capabilities geared toward supporting eventual missions to Mars including solar electric propulsion systems, deep space habitation systems, in-situ resource utilization, and operations with reduced logistics capability. The demands of deep space require assuring robust communications and data download, while maintaining reliable and affordable access to space. These efforts, conducted in the proving ground, continue to be critical priorities within HEO's Space Operations and Exploration budgets, and will enable NASA to extend our progress along the capability driven framework.

Earth-Independent Activity

To enable space travel that is Earth independent, NASA will continue to incrementally and progressively expand capabilities and distance from Earth. We will need to complete development of entry and landing systems, partial-gravity countermeasures, and long-duration surface systems such as in-situ resource utilization (ISRU) and fission surface power. Activities are underway for concept development in coordination with the Science Mission Directorate and the Space Technology Mission Directorate. For example, the HEO and the Space Technology Mission Directorates are jointly funding the Mars Oxygen ISRU Experiment (MOXIE) on the Science Mission Directorate’s Mars 2020 rover mission, which will produce oxygen from Martian atmospheric carbon dioxide.

EXPLORATION

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Exploration Systems Development	3115.2	3245.3	**2862.9**	2895.7	2971.7	3096.2	3127.1
Commercial Spaceflight	696.0	805.0	**1243.8**	1184.8	731.9	173.1	1.1
Exploration Research and Development	302.0	306.4	**399.2**	401.7	595.1	995.4	1077.2
Total Budget	**4113.2**	**4356.7**	**4505.9**	**4482.2**	**4298.7**	**4264.7**	**4205.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

EXPLORATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Exploration Systems Development	3115.2	3245.3	**2862.9**	2895.7	2971.7	3096.2	3127.1
Commercial Spaceflight	696.0	805.0	**1243.8**	1184.8	731.9	173.1	1.1
Exploration Research and Development	302.0	306.4	**399.2**	401.7	595.1	995.4	1077.2
Total Budget	**4113.2**	**4356.7**	**4505.9**	**4482.2**	**4298.7**	**4264.7**	**4205.4**
Change from FY 2015			**149.2**				
Percentage change from FY 2015			**3.4%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

NASA's Orion spacecraft looks back at Earth, through the lens of an onboard camera during its unpiloted flight test in orbit, Dec. 5, 2014.

As NASA shapes the future of human space exploration, the Agency has developed a sustainable, pioneering approach of progressively expanding capabilities and distance with an objective of extending human presence into the solar system, ultimately in ways that are more sustainable and even indefinite. 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 space flight program, partnering with the commercial space industry for human access to low Earth orbit and the International Space Station (ISS) to bolster American leadership, while using the ISS as a research testbed for long-duration space flight. 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, building the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, including missions to visit an asteroid and eventually Mars. The first foundational elements, including Orion, Space Launch System (SLS), and Exploration Ground Systems (EGS), will take us to the proving ground of cis-lunar space (the volume of space around the Moon) to conduct deep space long long-duration missions and operations testing for further exploration. At the same time, the Commercial Crew Program (CCP) aims to partner with American industry to build a US capability as well as 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 the ISS, building on the successful approach demonstrated for cargo resupply services.

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 crewed spacecraft. NASA must understand and mitigate the effects of long-term human exposure to space, and the Human Research Program (HRP) is conducting research on the ISS toward this end. NASA's Advanced Exploration Systems (AES) is also developing the technologies and maturing systems required for the deep space missions that astronauts will conduct in the Orion crew vehicle. NASA's long-term human space flight goals can only be accomplished with systems and technologies not yet developed. This research and development 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 2016

EGS will complete the planned System Integration Review (SIR) and Key Decision Point (KDP)-D that will evaluate EGS readiness to move from final design and fabrication phase to system assembly, integration and test, launch, and checkout.

To align upcoming HEO exploration and technology activities, the associated budgets have been established in AES, enabling effective coordination between research and technology capabilities required to support robotic, extravehicular activities, Asteroid Redirect Mission (ARM), and future exploration missions. Establishing ARM content under AES aligns key technologies and capabilities for future exploration missions.

ACHIEVEMENTS IN FY 2014

NASA engaged in rigorous testing of the Orion spacecraft leading up to the FY 2015 launch of Exploration Flight Test 1 (EFT-1), including parachute drop testing, water recovery evaluations, structural testing, crew module space environment testing, and spacecraft adapter fairing separation tests.

SLS performed a wide range of key hardware tests, including wind tunnel testing, core stage flight computer testing, and acoustic model testing. Vertical assembly center tool activation and test welds to support SLS fabrication took place, using half the labor needed to produce Space Shuttle external tanks. In addition, the first piece of SLS flight hardware, the Orion stage adapter, was completed for use on EFT-1. Traveling into deep space for extended periods of time requires a rocket with demonstrated cutting-edge technologies that can launch the payloads necessary to mount complex missions, and include an upper stage to provide additional power to reach deep space with large payload masses and volumes. As these achievements demonstrate, NASA's evolvable SLS development is well underway.

As the next generation of human space exploration vehicles are readied for flight, ground systems updates are key to supporting them. EGS worked with the US Navy to complete testing of the processes and equipment to recover Orion from the ocean after reentry. EGS began major launch pad enhancements as well as to the mobile launcher and vertical stacking facilities to accommodate the new flight hardware.

The commercial space industry continues to move forward to provide safe, reliable, and affordable crew transportation to low Earth orbit. The Agency's industry partners have worked successfully throughout the year to complete their contracted Commercial Crew integrated Capability (CCiCap) contract milestones, leading to production of a viable space transportation system that will reduce our reliance on foreign providers. For example, Boeing completed all of their CCP milestones, including an integrated vehicle wind tunnel test. SpaceX completed 11 of 15 milestones including a pad abort test plan review. Sierra Nevada completed 9 of 11 milestones including an initial integrated systems safety analysis. NASA awarded Commercial Crew transportation Capabilities (CCtCap) contracts to Boeing and SpaceX on September 16, 2014. NASA and Blue Origin included additional unfunded milestones in their Commercial Crew Development Round 2 (CCDev2) Space Act Agreement, allowing continuation of efforts on Blue Origin's crew transportation system.

HRP researched and developed requirements for radiation shielding technologies, monitoring and alert systems, biomedical screening, and optimal mission architectures as part of an integrated protection system. Utilizing ISS and ground-based facilities, HRP expanded research and facilitated development related to deep space habitat systems, exploration medical technologies, advanced space suit design, and a myriad of other activities. Advancing these technologies are required to travel for extended periods in the harsh environment of space. Space flight exposes astronauts to a host of risks, from radiation exposure, to physical changes, to psychological stresses. HRP works to understand and mitigate those risks to maximize crew health and performance.

During the year, AES activities included demonstrations of a precision landing and hazard avoidance system using laser sensors. To minimize upmass required on crewed asteroid missions, AES modified the existing crew pressure suits worn during launch and landing to enable their use for extravehicular activities and conducted pre-formulation activities for ARM. Research and technology activities such as these are aimed at expanding our technical and scientific knowledge to meet the demands of long-duration flight into deep space. This work is critical to extending human presence in the solar system.

WORK IN PROGRESS IN FY 2015

In December 2014, Orion successfully completed launch, landing, and recovery of EFT-1, reaching an altitude more than 3,600 miles above Earth's surface, roughly 15 times farther into space than the orbit of ISS. EFT-1 exposed the Orion heat shield to temperatures close to 80% of what it will endure returning from the vicinity of the Moon. This first successful test flight also allows NASA to refine coordination processes with the space network that provided critical communication and tracking services. The test flight data will help NASA to understand better many of the top risks to astronauts who will fly on Exploration Mission (EM)-2 and future missions.

Orion will continue design, development, and testing, focusing on EM-1 and EM-2. NASA continues working toward a capability to launch 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. 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. NASA has established launch capability readiness dates for SLS and EGS as shown below, and will do so for Orion as a product of its Key Decision Point-C review this spring. An integrated EM-1 launch date will be determined once the SLS, EGS, and Orion have completed their respective Critical Design Reviews.

EGS will continue progress on ground support systems, completing CDR, software upgrades, Vehicle Assembly Building (VAB) adjustable high-bay platform construction, mobile launcher, pad, and crawler transporter modifications.

Commercial Crew industry teams will complete remaining (CCiCap) milestones and achieve significant milestones as part of their CCtCap contract(s). Boeing and Space X both completed their first milestones under CCtCap Certification Baseline Reviews. These milestones will demonstrate that commercial providers are continuing to mature their capabilities towards NASA's goal of launching astronauts once again to ISS from US soil.

HRP will use the one-year mission of astronaut Scott Kelly and cosmonaut Mikhail Kornienko to the ISS to implement biomedical research that 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.

AES activities will continue to support the Bigelow Expandable Activity Module, scheduled to arrive at ISS in 2015 aboard a SpaceX commercial cargo resupply flight. This module will test inflatable structures technology for a deep space habitat on long-duration human missions beyond Orion's 21-day capability.

In support of additional next generation habitat modules for long-term missions, AES will collaborate with ISS and Exploration Systems Development and to enter into public-private partnerships under the NextSTEP Broad Area Announcements that pursue promising areas to enable habitat capabilities.

STMD, in coordination with ARM and ISRS, will begin long lead component acquisitions for solar electric propulsion (SEP) technology demonstration. The Agency will complete the robotic mission capture option down-select in January 2015 and the Robotic Mission Concept Review in Spring 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Orion, SLS, and EGS will continue to focus on preparing for the EM-1 mission, the first pairing of Orion and SLS. This 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 finalize EM-1 design and development engineering; complete the structural build; begin assembly, integration, and testing of the EM-1 crew module; and complete the parachute development test campaign. EGS will be finalizing efforts in the VAB, the launch pad, and other ground support systems to ensure readiness for EM-1 support. SLS will prepare for final major element tests and hardware production for EM-1, and ship hardware for integration and testing, including testing conducted by Rocket Propulsion Testing (RPT).

Commercial crew industry CCtCap teams will accomplish significant milestones under their contracts, such as Boeing's Integrated Parachute System Drop Tests and service module hot fire launch abort test and SpaceX's plans for uncrewed flight to ISS and Launch Site Operational Readiness Review.

HRP will continue research progress in support of long-duration health of the crew and risk mitigations, including a lighting countermeasure to help ISS crewmembers improve sleep and enhance performance, an ultrasound tool to monitor changes in lumbar and cervical spine, and a tool to detect kidney stones and provide treatment. This technology could change kidney stone treatment on Earth, enabling removal of a kidney stone during the first office visit.

EXPLORATION

As NASA works to extend human space exploration beyond low Earth orbit, AES will continue to develop in-space manufacturing technology, reliable life support, habitation technology, crew mobility systems, advanced in-space propulsion, and advanced space suits, leading to an ISS flight demonstration of new space suit capabilities as early as 2021. ARM will progress towards System Design Review (SDR) for the robotic mission, and leverage development of synergistic capabilities for In-Space Robotic Servicing (ISRS), such as automated rendezvous and docking sensors.

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 CREW PROGRAM

The Commercial Crew Program partners with the US private sector to develop and operate a safe, reliable, and affordable crew transportation capability 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 ISS. This innovative commercial approach will bolster American leadership, end US reliance on foreign providers for crew transportation, and stimulate the American commercialization of a necessary space transportation industry. Competition, a key to controlling costs over the long term and providing for a safe vehicle, remains an important component of the commercial crew program.

EXPLORATION RESEARCH AND DEVELOPMENT

Exploration Research and Development consists of two programs, HRP and AES, which map directly to the US Space Exploration Policy and the NASA Authorization Act of 2010. 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, ISS, and analog environments to research issues and develop countermeasures for future missions to deep space destinations, including Mars. AES 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 planned to be advanced through NASA's planned ARM.

ORION PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Crew Vehicle Development	1165.8	--	**1085.8**	1109.3	1112.4	1116.2	1127.5
Orion Program Integration and Support	31.2	--	**10.5**	10.5	10.5	10.5	10.5
Total Budget	**1197.0**	**1194.0**	**1096.3**	**1119.8**	**1122.9**	**1126.7**	**1138.0**
Change from FY 2015			**-97.7**				
Percentage change from FY 2015			**-8.2%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

NASA's Orion spacecraft sits on the pad atop a Delta IV Heavy rocket prior to the December 5th launch of Exploration Flight Test-1 from Kennedy Space Center. The two orbit flight sent Orion 3,600 miles into space – farther than any human space flight vehicle since the Apollo 17 mission in 1972.

With the successful completion of EFT-1 in December 2014, Orion has taken a major step toward transporting humans to deep space and back. The first of two uncrewed launches for the Orion spacecraft, EFT-1 is paving the way for astronauts to venture beyond low Earth orbit for the first time since the Apollo program in the 1960s and early 1970s.

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. Orion's launch abort system can activate within milliseconds to carry the crew from harm's way and position the module for a safe landing. The spacecraft's propulsion, thermal protection, avionics, and life support systems will enable 21- day missions with four crew. Its modular design will be capable of integrating additional new technical innovations as they become available.

After Orion's second uncrewed test flight, EM-1, the spacecraft will be ready to carry crew in FY 2021-2022. Orion will conduct the crewed rendezvous portion of the proposed ARM, which will find, capture, redirect, and sample 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.

ORION PROGRAM

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

Program Elements

ORION PROGRAM INTEGRATION AND SUPPORT

Orion program integration and support activities manage the SLS and Exploration Ground Systems (EGS) program interfaces. This effort is critical to ensuring that Orion's performance meets technical and safety specifications, and supports programmatic assessments key to achieving integrated technical, cost, and schedule management. In addition, the Orion 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. Coordination and timely integration across the three programs enables the Agency to avoid potential design overlaps schedule disconnects, and cost issues.

CREW VEHICLE DEVELOPMENT

See the Crew Vehicle Development Section.

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	1165.8	--	1085.8	1109.3	1112.4	1116.2	1127.5

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

Following more than four and half hours in orbit and travelling 3,600 miles above Earth to test systems critical to human deep space exploration, NASA's Orion spacecraft descends gently to the Pacific Ocean under three massive red and white main parachutes. After reentering the Earth's atmosphere at 20.000 miles per hour, splashdown in the Pacific Ocean occurred at 11:29 am ET on December 5th, at a speed of less than 20 miles per hour.

PROJECT PURPOSE

As NASA reaches beyond low Earth orbit to destinations across the solar system, the Orion crew vehicle took its first steps toward deep space with the launch of EFT-1. In the future, Orion will be capable of transporting humans to multiple destinations beyond our moon and into deep space, sustain them longer than ever before, and return them safely to Earth. Drawing from more than 50 years of human space flight R&D, Orion's design will meet the evolving needs of our nation's space program, and push the envelope of human exploration for decades to come.

For further programmatic information, go to: http://www.nasa.gov/orion.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

PROJECT PRELIMINARY PARAMETERS

Orion will be able to carry a crew of four astronauts beyond Earth orbit and provide habitation and life support for up to 21 days. The spacecraft's three components include the crew module, service module, and launch abort system, with a separate adapter to connect the spacecraft and launch vehicles. The 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 orbit. The service module is comprised of a crew module adapter and the ESA-

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

designed and developed service module section, and together they provide in-space power, propulsion, and other life 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. The abort system also provides a protective shell that shields the crew module from dangerous atmospheric loads and heating during ascent. Once Orion is out of the atmosphere and safely on its way to orbit, the spacecraft will jettison the system.

ACHIEVEMENTS IN FY 2014

FY 2014 saw the completion of the manufacturing of the EFT-1 spacecraft and subsequent successful flight test on December 5, 2014. Major assembly and test activities throughout 2014 contributed to this accomplishment. The spacecraft and avionics came to life with the initial power on, followed by extensive testing to ensure that components functioned properly. Delivery and installation of Orion's heat shield, the largest of its kind ever built, was also a major milestone. In addition, the crew and service modules were completed and mated, and were mounted to the spacecraft adapter. During this same time, the Delta IV Heavy launch vehicle was delivered and prepared for flight.

In parallel with the work associated with the EFT-1 mission, Orion's progress continued toward the first two Exploration Mission (EM-1 and EM-2) integrated flights with SLS. The program successfully completed its delta PDR, which was an update to the original design review and determined that the current design meets all system requirements with acceptable risk, and was within cost and schedule constraints. Orion began manufacturing components for EM-1, forging elements for the primary structure, building avionics kits, and procuring long-lead parts.

At facilities across the country, Orion also continued extensive ground testing. This included parachute drop testing, water recovery evaluations, structural testing, crew module space environment testing, and spacecraft adapter fairing separation tests.

NASA and ESA continued their ongoing partnership with progress on design and integration of the ESA-provided service module for the EM-1 spacecraft. The PDR board, consisting of NASA and ESA members, endorsed proceeding to the next project phase.

WORK IN PROGRESS IN FY 2015

The Orion program will continue to analyze data collected from EFT-1, which met all test objectives and demonstrated design and performance of the heat shield, parachute system, launch abort system jettison, and many other systems. During EFT-1, Orion orbited Earth twice, reaching an altitude of approximately 3,600 miles, roughly 15 times farther into space than the orbit of the ISS. Having sent Orion to such a high altitude allowed the spacecraft to return to Earth at speeds near 20,000 miles per hour. The spacecraft's return at this speed exposed the heat shield to temperatures close to 80 percent of what it will endure when returning from the vicinity of the Moon.

While extensive ground testing of Orion hardware is ongoing, it is challenging to duplicate the realities of the space environment on Earth. The data collected and analyzed from the test flight will enable increased efficiencies and reduced risk for future missions. Orion's first flight also allows NASA to refine

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

production and coordination processes with SLS, EGS, and Space Communication and Navigation, whose space network provides communication and tracking services. The test flight data will help NASA better understand many of the top risks to astronauts who will fly on EM-2 and future missions.

With completion of the first flight test, Orion will continue design, development, and testing, maintaining the shift in focus to EM-1 and EM-2 that started in 2014. Structural component manufacturing and assembly, which began the previous year, will continue, as well as building avionics kits, developing software, and procuring parts with long-lead time. The program will focus on a testing campaign to validate capabilities and increase confidence in the hardware needed in a deep space environment and required to return astronauts home safely. Orion will also upgrade its ground test article in support of the next phase of water impact testing at the LaRC hydro impact basin.

The program will continue to support ESA work on Orion service module design and testing. ESA will also begin manufacturing the service module for EM-1, starting with structural components, tubing, and tanks.

Finally, the program will complete key programmatic reviews, ensuring Orion's readiness to progress to the next phase of the development life cycle.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the program will continue to focus on preparing for Orion's EM-1 mission, an uncrewed test flight to distant retrograde lunar orbit, and the first pairing with SLS. This multi-day flight will provide the program with data, which, combined with data gained from EFT-1, will validate spacecraft design and operations. During FY 2016, Orion will finalize EM-1 design and development engineering; complete the structural build; and begin assembly, integration, and testing of the EM-1 crew module. Orion will also begin assembly, integration, and testing of the structural test article, which will go through a series of environmental tests at NASA's Plum Brook Station, to ensure that the design is capable of withstanding the harsh environment of space.

The program is implementing a plan that accelerates the manufacturing of the structural test article, which will now directly follow completion of the EM-1 crew module build, creating a more efficient manufacturing and assembly strategy. This acceleration also enables reuse of Orion's components, reducing the program's overall life cycle costs. In addition to structural testing, Orion will complete qualification testing on hardware flying on EM-1 and continue motor qualification testing of the launch abort system in support of crewed flights. FY 2016 will also mark the completion of the parachute development test campaign, previously planned for completion at the end of FY 2015. The program will then begin parachute qualification testing to support crewed flights.

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

ESTIMATED PROJECT SCHEDULE

Milestone	Formulation Authorization Document	FY 2016 PB Request
SRR		Mar 2007
SDR		Aug 2007
PDR		Aug 2009
KDP-A, Formulation Authorization	Feb 2012	Feb 2012
Resynchronization Review		Jul 2012
KDP-B	Q1 FY 2013	Jan 2013
Delta PDR	Q4 FY 2013	Aug 2014
EFT-1 Launch		Dec 2014
KDP-C, Project Confirmation	FY 2015	Q3 FY 2015
CDR		Q1 FY 2016
EM-1 Launch		Integrated Launch Date to be determined in December 2015
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 are 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	FY 2021 – 2022

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

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 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	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	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 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 meet flight test objectives to identify gaps and risks, and assess and reduce risk to flight hardware.
If: Mission loads and thermal strain incompatibility between Avcoat ablator and heat shield structure create an unacceptable level of ablator cracking or delamination, Then: A new heat shield architecture may be required.	Orion will continue to evaluate contributors to Avcoat cracking on the EFT-1 heat shield and perform trade studies, development tests, and analyses to evaluate a heat shield design that will reduce cracking and satisfy EM design and performance requirements.

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

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 has definitized a contract modification 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 EM-1. Incorporating the partnership with ESA also required a contract modification with Lockheed Martin to integrate the ESA-provided service module with the Lockheed Martin portion of the spacecraft.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Orion Design and Development	Lockheed Martin	Littleton, CO

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
SRR	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

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
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
PDR	SRB	Sep 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

CREW VEHICLE DEVELOPMENT

Formulation	Development	Operations

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Resynchron-ization Review	SRB	Jul 2012	Realigns 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 PDR if a significant divergence occurs	Program cleared to proceed to next phase	N/A
Delta PDR	SRB	Aug 2014	Updates the program's preliminary design ensures completeness and consistency; determines the program's readiness to proceed with the detailed design phase	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
CDR	SRB		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.		Q1 FY 2016

SPACE LAUNCH SYSTEM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Launch Vehicle Development	1557.7	1670.4	**1303.5**	1247.1	1313.9	1424.4	1436.4
SLS Program Integration and Support	42.3	--	**53.0**	96.5	93.7	92.1	95.2
Total in FY16 Budget Structure	**1600.0**	**1700.0**	**1356.5**	**1343.6**	**1407.6**	**1516.5**	**1531.6**
Programmatic CoF in CECR Account	139.3	52.3	**10.0**				
Exploration Ground Systems	318.2	351.3	**410.1**	432.3	441.2	453.0	458.0
Total in FY12 Budget Structure	**2057.5**	**2103.6**	**1776.6**	**1775.9**	**1848.8**	**1969.5**	**1989.6**
Change from FY 2015			**-343.5**				
Percentage change from FY 2015			**-20.2%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

FY 2015 SLS CoF CECR reflects FY15 President's Budget Request.

As NASA seeks to expand the boundaries of human space exploration, SLS is being readied to carry humans and equipment farther into deep space than ever before.

SLS is a critical capability for human exploration of the inner solar system. The vehicle's capabilities will evolve using a block upgrade approach, driven by near- and long-term exploration mission requirements. Initially, SLS will carry over 70 metric tons to low Earth orbit and nearly 30 metric tons to the exploration proving ground near the Moon. Follow-on upgrades, including an advanced Exploration Upper Stage (EUS) will improve vehicle lift performance to 105 metric tons to low Earth orbit and 40 metric tons to the lunar proving ground, significantly increasing mission capability. Ultimately, SLS will evolve to carry over 130 metric tons to low Earth orbit, necessary to launch the large elements needed for human exploration of Mars. NASA has begun preliminary planning for the EUS, which leverages technology investments made by the STMD in areas such as cryogenic fluid management and advanced composites. This close coordination demonstrated between STMD and HEOMD will serve as the foundation for future exploration technologies and capabilities needed to explore Mars in the 2030s.

NASA is leveraging a half-century of experience with launch vehicles like Saturn and Space Shuttle, along with advancements in technology and manufacturing practices, to build and operate SLS. The core stage needs only half the weld manufacturing labor of the Space Shuttle external tank. The Agency will continue to identify and implement affordability strategies to ensure that SLS is as cost-effective as possible.

EM-1 and EM-2 will prove system capabilities necessary for the Asteroid Redirect Robotic Mission.

For further programmatic information, go to: http://www.nasa.gov/exploration/systems/sls/index.html.

SPACE LAUNCH SYSTEM

Exploration Mission-1 flight hardware is in production at the Michoud Assembly Facility in Louisiana. Here technicians use the Vertical Weld Center to assemble barrel panels for the core stage engine section – one of five major Space Launch System sub-elements.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 request for SLS funding is as planned in the FY 2015 Budget and the SLS Preliminary Design Review and keeps the SLS EM-1 on track for a launch capability readiness date of November 2018.

Program Elements

SLS PROGRAM INTEGRATION AND SUPPORT

SLS program integration and support activities manage the Orion and EGS program interfaces. This effort is critical to ensuring that SLS systems performance meets technical and safety specifications, and supports the programmatic assessments key to achieving integrated technical, cost, and schedule management. In addition, the SLS 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. Coordination and timely integration across the three programs enables the Agency to avoid potential design overlaps, schedule disconnects, and cost issues.

LAUNCH VEHICLE DEVELOPMENT

See Launch Vehicle Development Section.

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	Notional FY 2018	Notional FY 2019	Notional FY 2020	BTC	Total
Formulation	2674.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	2674.0
Development/Implementation	21.5	1580.9	1663.2	**1303.5**	1247.1	1205.2	0.0	0.0	0.0	7021.4
Operations/Close-out	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0
2015 MPAR LCC Estimate	**2695.5**	**1580.9**	**1663.2**	**1303.5**	**1247.1**	**1205.2**	**0.0**	**0.0**	**0.0**	**9695.4**
Total Budget	**0.0**	**1557.7**	**1670.4**	**1303.5**	**1247.1**	**1313.9**	**1424.4**	**1436.4**	**0.0**	**9953.4**
Change from FY 2015				**-366.9**						
Percentage change from FY 2015				**-22.0%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

PROJECT PURPOSE

As NASA expands its focus for human space flight to destinations across the solar system, the Launch Vehicle Development project will enable deep space exploration with the Space Launch System (SLS) launch vehicle. This heavy-lift rocket will have a lift capability more than two and one 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

PROJECT PARAMETERS

Launch Vehicle Development will work to achieve cost, schedule, and performance goals by utilizing hardware designed for previous programs, including Space Shuttle main engines, Constellation five-segment solid rocket boosters, and an interim cryogenic propulsion stage, a derivative of the Delta IV cryogenic second stage. The program benefits from NASA's half-century of experience with liquid oxygen and liquid hydrogen heavy-lift vehicles, large solid rocket motors, and advances in technology and manufacturing practices.

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

In the Operations and Checkout building at KSC, technicians prepare to install Orion onto the Multi-purpose Crew Vehicle Stage Adapter (MSA), which secured the spacecraft to the Delta IV heavy cryogenic second stage for Exploration Flight Test 1, flown on December 5th. The Space Launch System (SLS) Program designed and built the MSA to attach the Orion spacecraft to the SLS interim cryogenic propulsion stage for Exploration Mission-1.

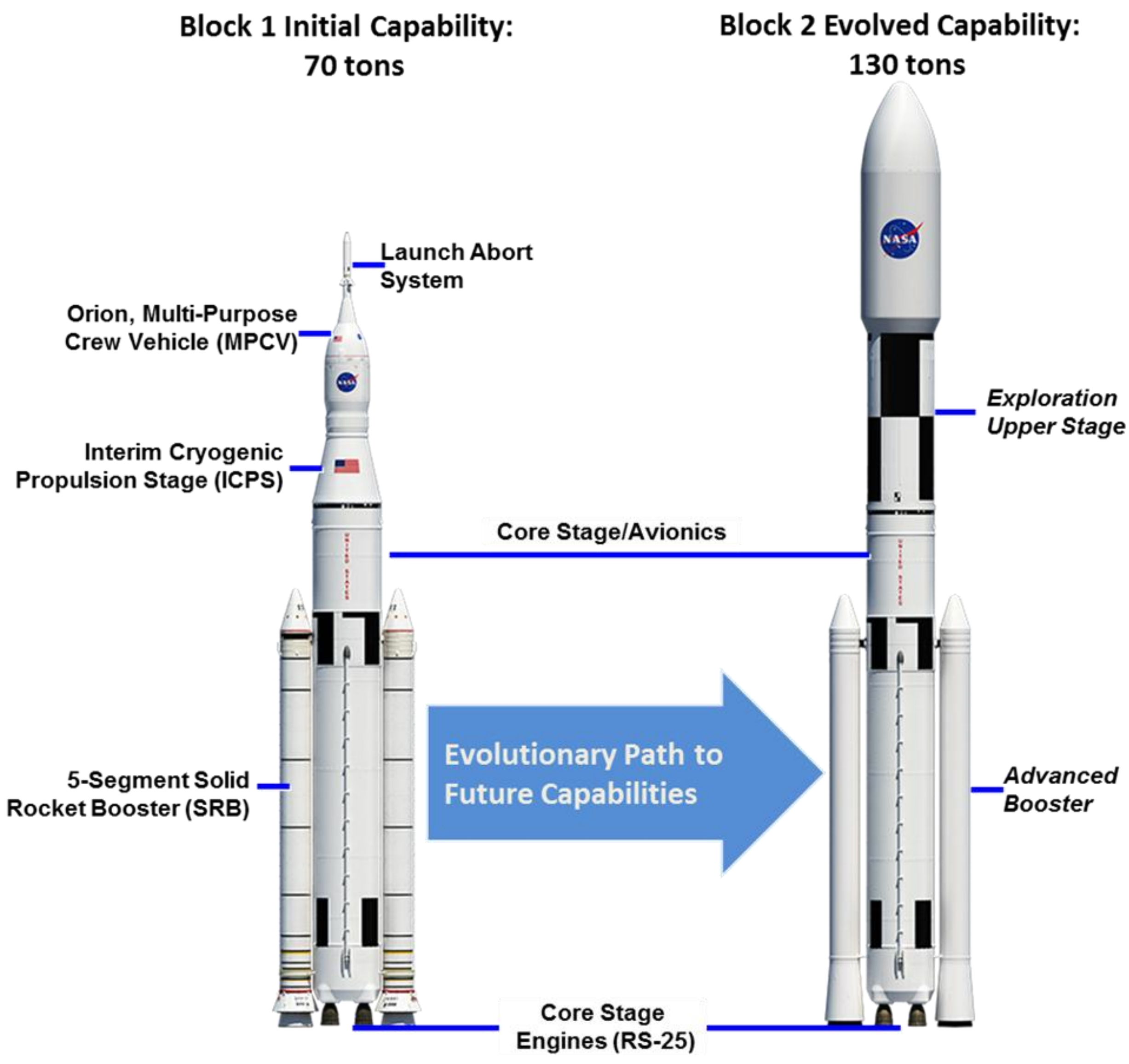
SLS vehicle design will be flexible and evolvable, based on mission requirements. In an effort to achieve schedule and cost efficiencies, each evolution shares the same core stage to accommodate both crew and cargo requirements as needed. SLS will provide unique capabilities for human exploration beyond low Earth orbit, including travel to asteroids, Mars, and other destinations in the solar system.

Initially, SLS will achieve a 70-metric ton lift capability to low Earth orbit, and nearly 30 metric tons to an exploration proving ground near the Moon. Follow-on upgrades, including an advanced EUS, will improve vehicle lift performance to 105 metric tons to low Earth orbit and 40 metric tons to cis-lunar space, where NASA will demonstrate deep space technologies and hardware needed for future missions, independent of Earth. Ultimately, SLS will be evolved to carry over 130 metric tons to low Earth orbit.

NASA has begun preliminary planning for the EUS, which leverages technology investments made by the Space Technology Mission Directorate (STMD) in areas such as cryogenic fluid management and advanced composites. This close coordination demonstrated between STMD and HEOMD will serve as the foundation for future exploration technologies and capabilities needed to explore Mars in the 2030s.

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations



ACHIEVEMENTS IN FY 2014

SLS is on track to provide all EM-1 flight hardware to KSC and support an EM-1 launch capability readiness date of no later than November 2018. With the conclusion of negotiations for the stages and Interim Cryogenic Propulsion Stage (ICPS) contracts in June and October, respectively, all major Block 1 elements are now on contract. For the SLS “Block 1” configuration flying on EM-1, the program successfully cleared the Agency’s KDP-C milestone in August, marking the transition from program formulation into development. Both the core stage and booster elements completed CDRs in July and August, respectively, keeping the program on track for the program-level CDR in FY 2015. Across

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

NASA, a wide range of key hardware tests supports preparation for next year's CDR, including the final buffet wind tunnel test at LaRC and core stage flight computer testing and acoustic model testing during launch at MSFC. In addition, EM-1 test and flight hardware production is underway.

Vertical Assembly Center (VAC) tool activation at the Michoud Assembly Facility (MAF) in Louisiana occurred in July, and the first full-duration test weld took place in September. The VAC is the final of six major weld tools at MAF that will produce the SLS core stage structure, using less than half the labor required to produce Space Shuttle external tanks. Other major SLS facility work in 2014 includes new structural test stands at MSFC, which broke ground in August. The completion of the first SLS flight hardware, the Orion stage adapter, in May 2014 was an integral element to the success of EFT-1 in December.

WORK IN PROGRESS IN FY 2015

SLS will conduct the program-level CDR to evaluate final designs of the integrated launch system. 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.

In support of EM-1, the project will complete assembly and test of the first flight RS-25 engine, initiate booster avionics fabrication and test, conduct booster qualification motor-1 testing, and begin developing the new booster thrust vector control assembly.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Plans include preparation for the final set of major SLS element tests and flight hardware production for EM-1.

At MAF, all five SLS core stage components (forward skirt, liquid oxygen tank, intertank, liquid hydrogen tank, and engine section) arrive at the final assembly area for integration, which also includes installation of the four RS-25 core stage engines. The completed core stage will be ready for shipment to NASA's SSC for the start of integrated core stage test firing. Test stand B-2 at SSC will be activated and ready to receive the core stage. EM-1 flight booster motor casting will also be underway. ICPS structural test article delivery is scheduled, and the flight article for EM-1 will be in production. The flight articles for the launch vehicle stage adapter and Orion vehicle stage adapter will also be in production. Testing of the second full booster qualification motor will certify EM-1 booster hardware.

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-A	Nov 2011	Nov 2011
Formulation Authorization	May 2012	May 2012
SRR/SDR	May 2012	May 2012
KDP-B Agency Project Management Council (APMC)	Jul 2012	Jul 2012
PDR Board	June 2013	Jun 2013
KDP-C APMC	Jan 2014	Jan 2014
CDR Board	Jul 2015	Jul 2015
KDP-D	Under Review	Under Review
EM-1 Launch Capability Readiness	Nov 2018	Nov 2018

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	7,021.4	70	2015	7,021.4	0.0	EM-1 Capability Readiness	Nov 2018	Nov 2018	N/A

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

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**7,021.4**	**7,021.4**	**N/A**
Stages	3,138.7	3,138.7	N/A
Engines	1,198.3	1,198.3	N/A
Booster	1,090.3	1,090.3	N/A
Other	1,594.2	1,594.2	N/A

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 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, including core and upper stages, liquid engine and avionics integration	Provider: MSFC Lead Center: MSFC Performing Center(s): MSFC, SSC, and KSC Cost Share Partner(s): N/A	None
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

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

Project Risks

Risk Statement	Mitigation
If: For the SLS boosters, small voids seen between the motor propellant and booster liner in early qualification motor aft segments are not addressed, Then: The delay in two booster qualification motor tests could affect the EM-1 launch capability readiness date of November 2018.	SLS is building several motor test articles and full process simulation segments for testing to analyze the potential safety impacts of voids for both qualification and flight motors. Tests and analyses to date suggest that the program understands the complex chemical and manufacturing interactions between the new booster liner and propellant. Validation will come with the qualification motor 1 (QM-1) test firing planned in FY 2015.
If: The delivery of the core stage is delayed beyond June 2018, Then: The delay could affect the EM-1 launch capability readiness date of November 2018.	Following completion of the stages contract definitization in June 2014, NASA and Boeing are establishing development and manufacturing and testing schedules necessary to support EM-1 launch capability readiness, taking into account SLS program verification and validation requirements as well as available resources.

Acquisition Strategy

MAJOR CONTRACTS/AWARDS

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. NASA awarded the stages contract to Boeing in June 2014.

Element	Vendor	Location (of work performance)
Boosters	Alliant Techsystems, Inc.	Magna, UT
Core Stage Engine	Aerojet – Rocketdyne	Desoto Park, CA
Interim Cryogenic Propulsion Stage	Boeing Aerospace	Huntsville, AL
Stages	Boeing Aerospace	Huntsville, AL

LAUNCH VEHICLE DEVELOPMENT

Formulation	Development	Operations

INDEPENDENT REVIEWS

NASA established an SRB to perform the independent reviews of the Space Launch Vehicle project as required by NPR 7120.5.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
SRR/SDR	SRB	Jun 2012	The purpose of the SRR is to evaluate whether the functional and performance requirements, defined for the system, are responsive to program requirements on the project and represent achievable capabilities. 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. The review determines whether the project's maturity of mission/system definition and associated plans are sufficient to begin Phase B. The SLS program combined the SRR and SDR into a single KDP-B review, as allowed by NASA NPR 7120.5.	The SRB found the SLS 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. The review determines if the design is appropriately mature to continue with the final design and fabrication phase.	TBD	Q4 FY 2015

EXPLORATION GROUND SYSTEMS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**318.2**	**351.3**	**410.1**	**432.3**	**441.2**	**453.0**	**457.5**
Change from FY 2015			**58.8**				
Percentage change from FY 2015			**16.7%**				

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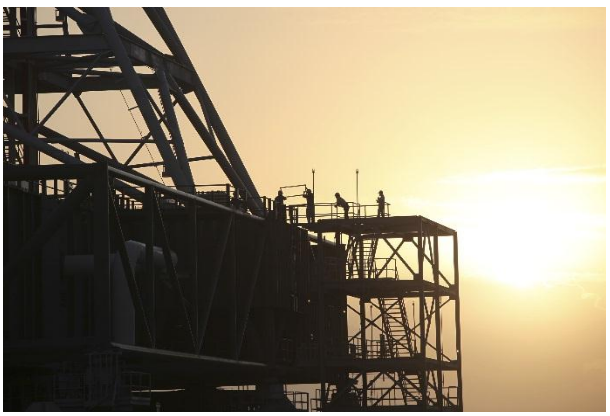


Crews at Kennedy Space Center perform modifications to the Mobile Launcher to accommodate the weight, size, and thrust of NASA's new Space Launch System and Orion crew vehicle. The upgraded launcher will carry the stacked rocket and crew vehicle to Launch Pad 39B for Exploration Mission-1 later this decade.

The Exploration Ground Systems (EGS) program enables integration and launch of the Space Launch System (SLS) and Orion Vehicle. EGS is making required facility and ground support equipment modifications at the Kennedy Space Center (KSC) to enable assembly, test, launch, and recovery of the SLS and Orion flight elements. EGS is also modernizing communication and control systems to support these activities. Upon completion, the KSC launch site will be able to provide a more flexible, affordable, and responsive national launch capability. The beneficiaries are current and future NASA programs including Orion, SLS, and additional customers such as US government agencies and commercial industry.

For further programmatic information, go to http://go.nasa.gov/groundsystems.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

EXPLORATION GROUND SYSTEMS

Program Elements

EGS PROGRAM INTEGRATION AND SUPPORT

EGS program integration and support activities manage the SLS and Orion program interfaces. This effort is critical to ensuring that ground systems performance meets technical and safety specifications and supports the programmatic assessments key to achieving 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. Coordination and timely integration across the three programs enables the Agency 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

FY 2016 Budget

Budget Authority (in $ millions)	Prior	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	716.8	252.5	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	969.3
Development/Implementation	0.0	175.6	356.2	**390.9**	417.1	425.9	77.9	0.0	0.0	1843.6
Operations/Close-out	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	0.0
2015 MPAR LCC Estimate	**716.8**	**428.1**	**356.2**	**390.9**	**417.1**	**425.9**	**77.9**	**0.0**	**0.0**	**2812.9**
Total Budget	**0.0**	**315.8**	**312.9**	**390.9**	**417.1**	**425.9**	**437.7**	**442.1**	**0.0**	**2742.3**
Change from FY 2015				**78.0**						
Percentage change from FY 2015				**24.9%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

PROJECT PURPOSE

As NASA enters a new era in human space exploration, space operations at KSC are evolving to accommodate NASA's next-generation human space exploration vehicles. EGS is developing the ground systems infrastructure required to assemble, test, and launch SLS and Orion, along with recovery of Orion.

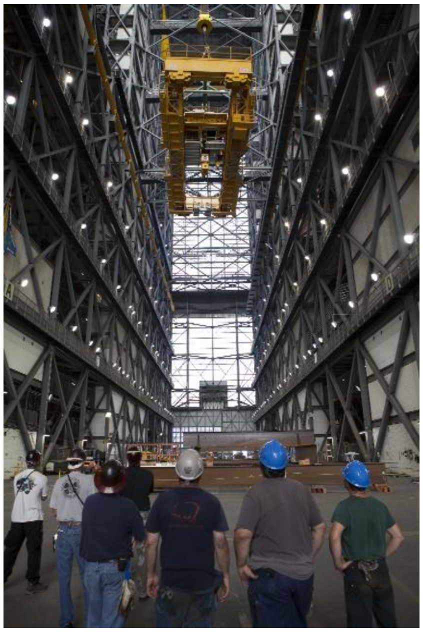
For more programmatic information, go to: http://go.nasa.gov/groundsystems.

EXPLANATION OF MAJOR CHANGES IN FY 2016

EGS will complete the planned SIR and KDP-D that will evaluate EGS readiness to move from final design and fabrication phase to system assembly, integration and test, launch, and checkout.

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations



Inside the Vehicle Assembly Building at Kennedy Space Center, the construction crew watches a 175-ton crane lowered from Level 16 to the transfer aisle floor. The Exploration Ground Systems project will upgrade the crane's 45-year-old controls to improve reliability, precision and safety. When upgrades are complete, the crane will provide lift capability for NASA and other exploration vehicles, including the Agency's Space Launch System and Orion crew vehicle.

PROJECT 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 the first two Exploration Missions, 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. Additional work required to launch astronauts into space includes modifying the mobile launcher and crawler-transporters; preparing Launch Complex 39B; and modernizing computers, tracking systems, and other networks.

ACHIEVEMENTS IN FY 2014

In support of EFT-1, EGS completed several recovery tests in 2014. As a result of these tests, the team selected a US Navy landing platform/dock well deck ship as the primary EFT-1 recovery method, and selected a salvage crane lift ship as a back-up option. EGS successfully completed PDR in January 2014 and KDP-C in May 2014, confirming that the project had achieved stable design requirements and is authorized to proceed to the next level of developmental readiness. Also in FY 2014, the team continued modernization and compatibility efforts to support the EM-1 launch with final designs, equipment fabrication, and facility construction. Major infrastructure enhancements to prepare Launch Complex 39B for the EM-1 mission and future flights include the flame trench, flame deflector, ignition overpressure, and sound suppression system, which will safely channel the extraordinary energy released by the rocket during launch away from critical systems.

In FY 2014, EGS will complete a new adjustable platform design and award the construction contract to provide ground crew access to the vehicles on the mobile launcher in the VAB where vertical stacking will occur. The team is modifying the mobile launch tower, originally designed for the Ares I rocket, to support SLS and Orion umbilical and crew access requirements. EGS also made significant progress on end-to-end spaceport command and control system applications and displays, along with transmission, imagery, and voice communication infrastructure. Integrated verification and validation activity began, to ensure mission success and seamless integration and launch site processing during EM-1.

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations

WORK IN PROGRESS IN FY 2015

EGS successfully completed the landing and recovery operations of the Orion crew module on December 5, 2014, marking the end of the first flight test. After having traveled two orbits around the Earth and 3,600 miles into space, EGS then sent Orion on a cross-country trek back to KSC for post-mission analysis.

The program will begin installing ground support equipment and complete structural and facility modifications on the mobile launcher. In the VAB, adjustable high-bay platform construction will continue, providing access levels required for SLS vehicle processing. At Launch Complex 39B, EGS will begin Pad B flame trench/flame deflector construction and complete modifications for infrastructure and propellant and gas systems.

EGS will continue installing and upgrading software to support end-to-end spaceport command and control system applications and displays required in ground processing facilities. Life extension modifications for the crawler transporter will continue in order to complete roller bearings, jacking, equalizing, and leveling (JEL) cylinder replacement. These modifications are necessary for future NASA space exploration, beginning with EM-1 and EM-2, followed by missions beyond low Earth orbit.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Major program readiness will near its final preparation phase for the EM-1 launch. The program will complete structural and facility modifications on the mobile launcher, and finish installing ground support equipment. EGS will conduct Launch Equipment Test Facility umbilical testing, complete installation of the crawler transporter JEL cylinder, and complete Multi-Payload Processing Facility upgrades. Command, control, and communications systems software and displays that support end-to-end spaceport applications will be readied to support launch. In the VAB, EGS will complete adjustable high-bay platform construction, and utilize in support of SLS stacking and integration for EM-1. At Launch Complex 39B, EGS will complete flame trench/flame deflector, as well as modifications for infrastructure and propellant and gas systems in preparation for launch. The program will complete CDR to evaluate ground systems design integrity, and its ability to meet mission requirements within available resources with appropriate margins and acceptable risk.

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
KDP-A	Feb 2012	Feb 2012
Formulation Authorization	Apr 2012	Apr 2012
SRR/SDR	Aug 2012	Aug 2012
KDP-B APMC	Nov 2012	Nov 2012
PDR Board	Mar 2014	Mar 2014
KDP-C APMC	May 2014	May 2014
CDR Board	Dec 2015	Dec 2015
KDP-D	Under Review	Under Review
EM-1 Launch Capability Readiness	Nov 2018	Nov 2018

Development Cost and Schedule

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2014	1,843.5	70	2015	1,843.5	N/A	EM-1 Capability Readiness	Nov 2018	Nov 2018	N/A

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.

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**2,812.9**	**2,812.9**	**N/A**
Phase A (includes CoF)	307.3	307.3	N/A
Phase B (includes CoF)	662.0	662.0	N/A
Mobile Launcher	213.1	213.1	N/A
LC-39B Pad	77.5	77.5	N/A
VAB	92.7	92.7	N/A
Command, Control and Communications	198.0	198.0	N/A
Offline Processing & Infrastructure	110.2	110.2	N/A
Other (includes CoF)	1,046.7	1,046.7	N/A
Project Managed UFE	105.4	105.4	N/A

Project Management & Commitments

The Ground Systems Development and Operations Program Office (GSDO) manage EGS and 21st Century Space Launch Complex (21CSLC) activities. GSDO balances customer requirements among SLS, Orion, and other Government and commercial users to provide synergy between EGS and 21CSLC. EGS is developing ground systems infrastructure necessary to assemble, test, launch, and recover SLS and Orion elements, while 21CSLC is focusing on enabling NASA facilities to support multiple users.

Element	Description	Provider Details	Change from Baseline
Vehicle Integration and Launch (VIL)	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

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	**Development**	Operations

Element	Description	Provider Details	Change from Baseline
Offline Processing and Integration	Enables payload processing activity, manufacturing, testing, servicing, and hazardous operations, and recovery in support of Orion	Provider: KSC Lead Center: KSC Performing Center(s): N/A Cost Share Partner(s): N/A	N/A
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
Program 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
If: Given that the SLS core stage uses a large amount of liquid hydrogen (LH2), there is a possibility of insufficient LH2 storage capacity at LC-39 Pad B to support a short-term (24/48/72-hour) turnaround, Then: Pad B operations will not support the 24-hour requirement.	EGS studied options to meet a potential scrub turnaround requirement. Two of four options are under consideration: Option A (preferred) uses 28 vendor-supplied LH2 tankers to provide additional LH2 capacity; and Option C (alternate) uses LH2 sphere at LC-39 Pad A to provide additional LH2 capacity (requires repair and reactivation of Pad A LH2 sphere, and new manifold to fill five LH2 tankers simultaneously).
If: There is insufficient time to perform integrated testing activities at VAB and Pad B, Then: A delay will occur in the scheduled operational readiness date.	Systems integration and test schedule assumes six months for testing, but analysis shows testing may exceed six months. To mitigate the risk, EGS developed an optimized timeline and task list. Mitigation activities include improved integrated validation and verification timelines and optimization of schedules.
If: There is insufficient time allotted to perform integrated operations for EM-1 at the VAB and Pad B, Then: A delay will occur in the scheduled EM-1 launch date.	EGS has proposed a schedule to optimize vehicle integration, launch development, systems integration, and test schedule activities.

EXPLORATION GROUND SYSTEMS DEVELOPMENT

Formulation	Development	Operations

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. For more routine work, EGS also uses pre-qualified IDIQ contractors 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 GSE fabrication firm-fixed-price contracts. A 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
VAB High Bay Platform Construction	Hensel Phelps Construction, Inc.	KSC

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
All	SRB	Nov 2012	Provides independent assessment of program 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	Mar 2014	Evaluates completeness and consistency of program preliminary design; determines readiness to proceed with detailed design phase	Program cleared to proceed to next phase	N/A
CDR	SRB	Dec 2015	Demonstrates that program design is mature; supports full-scale fabrication, assembly, integration, and test; and meets overall performance requirements within cost and schedule constraints		TBD

COMMERCIAL CREW

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	696.0	--	1243.8	1184.8	731.9	173.1	1.1

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

American ingenuity is displayed in the photo montage above, which shows the diversity and innovation of spacecraft in the NASA Commercial Crew Program. Clockwise from upper left: Blue Origin Space Vehicle, Boeing CST-100, SpaceX Crew Dragon, and Sierra Nevada Dream Chaser.

NASA is looking to the US private sector to develop and operate safe, reliable, and affordable crew transportation to low Earth orbit, including to the ISS. Partnering with the commercial space industry for access to low Earth orbit and the 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 low Earth orbit, NASA is able to shift its focus to the exploration of deep space with the SLS and Orion crew vehicle.

Through the Commercial Crew Program (CCP), NASA provides technical and financial support to industry partners during development of their crew transportation systems, and certifies them to carry NASA astronauts to and from the ISS.

The first phase of the development effort was a series of competitively awarded Space Act Agreements, followed by Certification Products Contracts (CPC). The scope of the contracts included submittal and technical disposition of specific, early development certification products. The CPC effort allowed the partners to gain insight into NASA human space flight requirements and gave NASA early insight into partner designs and approaches.

CCP entered the final certification phase with the award of two Commercial Crew transportation Capabilities (CCtCap) contracts in September 2014. Embarking on this final phase means that by the end of 2017 NASA will be able to certify that all mission and safety requirements are met in the commercial crew transportation systems resulting in new US human access to LEO.

NASA measures partner progress against fixed-price milestones, based on performance of agreed upon entrance and success criteria. Although the content varies by partner, milestones are designed to demonstrate progress toward completing crew transportation system development, such as risk reduction testing, design reviews, hardware development, and flight tests. The Government pays for milestones only after completion. When NASA’s industry partners successfully achieve all milestones and completed the certification process, NASA will use these systems to satisfy the Agency's ISS crew transportation and rescue requirements.

The completed transportation systems will support four NASA or NASA-sponsored crew on each flight, and provide emergency crew return, transport/return of pressurized ISS cargo, and crew safe haven while docked to the ISS. The benefits of competition in implementing the CCtCap program are numerous such as controlling costs in the long term and maximizing crew safety, as reinforced in statements by the Government Accountability Office, Aerospace Safety Advisory Panel (ASAP), and NASA Inspector General. The CCtCap awards represent a significant milestone in US human space flight, with the goal of ending our sole reliance on foreign crew transportation to the ISS, and certification of safe, cost-effective US commercial crew transportation systems. In addition, this approach helps stimulate growth of a new space transportation industry available to all potential customers, strengthening America's space industrial base and 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 2016

The funding increase is required as the two remaining competitors move further into the development phase.

ACHIEVEMENTS IN FY 2014

NASA's industry partners, Blue Origin, The Boeing Company (Boeing), Sierra Nevada Corporation (SNC), and Space Exploration Technologies (SpaceX), made significant progress developing viable commercial crew transportation systems. NASA and Blue Origin modified their Commercial Crew Development Round 2 (CCDev2) Space Act Agreement to include additional unfunded milestones, allowing them to continue working together to mature Blue Origin's crew transportation system.

NASA's follow-on initiative, CCiCap, made significant progress completing planned milestones. By the end of FY 2014, Boeing completed all 20 milestones, including an integrated vehicle wind tunnel test to fully understand aerodynamic environments and reduce potential design risks. Sierra Nevada completed 9 of 11 milestones, including their initial integrated systems safety analysis to assess potential safety hazards and controls for a variety of spacecraft and systems. SpaceX completed 11 of 15 milestones, including a pad abort test plan review, proving that test articles are capable of meeting test requirements and schedule.

Boeing, Sierra Nevada, and SpaceX completed Certification Products Contracts in FY 2014. The products provided under these contracts proved beneficial in honing industry designs to meet NASA requirements. NASA awarded CCtCap contracts on September 16, 2014 to Boeing and SpaceX. Under these contracts, Boeing and SpaceX will complete design, development, test, evaluation, certification, and flight of integrated crew transportation systems capable of carrying crew to and from the ISS in accordance with NASA certification standards and requirements. Each contract includes at least one crewed flight test with a minimum of one NASA astronaut aboard to verify that the fully integrated rocket and spacecraft can launch, maneuver in orbit, dock to the ISS, and to validate system performance.

COMMERCIAL CREW

WORK IN PROGRESS IN FY 2015

Sierra Nevada and SpaceX will continue to make progress on its remaining CCiCap milestones, including engineering test article flight testing and reaction control system testing for Sierra Nevada, as well as pad abort and in-flight abort testing for SpaceX.

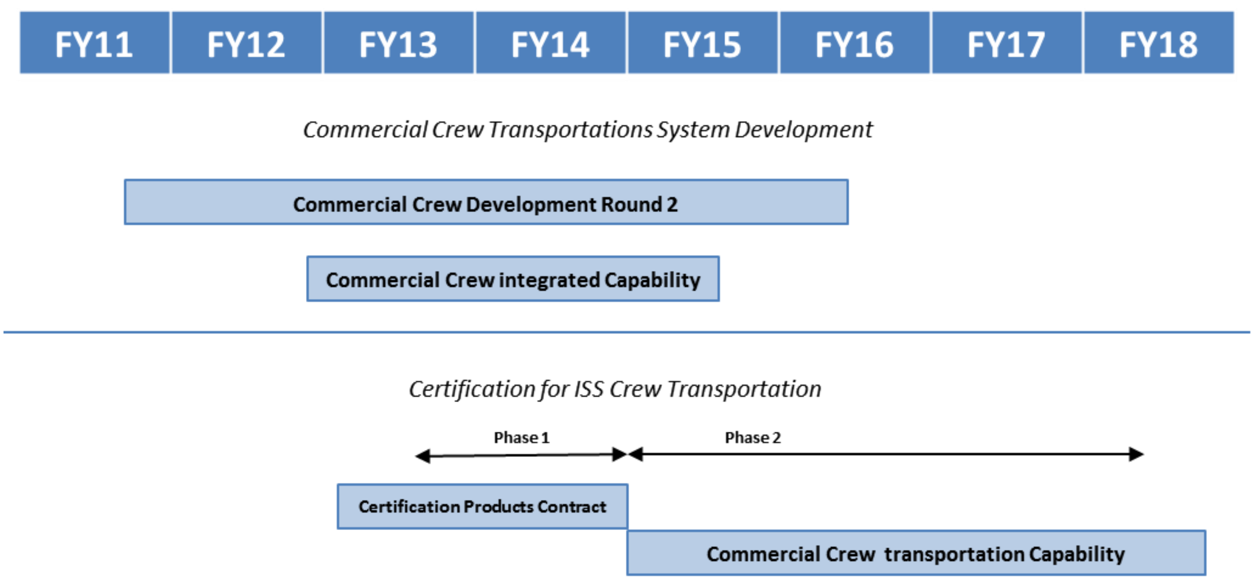
In addition, Boeing and SpaceX will complete several CCtCap milestones, the first being the Certification Baseline Review (CBR). This is a key milestone for industry partners to identify baseline requirements, provide a more detailed plan and schedule for contracted work, and define top safety, technical, cost, and schedule risks. CBR establishes the baseline for contract execution and is essential to developing a baseline cost commitment for the CCP. Other critical milestones include delta CDRs for both Boeing and SpaceX.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Industry teams will continue to accomplish significant milestones under their CCtCap contracts, demonstrating progress toward securing US crew transportation capability while meeting NASA mission and safety requirements. Key work planned for Boeing includes the Integrated Parachute System Drop Tests and service module hot-fire launch abort test, while SpaceX plans include an uncrewed flight to the ISS and Launch Site Operational Readiness Review for crew.

Program Schedule

Progression of Commercial Crew Development Efforts



Program Management & Commitments

The HEO team at NASA Headquarters performs strategic management and oversight of Commercial Spaceflight, and KSC is responsible for CCP management, in collaboration with JSC. The CCP 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, Sierra Nevada, SpaceX Lead Center: KSC Performing Center(s): All Cost Share Partner(s): Industry Partners (shown 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 low Earth orbit and the ISS. In the early lifecycle stages, CCDev activities focused on stimulating industry efforts that successfully matured subsystems and elements of commercial crew space flight concepts, enabling technologies and capabilities. This was followed by CCDev2, which addressed new concepts to mature design and development of primary elements, such as launch vehicle or spacecraft. Subsequently, NASA continued this effort with CCiCap Space Act Agreements to continue partner progress in their integrated design and development efforts. For these initial efforts, NASA utilized Space Act Agreements, which provided maximum flexibility to the provider and maximum affordability to the Government. Concurrently with CCiCap agreements, NASA awarded Certification Products Contracts to industry to begin the process of NASA certifying their crew transportation systems. The current and final stage of the acquisition lifecycle began with the award of two CCtCap contracts in September 2014 for the development, test, evaluation, and final NASA certification of a Crew Transportation System. CCtCap contracts include demonstration of crewed ISS missions and subsequent service missions, assuming sufficient budget and technical progress, and a special studies services portion, which can be used to perform special studies, tests, or analyses, as needed by NASA, to reduce Program risk. NASA used FAR-based fixed-price contracts during this phase.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
CCDev2	Blue Origin	Kent, WA
CCtCap	Boeing	Houston, TX
CCiCap	Sierra Nevada	Louisville, CO
CCiCap / CCtCap	SpaceX	Hawthorne, CA

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	NASA Advisory Council	Jul 2014	To provide independent guidance for the NASA Administrator	No formal recommendations or findings were specified for CCP.	Apr 2015
Other	ASAP	Oct 2014	To provide independent assessments of safety to the NASA Administrator	Panel stated that NASA should continue to assess the resource needs to accomplish certification tasks with two providers.	Jan 2015
Other	SRB	Oct 2014	To assess funding and schedule reserve requirements, cost effectiveness during development and impacts to future sustaining operations, and efforts required for successful program implementation	TBD	Fall 2015

Historical Performance

Through FY 2014

Commercial Orbital Transportation System (COTS) Partner	No. of Milestones	Total Potential Value (in $M)	No. Milestones Completed	Funding for Completed Milestones (in $M)	% Milestones Completed	% Funding Completed	Status
SpaceX	40	396.0	40	396.0	100	100	Completed
Orbital	29	288.0	29	288.0	100	100	Completed
Rocketplane-Kistler	15	206.8	3	32.1	20	16	Terminated

COMMERCIAL CREW

CCDev1 Partner	No. of Milestones	Total Potential Value (in $M)	No. Milestones Completed	Funding for Completed Milestones (in $M)	% Milestones Completed	% Funding Completed	Status
Sierra Nevada	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	4	6.7	4	6.7	100	100	Completed

CCDev2 Partner	No. of Milestones	Total Potential Value (in $M)	No. Milestones Completed	Funding for Completed Milestones (in $M)	% Milestones Completed	% Funding Completed	Status
Sierra Nevada	13	105.6	13	110.1	100	92	Completed
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

CCiCap Partner	No. of Milestones	Total Potential Value (in $M)	No. Milestones Completed	Funding for Completed Milestones (in $M)	% Milestones Completed	% Funding Completed	Status
Sierra Nevada	11	227.5	9	209.5	82	92	Active
Boeing	20	480.0	20	480.0	100	100	Completed
SpaceX	15	460.0	11	360.0	73	78	Active

Chart only includes funded milestones. CCtCap was awarded on September 16, 2014. No CCtCap milestones were planned or completed in FY 2014.

HUMAN RESEARCH PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	149.4	--	167.8	170.3	178.2	178.2	180.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

NASA astronaut Karen Nyberg uses a fundoscope to examine her retina as part of ocular surveillance flight study on the International Space Station. To better understand vision changes during long duration space missions, this examination is part of the first research effort to monitor and systematically document crew eye health while in orbit.

Sending astronauts into space involves a multitude of complicated systems, but perhaps the most complex is the human system. While NASA has amassed more than 50 years of crew experience in low Earth orbit, researchers continue to unravel the mysteries of how the human body responds to the harsh environment of space. 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 missions beyond low Earth orbit.

As NASA prepares to conduct crewed missions in cis-lunar space using SLS and Orion, and eventually at other locations, including Mars, HRP is developing the technological and scientific expertise to send humans into deep space for longer durations. Working with the National Academies, National Council on Radiation Protection, and other external partners, HRP continues to deliver products and strategies to protect crew health and safety, and maximize productivity while living and working in space. Experiments on the ISS, as well as ground-based analog environments and laboratories, expand research and technology development for protecting the human system in multiple ways. Investigations regarding space radiation protection, pharmaceutical advances, deep space habitat systems, innovative medical technologies, and new exploration capabilities, such as developing vehicle and spacesuit requirements and countermeasures that ensure crew health during all phases of flight are all underway.

Space radiation poses significant health risks for crewmembers, including the possibility of developing cancer later in life, radiation sickness during the mission, and post-mission effects on the nervous and cardiovascular systems. HRP is working with the Advanced Exploration Systems (AES), Crew Health and Safety, and Orion teams on both in-mission and post-mission radiation countermeasures to minimize exposures and provide radiation protection. This collaborative effort involves developing advanced radiation shielding technologies, in partnership with AES, develop standards and provide the requirements for real-time radiation alert systems, optimal mission architectures, biomedical radiation sensitivity screening, as well as incorporating post-mission health surveillance to ensure that crewmembers can safely live and work in space without exceeding acceptable radiation health risks.

In collaboration with other federal agencies, such as the Department of Defense, the Department of Energy, and the National Institutes of Health, HRP supports space human system research to increase understanding of the effects of microgravity on human physiological systems. This knowledge is critical to NASA's plans for long-duration human space missions beyond low Earth orbit. Additionally, as is the case with many space-based medical investigations, this research may also lead to significant advancements in treating patients on Earth.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None

ACHIEVEMENTS IN FY 2014

In order to investigate astronaut health and performance, HRP and the National Space Biomedical Research Institute (NSBRI) selected 39 research proposals from 12 states and 23 institutions for funding, committing approximately $24.5 million over the lifetime of the grants. Proposals included research to mitigate crew health and radiation exposure risks, which will enable safer human space exploration. Research in space radiation will employ experimental approaches to understand how space radiation may contribute to development of cancer, heart and circulatory disease, and long-term cognitive function problems.

Current research indicates approximately 75 percent of astronauts show ocular changes during ISS missions. Researchers continued ISS ocular surveillance biomedical investigations to address the visual impairment astronauts can experience from microgravity exposure. These investigations gathered information on the visual changes that occur in ISS crewmembers to better understand the risk factors and develop potential countermeasures.

HRP conducted approximately 16 space biomedical research investigations during each ISS mission increment, completed 3 flight investigations, and initiated 7 new research investigations. This included a microbiome study to investigate the variety of microorganisms on, in, and around astronauts during space flight missions. The human body hosts millions of tiny organisms called microbes that play a key role in human health; it is important to understand the changes to this microbial population during long-duration space exploration. By sampling an astronaut's microbiome on Earth and in space, researchers hope to define the signatures of human response to a variety of relevant aspects of space travel. Potential applications to human health on Earth include early detection of diseases, alterations in metabolic function, and immune system deficiency.

In preparation for the 2015 ISS one-year mission, HRP completed a joint US/Russian research plan that included long-duration collaborative studies on ocular health, immune and cardiovascular systems, cognitive performance testing, and effectiveness of countermeasure against bone and muscle loss. Additionally, HRP and NSBRI selected 10 genomics investigations as part of the twin study that will compare astronaut Scott Kelly on the ISS and his identical twin brother, retired astronaut Mark Kelly, on Earth.

HUMAN RESEARCH PROGRAM

WORK IN PROGRESS IN FY 2015

Throughout FY 2015, HRP will have approximately 20 ongoing ISS space biomedical research investigations during each of 2 mission increments. These investigations will include work associated with both the one-year and six-month mission crews.

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—the longest mission ever assigned to a US astronaut. During the year, HRP will implement biomedical research that 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 remains on Earth. For the first time, scientists can observe factors, 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 space flight and its impacts on the human body at the molecular level.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

HRP will conclude the one-year joint US/Russian ISS mission. For the first time, NASA will be able to obtain long-duration data on ocular health, immune and cardiovascular systems, cognitive performance testing, and countermeasure effectiveness against bone and muscle loss. Additionally, findings of the identical twin study will provide new “omics” data to study the effects of space flight on the entire complement of biomolecules, such as proteins (proteomics), genes (genomics), etc.

Additional studies to mitigate the risk of long-duration space flight include a lighting countermeasure to help ISS crewmembers improve sleep and enhance performance, as well as an ultrasound tool to monitor changes in lumbar and cervical spine. In addition, the risk of developing kidney stones increases during space flight due to the microgravity environment and crew dehydration. A new tool developed by NSBRI will detect kidney stones and provide treatment by moving the stone using a focused, high-intensity ultrasound. This technology could change kidney stone treatment on Earth, enabling removal of a kidney stone during the first office visit.

Program Elements

EXPLORATION MEDICAL CAPABILITY

As NASA makes plans to extend human exploration beyond low Earth orbit, 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 requirements for medical equipment and clinical care, develop remote medical technologies, and assess medical requirements unique to long-duration space missions.

HUMAN RESEARCH PROGRAM

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 space flight, 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, the unique stresses and challenges of space flight can 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 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, habitat, or 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 space flight, 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.

ISS MEDICAL PROJECTS

I ISS provides a unique testbed 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
Dec 2015	Complete Recommendation Report on Feasibility of Using Ultrasound Tool to Monitor Changes in the Lumbar and Cervical Spine
Jan 2016	2016 NASA Research Announcement in Space Radiation Release
Jan 2016	Deliver Space Radiation Exposure Calculation Tool (HZETRN2015)
Feb 2016	2016 HRP Investigator's Workshop
Feb 2016	Deliver ISS Operational Dynamic Lighting Schedule to Enable Implementation of ISS Lighting Countermeasure to Improve Sleep and Enhance Performance
Feb 2016	Deliver Individualized Real-Time Neurocognitive Assessment Toolkit
Mar 2016	Complete Technical Study on Comparison of Non-Invasive and Invasive Intracranial Pressure Measurement
Mar 2016	Complete Study on the Effects of Microgravity During Parabolic Flight on Intracranial Pressure
Mar 2016	Deliver Guidelines to Enable Automation in Allocating Crew Tasks to Improve Operational Performance
Apr 2016	Recommendation to Space Medicine (Anbar) on the Feasibility of Using Calcium Isotopes to Quantify Inflight Changes of Bone Loss and Formation
May 2016	2015 Human Exploration Research Opportunity NRA Selections
June 2016	Complete 2015/2016 Mission X: Train Like an Astronaut Fitness Challenge
Aug 2016	2016 Human Exploration Research Opportunity NRA Release
Sep 2016	2016 NASA Research Announcement in Space Radiation Selections
Sep 2016	Complete Study on Assessment of Advanced Ultrasound Technology to Prevent Renal Stone Complications During Space Exploration

Program Management & Commitments

The Program office located at JSC with the support of ARC, GRC, LaRC and KSC manages HRP.

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 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): N/A
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 NASA research announcements (NRAs) to provide scientists the opportunity to develop complete flight experiments and allow universities to participate in flight research by involving their scientists and engineering schools. In conjunction with the NSBRI, HRP plans to announce two NRAs in 2016.

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 2014	Peer review of NRA	Selected grantees	Jul 2015
Quality	SRB/External Independent Review	Nov 2014	Review of research projects, gaps, and tasks	Verifies project prioritization/ reprioritization	Nov 2015
Quality	National Academies	Jun 2014	Review of NASA research on human health risks	Verifies project prioritization/repriori tization	Jun 2015
Quality	Independent Program Assessment Office (IPAO)	Sep 2012	Review of program management policies and practices	Verifies adherence to NASA program management policies	Sep 2015
Quality	National Council on Radiation Protection (NCRP)	Jul 2014	Review of space radiation health risks	Establish research priorities for space radiation research	Jul 2015

ADVANCED EXPLORATION SYSTEMS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	152.7	--	231.4	231.4	416.9	817.2	897.2

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

Bigelow Aerospace Integration Engineer Sofia Russ stands inside the Bigelow Expandable Activity Module (BEAM) qualification unit after successful testing in preparation for flight in 2015. BEAM is a human-rated, expandable habitation structure utilizing the International Space Station to conduct fundamental research on performance of expandable modules in the space environment.

Advanced Exploration Systems (AES) develops foundational technologies and high-priority capabilities that will become the building blocks for future human space missions. Using an approach that couples focused, in-house activities 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 space flight 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 flight-like environments, validating operational concepts, gaining valuable hands-on experience with hardware, and mastering the skills necessary for future space missions. The Agency is able to uncover potential risks of new capabilities before integration into more critical systems by performing early integration of complex systems, testing those systems in the proper environments, and flying the technology. This early risk reduction helps to avoid cost problems and improve the affordability of future space exploration.

AES activities focus on human space flight systems for deep space and robotic precursor missions to identify and fill in knowledge gaps related to potential destinations in advance of flight missions. Major areas of work include systems development for more reliable life support; deep space habitation technology; advanced in-space propulsion; crew mobility systems; advanced space suits; landing capabilities; and in situ resource characterization, processing, and usage. Within this framework, AES is developing concepts for astronaut EVA with an asteroid, developing public-private partnerships for lander capabilities, and creating the means to support missions using space resources. These efforts will enable human space flight to become increasingly Earth independent and capable of pioneering space to expand human presence into the solar system. Through pioneering, we seek the capacity to work, learn, operate, and thrive safely in space for an extended, and eventually indefinite, period with a reduced supply chain to Earth.

NASA also continues to leverage and technically align HEOMD, STMD and SMD core capabilities, technology developments, and innovative approaches. The Asteroid Redirect Mission (ARM) formulation effort leverages technologies needed for other sustainable exploration missions and/or activities. For example, ARM leverages advanced solar electric propulsion (SEP) technologies in STMD and the private sector; advanced controls, sensors, and robotics technologies in ISRS; international docking system developments in the ISS program; and AES EVA activities. The advanced SEP system will place the spacecraft and asteroid in orbit around the moon – specifically a lunar distant retrograde orbit where it can remain stable for decades to come. There the asteroid and spacecraft pair will become an asset in the proving ground region of cis-lunar space. In the mid-2020s, using the SLS and Orion vehicles, astronauts will demonstrate advanced in-space EVA operations to collect asteroid samples and return to Earth. AES also works closely with SMD on the Joint Robotic Precursor Activity to develop instruments, support research and analysis, and plan and conduct robotic missions that are precursors for eventual human exploration.

EXPLANATION OF MAJOR CHANGES IN FY 2016

To align upcoming HEO exploration and technology activities, the AES budget consolidates their funding in FY 2016. This consolidation enables investments to be coordinated effectively between research and technology capabilities to support robotic, EVA, ARM, and future exploration missions. Establishing ARM content under AES aligns key technologies and capabilities for future exploration missions.

ACHIEVEMENTS IN FY 2014

AES modified existing crew pressure suits, worn during launch and landing, to enable use for EVA on crewed asteroid missions. This single-suit approach will eliminate the need to bring a second, EVA-dedicated suit. Astronauts training for future human exploration missions continue to test the modified suit in NASA’s Neutral Buoyancy Laboratory to simulate ARM operations. The program successfully completed extensive Advanced Space Suit Portable Life Support System 2.0 testing of all components, subsystems, and controller algorithms. The first EVA simulation was achieved using the fully integrated test system and human metabolic simulator.

NASA conducted ARM pre-formulation activities, which included engaging technical communities and the public, and continued ongoing technology and capabilities activities. As part of this engagement, AES led development and selection of 18 proposals for 6-month studies from the ARM Broad Agency Announcement (BAA), which included 4 concepts for an asteroid capture system.

AES finished developing two experiments for the Orion EFT-1 mission, launched in December 2014. The first included solid-state detectors to measure radiation inside the capsule as it passed through the Earth’s radiation belts. The second was an advanced caution and warning system to monitor the health of critical vehicle systems using data transmitted to the ground. These tests allowed NASA to develop and test early version of sensors and systems for Orion, as well as other habitation vehicles in a highly relevant environment, and reduce future risks related to these critical systems.

ADVANCED EXPLORATION SYSTEMS

The Morpheus lander technology test bed effectively completed 27 flight tests, including 15 free flights. The last two demonstrated a precision landing and hazard avoidance system using laser sensors to detect rocks and craters in a landing zone. During free flights, Morpheus left the ground, reached an altitude of several hundred meters, and automatically landed in terrain simulating the surface of a planet. In the future, this capability will allow robotic missions approaching a planetary surface to safely land closer to targets of scientific interest. The Morpheus lander also demonstrated new propulsion system technology using liquid oxygen and methane for propellants. The NASA expertise developed through these demonstrations is being leveraged to support a number of NASA programs, and informing industry efforts to develop commercial lunar landing capabilities under the Lunar CATAYST initiative.

WORK IN PROGRESS IN FY 2015

As AES concludes the majority of the development work from FY 2012 – FY 2014, FY 2015 brings a new set of activities to leverage current achievements. These activities include integrated life support, an advanced space suit, autonomous systems and operations, modular power systems, radiation sensors, avionics and software, instruments for the Mars 2020 mission, and low-cost small spacecraft to answer strategic knowledge gaps. In addition, AES will study options to augment Orion's habitation and EVA capabilities for extended deep space missions. These efforts include a solicitation called the NextSTEP: this BAA will fund industry activities and participation in formulating these habitation options.

For ARM, the Robotic Mission Concept Review is scheduled for the spring of 2015. In addition, STMD and ISS/ISRS will lead efforts to begin long-lead ARM component acquisitions.

The Bigelow Expandable Activity Module (BEAM) is scheduled to arrive at ISS in 2015 aboard the SpaceX-8 cargo resupply mission. BEAM is an expandable habitat compacted for launch and then expanded in orbit to give the crew additional living space. The module will be attached to ISS and test expandable structures technology that can be used for a deep space habitat on human missions. Sensors inside BEAM will measure the structure's strength, detect pressure leaks caused by micrometeoroid punctures, and monitor thermal and radiation environments during flight.

AES will continue developing secondary CubeSat payloads in 2015 to fly on SLS in 2017. Initial mission concept selections included 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 visit candidate asteroids for future human exploration.

AES will complete the PDRs for Mars 2020 mission payloads to demonstrate production of oxygen from the atmosphere and measure surface weather conditions. AES will also conduct human-in-the-loop testing of a short-duration space suit for in-space cis-lunar missions, such as ARM, and develop concepts for instruments and EVA tools for demonstration on ARM to find potentially valuable asteroid resources such as metals and water.

In support of additional next generation habitat modules for long-term missions, AES will collaborate with HEO's ISS and ESD programs to enter into public-private partnerships under the NextSTEP BAA to pursue promising areas to enable habitat capabilities. In addition, AES will begin new efforts related to in-space manufacturing. As part of the integrated life support activity, AES will accelerate work on three planned ISS flight demonstrations: high pressure/high purity oxygen generation system, cascade distillation system for wastewater processing, and miniature monitoring instrument for atmospheric contaminants.

ADVANCED EXPLORATION SYSTEMS

KEY ACHIEVEMENTS PLANNED FOR FY 2016

As NASA works to extend human space exploration beyond low Earth orbit, AES will continue to develop reliable life support; habitation technology; crew mobility systems; advanced in-space propulsion; advanced space suits; landing capabilities; and in situ resource characterization, processing, and usage. Leading to an ISS flight demonstration as early as 2021, AES will test a new space suit in a vacuum chamber with a human subject. AES will also develop and test highly reliable life support systems, such as atmosphere recovery systems, increased water recovery, fire safety, and smaller monitoring systems, to deploy on ISS and, Orion; and that could be used for future habitation systems beyond low earth orbit.

Beginning in FY 2016, AES plans to launch the first of three Spacecraft Fire Safety experiments (Saffire-1). Saffire is a set of rigorous tests to increase knowledge on risk, detection, suppression, and cleanup related to fire safety in space. After the initial three tests are completed, the sequence of Saffire experiments will continue, with each test building upon data from the previous to move through the entire fire detection, suppression, and post-fire clean up phases.

In addition, AES will maintain investments in “massless” exploration efforts, including in-space manufacturing technology development and demonstration on ISS. The in-space manufacturing effort will develop and test 3D printing processes for metallic parts, laser scanners to measure the dimensions of 3D printed parts, and systems to recycle discarded plastic to produce feedstock for 3D printers.

AES plans to conduct ground tests of advanced in-space propulsion technologies to reduce travel time to destinations beyond Low-Earth orbit, including high-power electric propulsion systems selected via the NextSTEP BAA.

The ARM element incorporated into AES in FY 2016 will progress towards a SDR for the robotic mission, and leverage development of synergistic capabilities for ISRS. NASA will continue planning for a mid-2020s crewed mission concept, including seeking potential partnerships.

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 space. Activities include the expandable habitat BEAM, 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 enable the crew to conduct “hands-on” exploration and in-space operations. EVA and space suit advancements will lead to a next generation space suit and portable life support system that are significant advancements beyond the current capabilities used today that rely on technology developed over 30 years ago, which will give astronauts improved dexterity and mobility in space environments, higher levels of reusability, in addition to 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 and human missions by improving autonomous precision landing on planetary surfaces, as well as potential new propellants and/or propulsion systems. These landing capabilities are being shared through public-private partnerships with industry under the Lunar CATALYST initiative. Other ongoing initiatives advance propulsion systems and modular power for multiple exploration vehicles and systems.

OPERATIONS

The Operations domain focuses on systems to 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 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 RAD instrument operations on the Curiosity rover to measure the radiation environment on Mars, the internal and public-private partnership EM-1 secondary missions, and instruments planned for the Mars 2020 mission.

ADVANCED EXPLORATION SYSTEMS

Program Schedule

Date	Significant Event
Dec 2014	Launch radiation environment monitors and test advanced caution and warning system on EFT-1
Feb 2014	Complete down selection of reactor fuel element materials for nuclear thermal propulsion
Dec 2014	Completed risk reduction tech maturation for ARM capture concepts down select mission capture concept options
Spring 2015	Complete ARM Mission Concept Review
Mar 2015	Deliver BEAM for launch to ISS
Mar 2015	Select commercial partners for development of initial habitation capabilities concepts for the proving ground via NextSTEP BAA
May 2015	Complete SRR for demonstration of high-pressure oxygen generation system on ISS
Aug 2015	Complete PDRs for the Mars 2020 mission instruments
Sep 2015	Complete human-in-the-loop testing of short duration space suit for in-space cis-lunar applications, such as the Asteroid Redirect Crewed Mission
Sep 2015	Complete CDR for Cascade Distillation System wastewater processor
TBD 2016	Complete cross-Directorate mission requirements integration for ARM robotic mission
TBD 2016	Integrate Saffire-I fire safety flight experiment with Cygnus spacecraft
TBD 2016	Integrate Saffire-II fire safety flight experiment with Cygnus spacecraft

Program Management & Commitments

HEOMD 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 SMD 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 SMD 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): JSC, MSFC and JPL Cost Share Partner(s): Bigelow Aerospace, NextSTEP BAA Awardees
Vehicle Systems	Provider: NASA Centers Lead Center: HQ Performing Center(s): GRC, JSC, MSFC, and JPL Cost Share Partner(s): NextSTEP BAA Awardees
Operations	Provider: NASA Centers Lead Center: HQ Performing Center(s): ARC, JSC, KSC, and MSFC Cost Share Partner(s): N/A
Robotic Precursor Activities	Provider: NASA Centers Lead Center: HQ Performing Center(s): ARC, JPL, MSFC, and KSC Cost Share Partner(s): SMD, STMD, NextSTEP BAA Awardees

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 specialized skills within the civil service workforce, but may also utilize a small amount of contractor effort in areas where NASA can cost effectively leverage their skills and knowledge.

AES continues to increase the use of competitively selected external awards and public-private partnerships. 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.

In FY 2014, AES utilized several externally competed solicitations. AES contributed to the development of the SMD-led Mars 2020 AO and participated in the technical and programmatic reviews, and competitively selected two payloads for the Mars 2020 mission addressing key strategic knowledge gaps for human exploration. The AES Lunar CATALYST competitive solicitation awarded non-reimbursable Space Act Agreements to three commercial partners for joint development of lunar payload delivery capabilities, with NASA providing engineering expertise, test facilities, software, and loaned hardware to the partners.

AES supported ARM by issuing a BAA and selected 18 industry-led studies of asteroid capture systems, rendezvous sensors, commercial spacecraft buses, and partnership opportunities for secondary payloads to enhance crewed missions.

In FY 2015, AES plans to build upon prior experience to generate additional BAA awards from the NextSTEP BAA, allowing NASA to award public-private partnerships for advanced propulsion, habitation, and small satellite capability development to enable pioneering of space. NASA will award fixed-priced milestone contracts that require significant corporate resources to be engaged in the three thrust areas.

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: Lander Capabilities	Moon Express, Astrobotic Technologies, and Masten Space Systems	MSFC, JSC, and KSC
ARM BAA Award	Airborne Systems Jacobs, Space Systems/Loral, Altius Space Machines	JSC and GSFC
NextSTEP BAA Awards Proposals submitted by December 12, 2014 Selections to be made by April 2015	TBD	TBD

ADVANCED EXPLORATION SYSTEMS

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. ARM is conducting an Independent Technical and Cost Assessment using resources within NASA to review technical risks and cost estimate in the pre-formulation phase of the mission leading to the MCR.

SPACE OPERATIONS

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
International Space Station	2964.1	--	**3105.6**	3273.9	3641.0	3826.0	4038.3
Space and Flight Support (SFS)	809.9	--	**898.1**	917.3	863.8	844.8	826.1
Total Budget	**3774.0**	**3827.8**	**4003.7**	**4191.2**	**4504.9**	**4670.8**	**4864.3**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

SPACE OPERATIONS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
International Space Station	2964.1	--	**3105.6**	3273.9	3641.0	3826.0	4038.3
Space and Flight Support (SFS)	809.9	--	**898.1**	917.3	863.8	844.8	826.1
Total Budget	**3774.0**	**3827.8**	**4003.7**	**4191.2**	**4504.9**	**4670.8**	**4864.3**
Change from FY 2015			**175.9**				
Percentage change from FY 2015			**4.6%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

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During a six-hour, 13-minute spacewalk on October 7, 2014, NASA astronaut Reid Wiseman and European Space Agency astronaut Alexander Gerst (out of frame) worked outside the Station's Quest airlock relocating a failed cooling pump to external stowage and installing gear that provides backup power to external robotics equipment. A bright sun is visible at upper left.

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 ISS for conducting research and technology development and sustaining 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](http://www.nasa.gov/directorates/heo/home/index.html).

EXPLANATION OF MAJOR CHANGES IN FY 2016

The Space Network Ground Segment Sustainment (SGSS) shifts the planned implementation of a major operational capability upgrade from FY 2016 to a date to be determined, pending approval of a budget and schedule replan.

SPACE OPERATIONS

ACHIEVEMENTS IN FY 2014

Future long-duration human space flight 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 space flight on human health. ISS hosted 368 experiments in a wide range of various scientific and technology areas, including rodent research into space flight-induced changes to physiology and behavior. Other examples of research include RapidScat, a two-year mission to measure ocean surface wind speed and direction, which will help improve weather forecasts and hurricane monitoring; and installation and activation of the Vegetable Production System on ISS which will determine whether humans can successfully grow food in microgravity during long-duration missions.

Monitoring crew health aboard ISS is a vital tool as astronauts prepare for deep space missions in the proving ground and beyond. Medical evaluations carried out over years on ISS have revealed numerous adverse effects that microgravity can have on the human body, such as vision changes and bone mass loss. Researchers and other experts worked throughout the year to develop recommendations and methods for monitoring and mitigating these conditions during long-duration missions.

Even aboard the Earth-reliant ISS, ensuring that the crew always has a sufficient supply of food, water, and oxygen requires careful planning and logistics. Commercial providers successfully launched four cargo resupply missions to the ISS in FY 2014, carrying critical investigations, experiments, and supplies.

LSP supported the launches of three major missions, including a Mars orbiter and a new Tracking and Data Relay Satellite (TDRS) for Space Communications and Navigation (SCaN)'s orbiting fleet of communication satellites. As human exploration reaches into deep space, NASA's near-term robotic missions serve as capability pathfinders and provide crucial data that will inform development of future space expeditions. LSP ensures these missions reach space by acquiring commercially available launch services and working with customers and providers, from pre-mission planning through post-launch.

SCaN continued work to define NASA's space communication needs over the decades to come, and continued to develop technologies that will enable future missions to transmit at higher data rates, reducing costs and providing opportunities for new exploration and science missions. To that end, the Lunar Laser Communication Demonstration (LLCD) experiment established laser communications between the Earth and the Moon at data rates over six times higher than current radio frequency systems. This evolving laser technology will play a crucial role as humans leave low Earth orbit and travel further into space.

Rocket Propulsion Testing (RPT) completed testing of the J2-X upper stage engine. RPT also modified the test stand in preparation for Space Launch System (SLS) core stage engine testing in early FY 2015. Testing the propulsion systems that will transport astronauts to cis-lunar space and beyond is critical to future mission success, and RPT provides that support.

WORK IN PROGRESS IN FY 2015

HEO is working with international partners to maintain and operate ISS as a platform for research and expand the commercial utilization of LEO. ISS research and technology demonstrations are critical to understanding the risks and the effective countermeasures necessary for long duration missions. NASA's new "open science" approach will greatly expand availability of data to a larger research community, maximizing return on investment, and opening up new findings in research and technology development.

The increase of research opportunities will help to expand our exploration capabilities from being Earth-reliant to becoming more Earth independent.

Beginning in spring 2015, a one-year crew expedition of one NASA astronaut and one Russian cosmonaut will help scientists better understand the impacts of long-duration space flight on the human body and aid in the development of effective countermeasures, ensuring crew health on this and future missions. HEO and our international partners are working on standards and criteria for long-duration space flight, especially prolonged radiation exposure.

To ensure visiting vehicle traffic flexibility and port redundancy, ISS will be moving several pressurized modules. A commercial provider will launch a commercial inflatable structure to ISS, the Bigelow Expandable Activity Module (BEAM), to investigate habitat technology, a critical requirement for future exploration missions.

Space Flight Support programs are providing the capabilities needed for NASA's missions and goals: affordable launch services, propulsion testing facilities, and reliable space communication. During FY 2015, RPT will continue RS-25 SLS core stage engine testing in support of deep space exploration missions.

Key Achievements Planned for FY 2016

NASA ISS and international partners will manage resources, logistics, systems, and operational procedures required to maintain a continuous six-crew member capability on ISS. The ISS team will install a second international docking adapter, creating a second docking port for commercial crew vehicles, supporting increased on-board research activity. ISS will also host a number of important Earth climate-focused research projects and the robust Center for the Advancement of Science in Space (CASIS) pipeline of projects, planned for launch in FY 2016.

The yearlong US and Russian crew expedition concludes in spring 2016. Health monitoring, clinical services and rehabilitation to the returning astronaut, and analysis of mission data will continue through the end of 2016. The new astronaut class selection process in FY 2016 will implement new assessments for skills critical for missions beyond low Earth orbit, where crew will travel in smaller vehicles without the benefit of real-time communication with the ground.

Space Flight Support programs will continue to provide capabilities required to support future missions, including affordable launch services, propulsion testing facilities, and reliable space communications. In addition, a commercial spacecraft will launch the Deep Space Atomic Clock (DSAC), intended to demonstrate the precision needed to navigate deep space.

Themes

International Space Station

The ISS is a unique technological achievement, and is the result of an international effort to conceive, plan, build, operate, and utilize a permanently crewed 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 biotechnology, materials and physical science, and the effects of long-duration space flight 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 US 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 (SFS) consists of multiple programs, providing Agency-level capabilities critical to the success of NASA missions and goals. The Human Space Flight Operations program ensures that NASA astronauts are fully prepared to carry out current and future missions safely. The LSP assures reliable access to space by providing leadership, expertise, and cost-effective expendable launch vehicle services for NASA missions. The 21st Century Launch Complex Program, nearing completion, ensures NASA’s launch facilities are ready to support future 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 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
ISS Systems Operations and Maintenance	1236.1	--	**1106.1**	1194.5	1327.7	1321.3	1327.6
ISS Research	330.7	--	**394.0**	362.3	364.2	370.6	376.8
ISS Crew and Cargo Transportation	1397.3	--	**1605.5**	1717.1	1949.1	2134.1	2333.9
Total Budget	**2964.1**	--	**3105.6**	**3273.9**	**3641.0**	**3826.0**	**4038.3**

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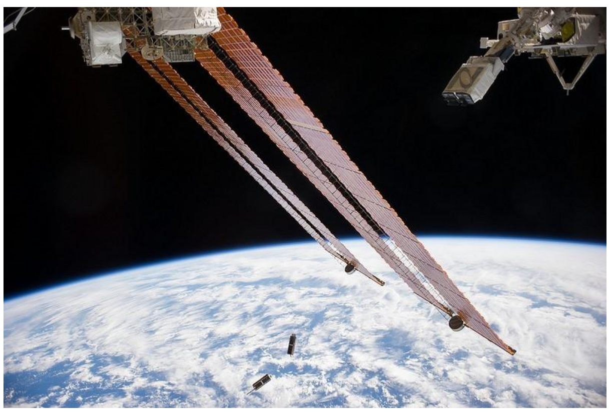


The CubeSat deployer (upper right) releases a pair of NanoRacks miniature satellites from the International Space Station as it orbits the Earth. The two “Doves” are part of a “flock” of Planet Labs satellites deployed to take images of Earth from space. The high frequency imaging will potentially be useful in detecting global changes in crop cover, construction, animal migrations, pest infestations, surface water, natural disasters, refugee camps, sea ice, pollution, traffic patterns.

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 the 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 United States and its Canadian, European, and Japanese partners. Russia exclusively operates the Russian segment.

Including its solar arrays, the 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, the 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, the US operating segment of the ISS houses three major science laboratories (US Destiny, European Columbus, and Japanese Kibo).

In January 2014, the Administration announced the United States’ intention to extend the ISS operations and utilization to at least 2024. This extension provides a decade of opportunity in which to accomplish three major objectives on the ISS: conduct research and technology development required to enable human exploration in deep space and eventually Mars; facilitate maturation of a commercial market for space-based research and activity in low Earth orbit; and conduct research in Earth, space, and fundamental biological and physical sciences. The ISS is essential to move human exploration of space

INTERNATIONAL SPACE STATION PROGRAM

from an Earth-reliant to an Earth-independent capability. 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 test bed for evolving critical technologies needed to venture farther into space, such as long-duration life support, navigation systems, advanced lightweight structures, propulsion, and power generation and storage.

The ISS program aims to provide direct research benefits to the public through its operations, research, and technology development activities. Designating the ISS as a National Laboratory enables partners in government, academia, and industry to utilize its unique environment and advanced facilities to perform investigations. 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 the 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.

For additional information on the ISS program, go to: 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ISS SYSTEMS OPERATIONS AND MAINTENANCE

Formulation	Development	Operations

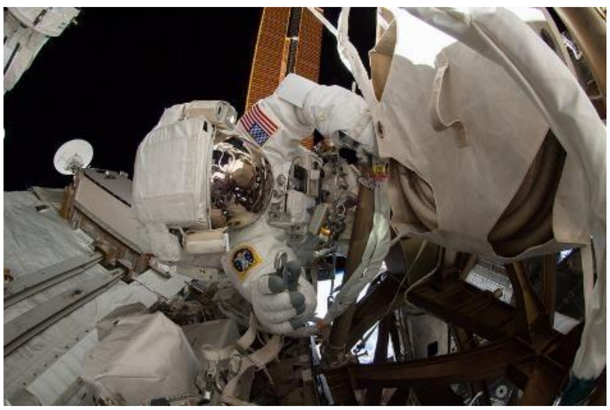
FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	1236.1	--	1106.1	1194.5	1327.7	1321.3	1327.6

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.



During a six hour, 13-minute spacewalk in October 2014, NASA astronaut Reid Wiseman works outside the Station's Quest airlock to relocate a failed cooling pump to external stowage, and install backup power equipment for external robotics.

The ISS is a complex research facility and human outpost in low Earth orbit that was 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 the ISS in the severe conditions of space and ensuring that crew always have a sufficient supply of food, water, and oxygen requires precise planning and logistics. Much like a house, the ISS needs routine maintenance and is subject to unexpected mechanical failures. However, the systems on the ISS are significantly more complicated than systems in an average home. Resolving problems can be challenging and often require the crew to make repairs in space with support from ground teams on Earth. Astronauts on the ISS cannot go to the local hardware store to buy materials, so support teams on Earth monitor and painstakingly plan for replacement parts and consumables, such as filters, to make sure they are available when needed.

The coordination and support necessary for the ISS 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 the crew. Even before the astronauts leave Earth, the Systems Operations and Maintenance project provides the crew training to prepare them for their stay aboard the ISS.

The ISS program considers all aspects of the mission when developing operations plans to meet program objectives. These include scheduling crew activities, choreographing the docking and undocking of visiting crew and supply ships, evaluating consumables supply, and managing stowage issues. The

ISS SYSTEMS OPERATIONS AND MAINTENANCE

Formulation	Development	Operations

Systems Operations and Maintenance project ensures that the ISS is operational and available to perform its research mission at all times.

Because the ISS is an international partnership, these program decisions are not made in isolation; they require collaboration with multiple countries to ensure all technical, schedule, and resources supply considerations are taken into account. The experience NASA is gaining through integration with its ISS partners is helping the Agency to better prepare for future partnerships in human space exploration.

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. Recently, a commercial CubeSat system on the ISS experienced problems deploying its satellites while in orbit. Mission control teams responded immediately to ensure that an inadvertent CubeSat release would not pose a risk to the ISS or visiting vehicles. Specialists continue to work with the deployer provider to fix the problem and return the system to service. Without this anomaly resolution capability, the ISS could not function as a safe, human-occupied, Earth-orbiting research facility.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

Throughout the year, NASA ground teams continued to monitor overall vehicle health and oversee general maintenance and performance of all ISS vehicle systems, including environmental control and life support, electrical power, propulsion, thermal control; and guidance, navigation and control. NASA completed investigation of a water leak inside the helmet of a spacewalking astronaut in July, implemented measures to prevent recurrence of the problem, and restored the capability to perform planned extravehicular activities (EVA). While the investigation continued, NASA safely and quickly performed contingency EVAs to replace critical external equipment, including two spacewalks in December to replace a malfunctioning component in an external thermal control system ammonia loop and another spacewalk in April to replace a failed backup multiplexer-demultiplexer computer relay system.

Successful operation and maintenance leads to an environment conducive to research. The ISS was host to 368 experiments. These included 64 experiments in biology and biotechnology, 91 in Earth and space science, 50 in educational activities, 36 in human research, 43 in physical science, and 84 in technology.

WORK IN PROGRESS IN FY 2015

The ISS Systems Operations and Maintenance project continues to maintain resources on orbit and on the ground to operate and utilize the ISS. NASA expects continued success in providing all necessary resources, including power, data, crew time, logistics, and accommodations, to support research while

ISS Systems Operations and Maintenance

Formulation	Development	Operations

operating safely with a crew of six astronauts. Four crew rotation and ten cargo resupply missions are planned in FY 2015, including both international partner and US commercial cargo flights.

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, propulsion, structures and mechanisms, thermal control, and guidance, navigation, and control.

The team supported one Russian EVA and two US EVAs to date, and plans to support six additional US EVAs, as well as one from the Russian segment. Many of the US EVAs will support major reconfiguration onboard ISS, beginning in FY 2015. NASA is relocating several pressurized modules, which will allow the ISS to accommodate two visiting vehicle-docking ports and two visiting vehicle-berthing ports, enabling traffic flexibility and port redundancy for US operating segment crew and cargo vehicle missions. The team plans to relocate the permanent multipurpose module (PMM) and pressurized mating adapter (PMA) #3. The PMM move will enable creation of a second visiting vehicle berthing port, while installing an international docking adapter on PMA #3 will create a docking port for commercial crew vehicles.

Beginning in spring 2015, a one-year crew expedition for one Russian cosmonaut and one NASA astronaut will help scientists better understand the impacts of long-duration space flight on the human body, and aid in the development of effective countermeasures.

Key Achievements Planned for FY 2016

NASA plans to work with the international partners to maintain a continuous six ISS crew member capability by coordinating and managing resources, logistics, systems, and operational procedures. The operations and maintenance project will continue to manage resource requirements and changes, 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, they will provide anomaly resolution and failure investigation as needed. While the yearlong US and Russian crew expedition concludes in spring 2016, data analysis will continue through the end of the year. The team will finish reconfiguring the US operating segment, and install a second international docking adapter on the relocated PMA #3, creating a second docking port for commercial crew vehicles.

Project Schedule

The table below provides a schedule for potential EVAs. However, the 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, the ISS Program plans routine maintenance EVAs once the list of tasks fulfills an EVA and the Program can accommodate the activity within the objectives for the increment while maintaining focus on utilization and research.

ISS SYSTEMS OPERATIONS AND MAINTENANCE

Formulation	Development	Operations

Date	Significant Event
Oct 2014	Two US EVAs
Oct 2014	Russian EVA
Feb 2015	Three US EVAs
Jun 2015	US EVA
Jun 2015	Russian EVA
Aug 2015	Two US EVAs
Dec 2015	US EVA

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, JSC 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. Requirements of this contract include sustaining engineering of US on-orbit segment hardware and software, technical integration across all of the ISS segments, end-to-end subsystem management for the majority of ISS subsystems and specialty engineering disciplines, and US on-orbit segment and integrated system certification of flight readiness.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
US on-orbit segment Sustaining Engineering Contract	The Boeing Company	JSC

ISS SYSTEMS OPERATIONS AND MAINTENANCE

Formulation	Development	Operations

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	NASA Advisory Council	Jul 2014	Provides independent guidance for the NASA Administrator	No formal recommendations or findings for ISS	Jan 2015
Other	NASA Aerospace Safety Advisory Panel	Oct 2014	Provides independent assessments of safety to the NASA Administrator	No formal recommendations or findings for ISS	Jan 2015

ISS RESEARCH

Formulation	Development	Operations

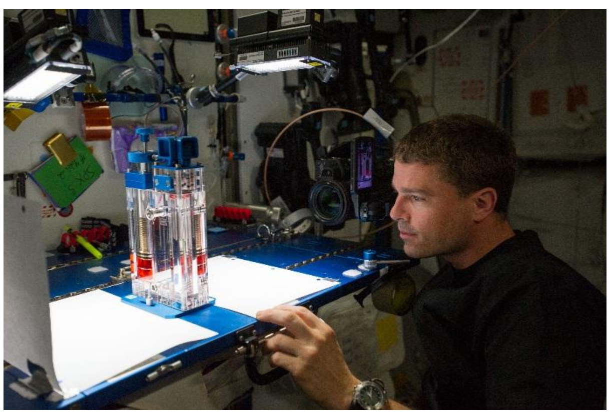
FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	330.7	--	394.0	362.3	364.2	370.6	376.8

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.



NASA flight engineer Reid Wiseman works with the Capillary Flow Experiment aboard ISS. This fluid physics investigation provides data to validate fluid behavior models in space, enabling optimal design of water and liquid propellant systems for future space flight. These studies also contribute to our understanding of water processes on Earth, leading to such advances as more efficient irrigation techniques and improved medical devices.

The 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, the ISS enables scientific investigation of physical, chemical, and biological processes in an environment very different from Earth. A range of science laboratories, external testbeds, and observatory sites are available aboard the ISS, allowing astronauts to conduct a wide variety of experiments in low Earth orbit.

The ISS supports research across a diverse array of disciplines, including physics, Earth science, space science, biology and biotechnology, human physiology, chemistry, and materials science. In addition, it is a platform for educational activities that enable the public to connect with NASA and inspire students to excel in science, technology, engineering, and mathematics academic disciplines.

As the name implies, the ISS 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 studies from the National Academies, such as the Decadal Survey on Biological and Physical Sciences in Space.

The ISS Research project funds fundamental and applied 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

ISS RESEARCH

Formulation	Development	Operations

sponsored and non-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 is support to CASIS, a non-profit organization that manages the ISS National Laboratory.

R&D conducted aboard the ISS holds the promise of next-generation technologies in health and medicine; robotics, manufacturing, and propulsion; and to develop applications that will benefit life on Earth. As NASA's only long-duration flight testbed, the ISS is critical to developing plans to extend human space exploration beyond low Earth orbit. Aboard the ISS, researchers study the effects of long-duration exposure to the space environment on the crew, devising and testing countermeasures to offset health risks. Additionally, researchers evaluate extended performance of equipment critical to long-duration flight by testing the hardware's ability to survive in the space environment, determining life-limiting issues and repair capabilities, and evaluating upgrades to improve performance. The amine swingbed hardware, designed for use in the future Orion capsule life support system, has been demonstrated on the ISS as an innovative and successful way to remove carbon dioxide from cabin air while minimizing water loss.

With the conclusion of Expedition 40 in September 2014, more than 2,000 investigators from 83 countries around the world have performed over 1,700 research investigations utilizing the ISS and over 1,000 research and development results have been published in scientific journals and magazines (Note: these are early estimates with final numbers expected to be published in early 2015). The ISS will continue to provide research opportunities to scientists, engineers, and technologists through at least 2024.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

Scientific accomplishments on the ISS continue to increase, as does the quantity of data returned from automated research instruments, and astronaut crew time dedicated to research. During FY 2014, the ISS hosted 368 experiments, including an estimated 64 in biology and biotechnology, 91 in Earth and space science, 50 in educational activities, 36 in human research, 43 in physical science, and 84 in technology.

NASA biological and physical sciences implemented a new research approach called open science, a way to maximize return on investment in ISS research by greatly increasing the number of investigations and development of translational applications, which will enhance the current traditional approach to NASA Research Announcements (NRAs). Open science experiments generate large amounts of data, which will be stored in NASA-developed databases, available for analysis of both human exploration and commercial applications. The GeneLab initiative is developing the first database to expand upon the growing field of "-omics:" a broad area of biological and molecular research. The database system will take advantage of research technologies to create a comprehensive and open environment full of scientific data, comparing life in space to life on earth.

ISS RESEARCH

Formulation	Development	Operations

SpX-4 delivered the first rodent investigation in September 2014. New rodent research habitats provide critical life sciences research capabilities and study physiological changes in space. Rodent research is particularly valuable because many aspects of rodent anatomy, physiology, and genetics are similar to those of humans. By studying rodents on the ISS, researchers can observe space flight-induced changes to tissues and cells, muscles and bones, cardiovascular and reproductive systems, and even behavior. This research better defines health risks and the countermeasures needed as humans expand their exploration of space and provides a platform for research into new drugs and causes of disease for application here on Earth.

Reusing hardware originally built to test parts of NASA's QuikScat satellite, NASA launched the RapidScat instrument to the ISS on a SpaceX Dragon cargo spacecraft for a two-year mission to measure ocean surface wind speed and direction. As an autonomous, externally mounted payload to the Columbus laboratory, this 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 (designed to last 2 years but operated for 10 years) 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 ISS's orbit intersects orbits of each of these satellites about once every hour, ISS-RapidScat will serve as a calibration standard and help scientists stitch together the ocean-surface wind data from multiple sources into a long-term record.

CASIS is making progress on its mission to engage non-traditional users and enable a new era for space investigations capable of improving life on Earth. FY 2014 marked the initial voyages of CASIS's research payloads, which included innovative research from both solicited and unsolicited research channels. CASIS established several new partnerships, including the United Nations, the Broad Institute, the MassChallenge Institute, and National Geographic, among others, to support a variety of applications, including water and forest management, humanitarian relief, disaster prevention and recovery. Together with the Red Sox Foundation and National Geographic Learning teams, CASIS also generated science, technology, engineering and math opportunities for young people. CASIS successfully integrated and launched their first two sets of research payloads, ranging from physical and biomedical science experiments to plant biology and education projects.

CASIS issued three requests for proposals in the areas of materials science, remote sensing, and enabling technologies. The Center continues to build significant momentum in the private sector, and is actively working with leading companies that include Merck, Eli Lilly, COBRA PUMA Golf, Proctor & Gamble, and Novartis. CASIS awarded 36 research and technology projects that include a wide diversity in discipline and application.

NASA completed installation and activation of Vegetable Production System (Veggie), the largest plant growth system to date for use in space, in FY 2014. This facility is key to studying how plants grow in space to determine whether humans can successfully grow food in microgravity during long-duration missions. Plants are not only a source of food, but 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 first Veggie investigation was delivered in April, and tested whether plants, grown in space, might harbor microorganisms that are potentially harmful to astronauts or if plants can supplement astronaut diets. The first crop grown in the Veggie system was lettuce. Astronauts harvested and returned it to Earth on SpX-4 for analysis of microbial content.

ISS RESEARCH

Formulation	Development	Operations

In-Space Robotic Servicing (ISRS) focused on maturing technologies and mission concepts for the Restore-L satellite servicing mission in low Earth orbit, and the Asteroid Redirect Mission (ARM). NASA completed initial Restore-L feasibility studies with three competitively selected industry spacecraft vendors. Leveraging the high degree of synergy between ISRS and ARM, NASA initiated technical risk reduction for ARM and rendezvous and proximity operations (RPO). ISRS is maturing RPO capabilities to support satellite servicing, ARM, and Orion, including the Raven sensor experiment, scheduled to fly to ISS in FY 2016. ATV-5 delivered two new task boards and a tool for the Robotic Refueling Mission-2 (RRM) coolant replenishment technology experiments. Development began for RRM-3, which NASA has slated for ISS installation in 2017, and will demonstrate cryogenic fluid and xenon transfer.

For a more comprehensive list of research achievements on the ISS, go to: http://www.nasa.gov/mission_pages/station/research/index.html.

WORK IN PROGRESS IN FY 2015

Although ISS crew visits are currently limited to six months, starting in spring 2015, a US astronaut and a Russian cosmonaut will remain aboard for a full year of research. The 12-month study will include investigating the effects of long-term stays in space on bone density, muscle mass, strength, vision, and human physiology. While critical for future exploration missions, this and other investigations will have important applications 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, and holds promise for medical treatments on Earth.

The first phase of a new fruit fly lab launched on the SpX-5 mission in FY 2015, enabling the study of micro- and fractional-gravity effects on animals. 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. Current insect research on Earth is opening new avenues for prevention and therapy to treat infections, cancer, and inflammatory disease. The new fruit fly lab will enable research into human genetic responses to long-duration stays in space.

Development will also continue on the Cold Atom Laboratory (CAL), which will take advantage of the microgravity environment to create the coldest matter in the universe—just a trillionth of a degree above absolute zero. The laboratory could enable significant discoveries in atomic physics, which could be applicable to next generation communications, navigation, timekeeping, and computing. JPL's CAL testbed recently succeeded in producing a Bose-Einstein condensate, a key achievement in developing the flight instrument destined for ISS. In preparation for delivery to the ISS in FY 2017, CAL is scheduled to complete the CDR phase in FY 2015.

Technology development and demonstration on the ISS is critical to exploration beyond low Earth orbit. In May, NASA plans to launch Bigelow Expandable Activity Module (BEAM), which will demonstrate inflatable habitat technology for future human space flight and exploration activities.

Additional space exploration advancements include the Zero Boil-Off Tank (ZBOT) fluids investigation, and 3D printing in zero gravity technology. Currently scheduled for launch in September 2015, ZBOT

ISS RESEARCH

Formulation	Development	Operations

will provide updated computer models for potential application to current research on reducing propellant launch mass, and improving existing models for developing cryogen storage systems. 3D printing in zero gravity will be the first step in demonstrating a machine shop, capable of creating new components in space – a critical enabling element of future exploration class missions for which resupply is difficult and costly.

NASA and CASIS teams are coordinating to effectively implement rodent science. In addition to the academic community, early candidates for research opportunities include the pharmaceutical industry and the US Army.

The externally mounted Cloud-Aerosol Transport System (CATS) will use a light detection and ranging (LIDAR) remote sensing instrument to measure atmospheric clouds and aerosols such as pollution, dust, and smoke to determine their impact to the Earth's climate. After launch to the ISS on SpX-5 in January, the investigation will perform long-duration observations of up to three years, and provide continuity with 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 ISS orbit 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.

NanoRacks will deploy their NanoRacks Exposure Platform (NREP) to be located on the Japanese Experiment Module – Exposed Facility (JEM-EF). This commercially developed platform is capable of hosting a number of individual investigations at one time. The ISS Program has scheduled the external Multi-User System for Earth Sensing (MUSES) platform for launch on H-II Transfer Vehicle-5. MUSES will simultaneously host up to four Earth observation instruments that can be changed, upgraded, and robotically serviced. Teledyne Brown Engineering is developing the Earth-imaging platform as part of its commercial space-based digital imaging business. Teledyne will operate, maintain, and sustain MUSES on a commercial basis, and provide services to hosted instruments for the ISS.

Within ISRS, Restore-L development will continue in FY 2015. RPO capabilities supporting satellite servicing, ARM, and Orion will continue to mature, including Raven. Design and development of ISRS capabilities, which NASA leveraged for ARM development, such as dexterous robotic capture, may be matured. NASA has planned RRM-2 operations in FY 2015. RRM-3 development will continue in preparation for installation on the ISS in 2017.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The Stratospheric Aerosol and Gas Experiment (SAGE) Earth observation facility, planned for a FY 2016 launch aboard SpX-10, will record changes to 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 these changes affect climate, and accurate long-term measurements such as those provided by SAGE are crucial for understanding the processes that control climate change.

The ISS Program has scheduled launch of the Total and Spectral Solar Irradiance Sensor (TSIS) which will provide two measurements critical for determining the Sun's influence on the Earth's climate: total

Formulation	Development	Operations

solar irradiance measurements of incoming solar radiation and spectral solar irradiance measurements to determine regions of the Earth's atmosphere affected by solar variability. Both measurements are required for understanding the natural influences on climate. The information will be used by NASA and other stakeholders, including NOAA and the Laboratory of Atmospheric and Space Physics at the University of Colorado.

The external payload Ecosystem Spaceborne Thermal Radiometer Experiment to Space Station (ECOSTRESS), launching to the ISS, will obtain critical insight into plant-water dynamics and how Earth's ecosystems change with climate. The unique ISS orbit enables ECOSTRESS to sample the diurnal (day/night) cycle in critical regions across the globe, currently missed by other instruments. ECOSTRESS science objectives include identification of critical thresholds of water use and water stress in key climate-sensitive biomes; detection of the timing, location, and predictive factors leading to plant water uptake decline and/or cessation over the diurnal cycle; and measurement of agricultural water consumption over the contiguous United States to improve drought estimation accuracy.

The Space Test Program Houston-5 Lightning Imaging System (STPH-5 LIS) will collect real-time lightning data, and enhance regional and global weather, climate, and chemistry studies of the Earth. Current lightning data collection misses up to 30 percent of lightning activity in the northern hemisphere, which is critically needed for the National Climate Assessment. The LIS will also allow critical daytime lightning data collection to improve understanding of mechanisms contributing to ground strikes and associated electromagnetic phenomena.

The Spacecraft Fire Experiment (SAFFIRE) will continue in FY 2016. SAFFIRE is an international collaborative project to perform fire safety experiments on three consecutive Cygnus resupply vehicle flights after they leave the ISS, and before reentry into Earth's atmosphere. The self-contained payload will test flammability of various materials in low-gravity environments to better understand the risk of fire in spacecraft. Investigating these smaller fires will further understanding of larger fires that cannot be studied in an inhabited vehicle.

The Advanced Combustion via Microgravity Experiments (ACME) project is series of studies of gaseous flames that will be conducted in the combustion integrated rack. ACME's primary and secondary goals are improved fuel efficiency and reduced pollutant production in practical combustion on Earth and spacecraft fire prevention through innovative research focused on materials flammability.

The Packed Bed Reactor Experiment investigates the role and effects of gravity on gas-liquid flow through porous media, which are critical components in life support systems, thermal control devices, fuel cells, and biological and chemical reactors. The results of these experiments will influence future environmental control system design.

CASIS continues to develop a robust pipeline of projects in life sciences, materials development, remote sensing and enabling technologies across private/commercial, academic and government segments. This includes more than 160 active projects currently planned through FY 2016, including 113 from commercial industry. The Center will continue to facilitate and expedite National Laboratory opportunities, ensuring researchers, principal investigators, and private commercial entities the most efficient pathway to flight. Additionally, they continue to broaden their partnerships with non-profits and private industry, helping to communicate the benefits of doing research on the ISS.

ISS RESEARCH

Formulation	Development	Operations

Upon successful completion of the first Fruit Fly Lab experiment in FY 2015, NASA has planned a second experiment for ISS installation in FY 2016, to study multiple generations of fruit flies and provide further insight into immune system research.

The ISRS project will continue Restore-L development. The ISS Program plans to fly the Raven sensor experiment to ISS in FY 2016. RAVEN will demonstrate a common rendezvous sensor suite for satellite servicing, ARM, and Orion. FY 2016 may include dexterous robotic capture system development for ARM, leveraging satellite servicing technologies. RRM-3 development will continue with transport to the ISS, planned for FY 2017.

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 the ISS.

Date	Significant Event
Nov 2014	Increment 42
Mar 2015	Increment 43
May 2015	Increment 44
Sep 2015	Increment 45
Nov 2015	Increment 46
Mar 2016	Increment 47
May 2016	Increment 48
Sep 2016	Increment 49

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.

ISS RESEARCH

Formulation	Development	Operations

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
MUSS (includes National Laboratory enabling activities)	MUSS activities support all research on the 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
ISRS	A technology development campaign to advance technologies such as dexterous robotics, autonomous rendezvous and docking systems, hypergolic propellant transfer systems, contact dynamics simulation platforms, and sophisticated tools and grippers with the ultimate goal of servicing a US Government satellite in low Earth Orbit.	Provider: NASA Centers and contractors Lead Center: HQ Performing Center(s): GSFC, JSC, and KSC Cost Share Partner(s): N/A	N/A

Acquisition Strategy

NASA awards contracts and grants for conducting research on the 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 ISS.

Peer review is the means to ensure a high-quality research program. Engaging leading members of the research community to assess the competitive merits of submitted proposals is essential to ensuring the productivity and quality of ISS Research. In FY 2014, the Biological and Physical Science project began implementing a new approach to research, termed “open science,” to maximize return on investment on research dollars. Open science will make greater quantities of flight experiment data available to larger scientific communities. The Biological and Physical Science project 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 announced

ISS RESEARCH

Formulation	Development	Operations

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 Academies 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 Academies added a committee 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
Mission Operations and Integration (MO&I) Contract	Teledyne Brown Engineering	Huntsville, AL
ISS National Laboratory Management Entity	CASIS	Tallahassee, FL

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Quality	Peer Review Panel	Jul 2014	Peer review of space biology NASA research announcement	Selection of grantees	Jul 2015
Other	NASA Advisory Council	Jul 2014	Provides independent guidance for the NASA Administrator	No formal recommendations or findings for ISS.	Jan 2015
Other	NASA Aerospace Safety Advisory Panel	Oct 2014	Provides independent assessments of safety to the NASA Administrator	No formal recommendations or findings for ISS.	Jan 2015

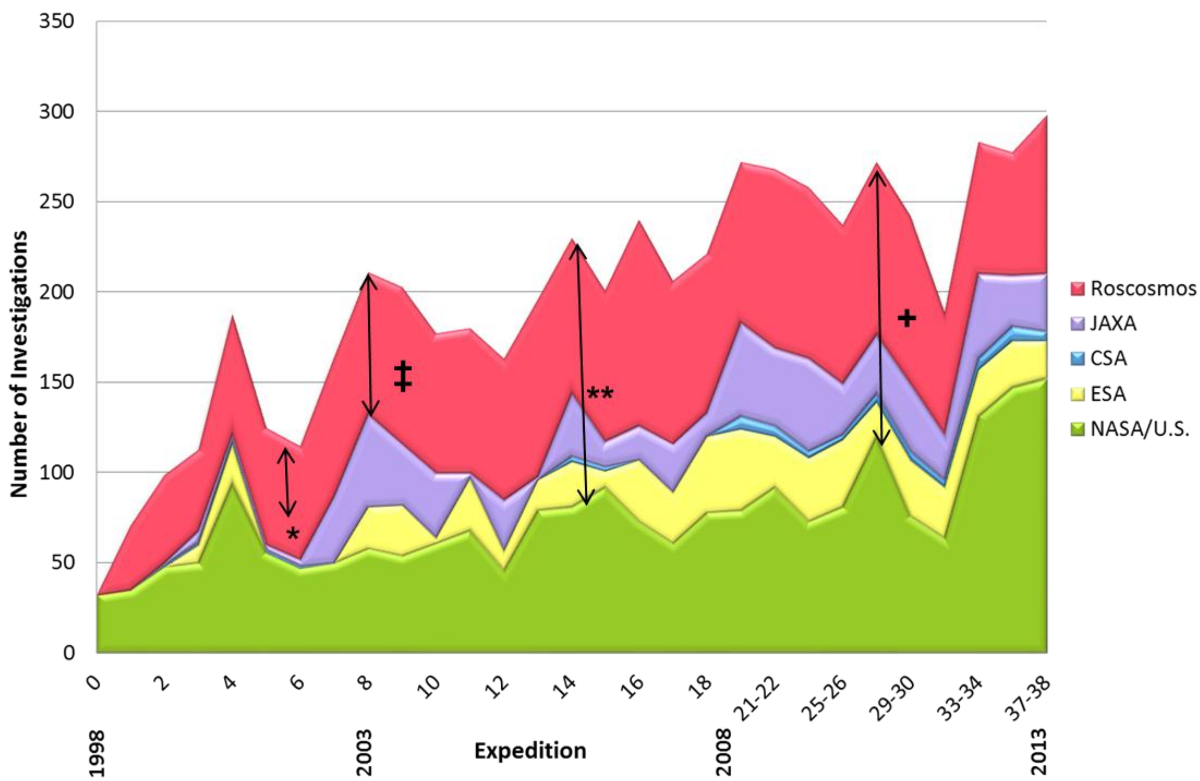
ISS RESEARCH

Formulation	Development	Operations

Historical Performance

In FY 2014, NASA estimates ISS performed over 284 research and technology investigations. The chart below displays historical data, by partner agency, for research investigations performed on the ISS since 1998.

Research and Technology Investigations per Expedition
December 1998 - March 2014



*** Post Columbia shuttle loss**
**** Shuttle Return to Flight**

*** Post Columbia shuttle loss**
+ Final Shuttle Flight

ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations

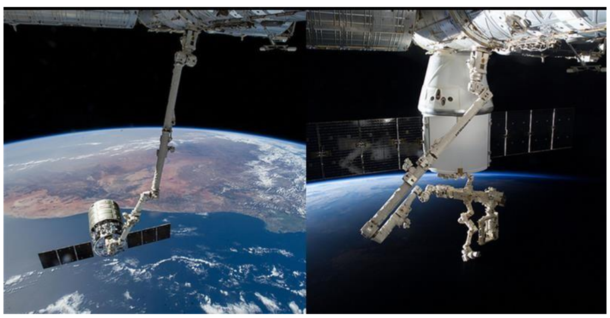
FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	1397.3	--	1605.5	1717.1	1949.1	2134.1	2333.9

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.



(Left) South Africa provides a backdrop as Canadarm2 prepares to release the Orbital Sciences commercial cargo craft after a month at the International Space Station. (Right) The SpaceX Dragon cargo vehicle is docked to the Station as the Special Purpose Dexterous Manipulator is positioned to remove external cargo.

Maintaining the 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 manages transportation services provided by both international partners and domestic commercial providers.

NASA purchases cargo delivery to the ISS under the Commercial Resupply Services (CRS) contracts with Orbital Sciences Corporation (OSC) and Space Exploration Technologies (SpaceX). The FY 2016 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 the ISS, including integration activities and the NASA docking system.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations

ACHIEVEMENTS IN FY 2014

SpaceX completed twelve milestones for performance in support of ten commercial resupply flights, including milestones for successful completion of one flight. SpX-3 launched on April 18, 2014, delivering 4,664 pounds of supplies to the orbiting laboratory, including crew supplies, scientific research hardware, and miscellaneous supplies. The SpaceX Dragon spacecraft returned 3,912 pounds of science, hardware, and crew supplies. SpX-4 launched on September 21, 2014, delivering about 3,240 pounds of supplies to support continuing space station research experiments, and returned in October 2014 with science samples from human research, biology and biotechnology studies; physical science investigations; and education activities. This mission returned almost 1,453 pounds of science, hardware, and crew supplies.

OSC launched the first CRS mission to the ISS from the Mid-Atlantic Regional Spaceport at NASA Wallops Flight Facility (WFF) in Virginia. Orbital completed nine milestones in support of eight commercial resupply flights, including milestones for successful completion of two flights. The Cygnus cargo carrier on Orb-1 mission, January 7, 2014, launched about 2,780 pounds of supplies to the station, including vital science experiments to expand the research capability. The Orb-2 mission launched on July 13, 2014, carrying 1,617 pounds of supplies for the station, including science experiments, crew provisions, spare parts, and experiment hardware.

The ISS Program also supported four Russian Soyuz launches in FY 2014, providing crew transportation and rescue services to the ISS for six US operating segment crewmembers.

Leading up to the 2014 Winter Olympics in Sochi, Russia, the traditional torch relay included an untraditional trip to the ISS. On November 7, 2013, a Russian Soyuz vehicle carried crew and the Olympic torch to ISS, where it was “relayed” inside the Station and outside, carried by a cosmonaut on a Russian spacewalk. While the Olympic torch had been to space before on the Space Shuttle, this marked the first time the torch was carried in open space during a spacewalk.

WORK IN PROGRESS IN FY 2015

Shortly after the Orb-3 launch on October 28, the OSC Antares rocket carrying a Cygnus spacecraft, suffered a catastrophic anomaly that caused the destruction of the spacecraft and cargo. No injuries occurred during the mishap and no critical cargo was lost. Station operations have contingencies and other cargo missions planned will help fill the gap from the cargo lost aboard this mission. Currently, the crew onboard the ISS are not in danger of running out of food or other necessary supplies. With NASA assistance, the OSC team is investigating the mishap, and will continue to work toward their next cargo flight once they fully understand the mishap.

For the remainder of FY 2015, the ISS Program is working on logistics flight scenarios to maintain an operational state while OSC returns Cygnus to flight status, currently planned for fall 2015. In total, NASA expects OSC to be prepared for Return to Flight status and complete five milestones in support of five commercial resupply flights. The ISS Program modified the manifest for the January SpX-5 flight to fly replacement hardware lost on Orb-3. This hardware was necessary for the revised increment plan, and to provide consumables to adjust logistics stored on-board. SpaceX can launch the three subsequent

ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations

missions according to the original manifest. In total, NASA expects SpaceX to launch four CRS flights, and complete 27 performance milestones in support of 12 commercial resupply flights.

Also in FY 2015, the project will support a crew flight plan that includes approximately four Soyuz launches, carrying a total of six US operating segment crewmembers to the ISS. The plan also includes four Progress launches and one H-II Transfer Vehicle (HTV) launch.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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 OSC to implement a plan that leads to the fulfillment of its contractual obligation for ISS resupply. NASA expects OSC to launch three CRS flights, and complete nine performance milestones in support of five flights. SpaceX plans to launch 4 commercial resupply flights, and complete 18 performance milestones in support of 8 flights

Project Schedule

Maintaining a regular rate of cargo delivery on a mix of NASA and partner vehicles ensures that the ISS can sustain nominal operations and maintenance, while allowing the program to respond to any anomalies that might occur. The table below shows the scheduled ISS flight plans for FY 2015 and FY 2016. NASA funds the SpaceX and OSC missions, as well as Soyuz seats related to US operating segment crew requirements. The planned spacing of the Soyuz crew rotation flights ensures a continuous six-crew presence on the ISS, as well as smooth transitions between crews.

ISS Crew and Cargo Transportation

Formulation	Development	Operations

Date	Significant Event
Oct 2014	Orb-3
Oct 2014	Progress 57P
Nov 2014	Soyuz 41S
Jan 2015	SpX-5
Feb 2015	Progress 58P
Mar 2015	Soyuz 42S
Apr 2015	SpX-6
Apr 2015	Progress 59P
May 2015	Soyuz 43S
Jun 2015	SpX-7
Aug 2015	Progress 60P
Aug 2015	HTV-5
Aug 2015	SpX-8
Sep 2015	Soyuz 44S
Oct 2015	Orb-4
Oct 2015	Progress 61P
Nov 2015	Soyuz 45S
Nov 2015	SpX-9
Jan 2016	SpX-10
Feb 2016	Progress 62P
Mar 2016	Soyuz 46S
Mar 2016	Orb-5
Apr 2016	Progress 63P
Apr 2016	SpX-11
May 2016	Soyuz 47S
Jun 2016	Orb-6
Jul 2016	Progress 64P
Aug 2016	SpX-12

ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations

Sep 2016	Soyuz 48S

Project Management & Commitments

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 the 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	OSC and SpaceX will provide cargo transportation to the 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

Acquisition Strategy

The ISS Program competitively procures all ISS cargo transportation services, excluding services obtained via barter with our international partners or nominal cargo transportation provided by Soyuz. NASA competitively awarded CRS contracts to SpaceX and Orbital on December 23, 2008, and services began in 2012. These are milestone-based, fixed-price indefinite-delivery-indefinite-quantity (IDIQ) contracts. On September 25, 2014, NASA released a Request for Proposal for Commercial Resupply Services 2 (CRS2) with initial responses received November 14, 2014. NASA expects to make awards in the third quarter of FY 2015 with cargo transportation services beginning in 2018. Like the current CRS contracts, CRS2 will award milestone-based, fixed-price IDIQ contracts. NASA has extended current CRS contracts to bridge the gap with the planned CRS2 procurement.

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 has purchased from Roscosmos crew

ISS CREW AND CARGO TRANSPORTATION

Formulation	Development	Operations

launches through 2017 and crew rescue and return through mid-2018. NASA will begin using domestic crew transportation services once available. The Commercial Crew Program has awarded Commercial Crew transportation Capabilities contracts to Boeing and SpaceX. Those awards include a minimum of at least two service missions per provider, with a maximum of up to six service missions per provider. The Commercial Crew Program will fund the two service flights. ISS Crew and Cargo Transportation will fund the remaining service flights.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
Crew transportation	Roscosmos	Moscow, Russia
Cargo transportation	OSC	Dulles, VA
Cargo transportation	SpaceX	Hawthorne, CA

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Other	NASA Advisory Council	Jul 2014	Provides independent guidance for the NASA Administrator	No formal recommendations or findings for the ISS	Jan 2015
Other	NASA Aerospace Safety Advisory Panel	Oct 2014	Provides independent assessments of safety to the NASA Administrator	No formal recommendations or findings for the ISS	Jan 2015

21ST CENTURY SPACE LAUNCH COMPLEX

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**39.6**	**--**	**23.3**	**11.8**	**0.0**	**0.0**	**0.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

Lightning strikes a tower at Launch Complex 40, as an AsiaSat communication satellite sits on the pad atop a SpaceX Falcon 9 rocket. Upgrades to Kennedy Space Center ground systems include the Mesoscale Eastern Range Lightning Information Network (MERLiN), which replaces the legacy lightning detection system. While MERLiN sensors pinpointed the location of this strike near the actual hit, the legacy system indicated a location some distance offshore. This performance improvement provides launch operators valuable data in assessing lightning hazards.

In FY 2011, NASA began the 21st Century Space Launch Complex (21CSLC) initiative within the Ground Systems Development and Operations program to support launch infrastructure, enable future exploration of the solar system, as well as new commercial opportunities in low Earth orbit. Its primary purpose is to modernize and transform the Florida launch and range complex at KSC, Cape Canaveral Air Force Station (CCAFS), and WFF into a more robust launch capability that could support multiple users. Beneficiaries of this activity included current and future NASA programs, other US government agencies, and commercial industry.

For more information, go to: http://www.nasa.gov/exploration/systems/ground/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

During FY 2014, NASA continued development of capabilities to support the multi-use, government/commercial spaceport at KSC and WFF. NASA completed design and started fabrication of a deployable launch system and universal propellant servicing system to support developing partnerships with small class, nano-satellite launch vehicle developers. The team also completed a study of a potential commercial small/medium class, human-rated launch provider. The Multi-Purpose Processing Facility (MPPF) for hazardous spacecraft processing reached the 75 percent construction milestone. The team finished remodeling the Space Shuttle heritage Firing Room 4 in the Launch Control Center (LCC) to support up to four independent command and control capabilities for future partner use. The advanced ground systems maintenance (AGSM) project completed formulation, design, and verification testing of an integrated health management demonstration system. The system successfully deployed into the LCC Firing Room and interfaced with the Spaceport Command and Control System.

The team is following recommendations of the joint NASA/Air Force Future State Definition Study on several projects. Upgrades to the range telemetry system passed PDR, and NASA is beginning major hardware procurements. The streamlined telemetry processing system demonstrated telemetry stream processing and stripping of range safety data in support of range requirements. 21CSLC largely completed the 50-megahertz Doppler radar wind profiler and the Eastern Range lightning system upgrade projects, and is awaiting final testing and activation. The real-time radio frequency (RF) monitoring project completed additional sensor installations, providing capability to monitor broad-spectrum RF radiation across the Florida Range, including location of RF sources in support of vehicle and spacecraft processing.

Further improvements and modernization of KSC environment and infrastructure continued to reduce future operating costs and enable the multi-use spaceport. These projects included installing meters to monitor commodity (gaseous nitrogen, helium, power) consumption at the various processing facilities. Additional projects involved installing new air handlers at the Booster Fabrication Facility to replace aging equipment. This activity is 50 percent completed. Developing environmentally friendly coatings and corrosion preventative compounds, which promise to reduce the effects of the salt air on structures and reduce the impact of the launch complex on the environment. These efforts are already finding applications on systems under development at KSC.

WFF completed the designs for modifications and repairs to building X-75, the relocation effort of Pad 1, and the replacement of island primary electrical feeder.

WORK IN PROGRESS IN FY 2015

In FY 2015, the team will complete the deployable launch system (DLS) and universal propellant servicing system (UPSS). Site preparations will be complete within the Launch Complex 39B perimeter to support verification and validation testing of the DLS, making it available for commercial launch provider use. Completion of the test site for the UPSS enables the development of commercial small class, launch vehicle propellant loading operations, using actual propellants in the desired configuration. AGSM will complete an integrated health management demonstration on the UPSS command and control system, including anomaly detection, prognostics, fault isolation, physics-based diagnostics, and smart pressure and temperature sensors. The team will complete MPPF construction, making the facility ready to support hazardous processing of spacecraft. Firing Room 4 outfitting in the LCC with a commercial off-the-shelf (COTS) command and control system will also be complete, ready for use by any commercial launch provider for launch processing and operations at KSC.

Completing CDR for Eastern Range telemetry upgrades enables antenna installation at KSC facilities. An instance of the streamlined telemetry processing system will test to support the downlink telemetry stream required by the Air Force Eastern Range for range safety purposes. The team will test the newly automated ascent imaging trackers, providing cost efficient launch imaging support for all launches at the Florida Range. Completion of the real-time RF monitoring project will provide insight into all RF radiation across the Florida Range, allowing safe and efficient spacecraft processing and monitoring of launch day RF interference. The team will complete enhancements of the range weather monitoring capability, including the 50-megahertz Doppler radar wind profiler and the Eastern Range lightning system upgrade projects. These enhancements will greatly reduce forecasting uncertainty, improve weather forecasting and monitoring across the Florida Range, and support all phases of launch vehicle processing and launch.

21CSLC will complete a number of infrastructure modernization projects, including refurbishing the nitrogen supply line servicing KSC and the Eastern Range launch sites. In addition, the team will complete upgrades to the multiple-object-tracking radar that provides reliable tracking of spacecraft and debris to enable the range safety process. 21CSLC continues research into environmentally friendly coatings and corrosion preventative compounds to extend structural system life in the salt air, and completes air handler installation in the booster fabrication facility.

Ongoing work at WFF includes repairs and modifications to building X-75. The construction is a new second story to the existing structure that will provide an elevated and protected housing for critical Island communications systems. Additionally, work continues on relocating the Max Launch Abort System (100K) Launch Pad, the (50K) Large Sounding Rocket Launch Pad and Range Infrastructure at Wallops. The infrastructure upgrades include improvements of access roads, utility systems, launch pad concrete base, and associated infrastructure. Finally, work will begin to provide reliable power to the Northern Areas of the Island, including the Payload Processing Facility, by replacing the existing electrical feeder and installing a conduit and feeder in a loop layout for redundancy. WFF will begin installation of a fiber optic conduit system to facilitate future fiber requirements.

Key Achievements Planned for FY 2016

In FY 2016, 21CSLC will complete most planned projects and activities. The team will finish replacing old, deteriorating cable ducts that provide critical communications connection between KSC and the Eastern Range. Plans include facility design for eventual replacement/upgrade of the converter compressor facility, which supplies gaseous nitrogen and helium to processing and launch sites across the Florida Range. This project will accommodate the ever-increasing demand for these commodities. In addition, the team will complete range telemetry upgrades and AGSM will complete demonstration of integrated health monitoring capabilities on real world systems through collaborations with the development team.

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 as shown in the table below.

Project/Element	Element Content
Offline Manufacturing, Processing and Recovery Systems	Repairs and upgrades 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 and WFF activities with their estimated completion timeframes.

Date	Significant Event
Oct 2013	Pad B Flame Trench refurbishment design complete
May 2014	Eastern Range Lightning System upgrade complete
Nov 2014	Advanced Ground System Maintenance Interface to End to End Command and Control System demonstration complete
Apr 2015	50-megahertz Doppler project complete
May 2016	Crawler Transport jacking, equalization and leveling system cylinders complete
Jan 2016	Replace Island Primary Electrical Feeder complete

Program Management & Commitments

The Ground Systems Development and Operations Program Office (GSDO) manage both Exploration Ground Systems (EGS) and 21CSLC activities at KSC. GSDO manages customer requirements between SLS, Orion, and multiple other Government and commercial users to ensure implementation of cost-effective, synergistic design solutions. GSFC manages WFF activities.

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): KSC Cost Share Partner(s): N/A

21ST CENTURY SPACE LAUNCH COMPLEX

Program Element	Provider
Range Interface and Control Services	Provider: 21CSLC Lead Center: KSC Performing Center(s): ARC, JPL, GRC, GSFC Cost Share Partner(s): US Air Force
Mission Focused Modernization	Provider: 21CSLC Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A
Florida Launch Modernization Infrastructure	Provider: 21CSLC Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): US Air Force
Environmental Remediation and Technologies	Provider: 21CSLC Lead Center: KSC Performing Center(s): KSC Cost Share Partner(s): N/A
Wallops Flight Facility	Provider: 21CSLC Lead Center: GSFC Performing Center(s): WFF Cost Share Partner(s): N/A

Acquisition Strategy

To maintain flexibility and maximize affordability, NASA serves as its own prime contractor for implementation of the 21CSLC and WFF activities. GSDO executes customer ground infrastructure and processing requirements by leveraging center and programmatic contracts at KSC. GSFC executes the projects at WFF in the same manner. GSDO also uses pre-qualified IDIQ 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 includes activities of varying size and content. Several of the activities are within the scope of existing center contracts. A contract is competitively bided if the activity is not within the scope of an existing agreement or contract.

21ST CENTURY SPACE LAUNCH COMPLEX

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
50 megahertz Doppler Radar Wind Profiler	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 of this nature are not subject to the independent review process. In addition, the total funding for 21CSLC falls below the threshold required to initiate a review. The 21st Century activity was a product of the 2011 National Space Policy Launch Infrastructure and Modernization Plan (NSTP PPD - 4 Implementation Action # 6). NASA and the US Air Force 45th Space Wing (45SW) conduct periodic reviews of completed studies to define requirements for improvements and fund range modernization. The 45SW and KSC hold quarterly reviews to provide governance for the investments and track development and progress toward realizing operational capabilities. WFF identifies 21st Century candidate development projects to NASA HQ who approve these projects and fund them directly.

SPACE COMMUNICATIONS AND NAVIGATION

FY 2016 Budget

	Actual			Notional			
Budget Authority (in $ millions)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
Space Communications Networks	477.0	--	**539.7**	543.8	504.7	463.4	425.9
Space Network Ground Systems Sust.	*97.7*	*109.1*	***160.7***	*114.6*	*48.5*	*25.9*	*0.0*
Space Communications Support	61.5	--	**92.7**	115.9	111.9	134.2	150.5
Total Budget	**538.5**	**--**	**632.4**	**659.7**	**616.6**	**597.6**	**576.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

Engineers and technicians prepare to mount NASA's new Tracking and Data Relay Satellite L (TDRS-L) atop a United Launch Alliance Atlas V rocket for its January 2014 launch. This third generation satellite joined the existing TDRS fleet on orbit to replenish NASA's Space Network.

The Space Communications and Navigation (SCaN) program provides mission-critical communications and navigation services required by all NASA spaceflight missions. These missions range from high altitude balloons at the edge of Earth's atmosphere to science satellites in low Earth orbit and the most distant manmade object, Voyager 1, which left the solar system and is now over 12 billion miles from our planet. For all of these missions, SCaN retrieves science and spacecraft health data, uploads commands, and sends data to individual control centers. Navigation services determine precisely where a satellite is and where it is going to enable 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 provides secure, reliable, and adaptable communication services not only to NASA internal customers, but also non-NASA customers who use the space communications capabilities on a daily basis.

SCaN customers include the Hubble Space Telescope in Earth orbit, the Curiosity rover on the surface of Mars, and the New Horizons robotic mission on its way to Pluto. The program supports the ISS as well as its commercial and international servicing vehicles, and will support commercial crew providers and the SLS and Orion crew vehicle when they launch in the future. SCaN will also provide the vital communications link with the James Webb Space Telescope (Webb) after launch in late 2018.

SPACE COMMUNICATIONS AND NAVIGATION

Additionally, SCaN supplies services to foreign governments, international partners, and non-NASA US missions on a reimbursable basis.

SCaN provides customer missions with the required communications and navigation. Customer requirements include mission orbit, navigation needs, data rate, and how often communication opportunities occur. SCaN networks and the customer spacecraft must match technical parameters, such as radio frequency, data coding, modulation scheme, polarization, and error correction. SCaN supports new spacecraft that 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. Additionally, SCaN tracks and characterizes near Earth objects within nine million miles, and determines their orbits for use by the Science Mission Directorate's Planetary Science Division for collision avoidance with Earth. SCaN is working to upgrade this capability to a distance of 42 million miles, which increases the time to develop viable solutions for orbital collision.

SCaN's three communications networks, Space, Near Earth, and Deep Space, provide these critical services to customer missions. The Space Network communicates with missions in Earth orbit, and provides constant communication with the ISS. In the future, it will also support commercial crew and Orion missions. The Near Earth Network communicates with suborbital missions and missions in low Earth orbit, highly elliptical Earth, and some lunar orbits. The Deep Space Network communicates with the most distant missions, such as interplanetary probes.

These three networks require maintenance, replenishment, modernization, and capacity expansion to ensure service for existing and planned missions. SCaN also purchases ground communications links from the NASA Integrated Services Network to move data between ground stations, NASA centers, and mission operation and data centers. SCaN has recently begun the systems analysis to determine how to effectively manage the networks as one entity, providing efficiency of operations and cost savings.

The TDRS Replenishment project has purchased three third-generation TDRS spacecraft for the Space Network that will ensure adequate services to customers into the early 2020s. Two are currently on orbit, and one is nearing the end 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 functions to efficiently integrate and plan current and future network capabilities to meet customer mission needs while reducing costs. These 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The Space Network Ground Segment Sustainment (SGSS) shifts the planned implementation of a major operational capability upgrade from FY 2016 to a date to be determined, pending approval of a budget and schedule replan.

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

FY 2016 Budget

		Actual	Enacted	Request	Notional					
Budget Authority (in $ millions)	Prior	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	BTC	Total
Formulation	125.8	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.0	125.8
Development/Implementation	79.3	97.7	--	--	--	--	--	--	--	TBD
Operations/Close-out	0.0	0.0	--	--	--	--	--	--	--	0.0
2016 MPAR LCC Estimate	**205.1**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**TBD**
Total Budget	**205.1**	**97.7**	**109.1**	**160.7**	**114.6**	**48.5**	**25.9**	**0.0**	**0.0**	**556.4**
Change from FY 2015				**51.6**						
Percentage change from FY 2015				**32.1%**						

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015. For projects in development, NASA's tentatively planned FY 2015 funding level is shown. FY 2015 funding levels are subject to change pending finalization of the FY 2015 operating plan.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

The SGSS project will update the budget and lifecycle cost (LCC) after completion of the pending review in summer 2015.

PROJECT PURPOSE

NASA’s science and human missions, such as the Hubble Space Telescope, ISS, and future Orion crew vehicle, require communication and navigation services. NASA’s Space Network provides these services with a fleet of 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, and amplifiers; and enough scheduling and control software to execute more than 145,000 mission passes per year.

Space Network ground stations, built in the 1980s, are becoming more difficult and expensive to maintain because manufacturers no longer support much of the equipment and software currently in use. Occasionally, it has been necessary for NASA to procure used components that require modifications before they can function in the network ground stations. Beyond the increased costs for maintenance and repair, the age and wear of the systems increases the risk that ground system failures will disrupt services to customers. If such disruptions occur, customers could lose critical science data or even spacecraft.

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

Operators work the consoles of NASA's Space Network ground control complex at White Sands, New Mexico. The network operates 24 hours a day, 7 days a week to ensure continuous communication with orbiting spacecraft and the International Space Station. To ensure that the network maintains its near 100 percent availability record, the Space Network Ground Segment Sustainment project works continuously to update equipment and software used to operate the Space Network.

In order to maintain reliable communications services to customer missions, the Space Network Ground Segment Sustainment (SGSS) project is replacing outdated and expensive 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 current 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. The SGSS concept and architecture will bring the Space Network into the digital age, providing decades of reliable service. NASA's approach to SGSS will reduce the cost of operations and maintenance by eliminating major periodic refurbishments or high-cost upgrades while continuing to increase capability and robustness.

EXPLANATION OF MAJOR CHANGES IN FY 2016

SGSS successfully completed the Technical portion of the CDR in 2013, confirming stable project design requirements. Early in FY 2014, NASA identified contractor inefficiencies as well as poor schedule and cost performance. Close scrutiny of the overall SGSS status, including the final budget estimate and scheduled completion date, resulted in a new management plan, changes to software coding metrics, a new management team, a new work breakdown Structure (WBS), and a new cost estimate at completion. The new software coding metrics allow near real-time feedback resulting in more accurate schedule monitoring and better resource allocation. They also allow the project to identify problems more quickly and to implement mitigation plans sooner and with more accuracy. The first installations of this new system hardware and software will begin in FY 2016.

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, 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.

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

ACHIEVEMENTS IN FY 2014

The SGSS project continued with major procurements and software coding, reorganized the project to better align with the development effort, and submitted a revised cost estimate to NASA management for review. NASA informed Congress of these activities via the FY 2014 operating plan and subsequent required notification letter. The reorganized workforce, changes in software coding, and changes in management improved performance efficiencies. Schedule milestones and cost at completion were under review as of the end of FY 2014.

WORK IN PROGRESS IN FY 2015

Members of the independent SRB, select members of the GSFC project team, senior managers from the SCaN program office, and managers from NASA Headquarters reviewed the revised cost to complete estimate and management plans from the prime contractor, General Dynamics. The Agency Program Management Council reviewed and approved a path forward to arrive at a new program baseline in summer 2015 while achieving specific project milestones and deliveries in FY 2015. Members of the GSFC project continue to monitor activity and progress at the contractor plant, prior to system deployment and transition activities. Improvements are evident on performance metrics due to closer alignment between the civil service and contractor staff and a clearer understanding of successful component parts leading to system integration and testing.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, the project will begin deployment to the WSC. This is an important step towards achieving the new, modernized Space Network, which will enable state of the art communications capability with the ISS, SLS, Orion, and other orbiting spacecraft well into the 21st century.

SCHEDULE COMMITMENTS/KEY MILESTONES

Milestone	Confirmation Baseline Date	FY 2016 PB Request
Formulation Authorization (complete)	Nov 2011	Nov 2011
PDR (complete)	Jul 2012	Jul 2012
KDP-C	Oct 2012	Mar 2013
CDR	May 2013	Aug 2013
SIR	Aug 2015	Under review*
KDP-D	Sep 2015	Under review*
ORR	Jun 2016	Under review*

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

Milestone	Confirmation Baseline Date	FY 2016 PB Request
FAR	Jun 2017	Under review*

**Pending review summer 2015.*

Development Cost and Schedule

The cited development cost is for SGSS.

Base Year	Base Year Develop-ment Cost Estimate ($M)	JCL (%)	Current Year	Current Year Develop-ment Cost Estimate ($M)	Cost Change (%)	Key Milestone	Base Year Milestone Data	Current Year Milestone Data	Milestone Change (mths)
2013	368.1	70	2014	TBD		FAR	Jun 2017	Under review*	11 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.

**Pending review summer 2015.*

Development Cost Details

Element	Base Year Development Cost Estimate ($M)	Current Year Development Cost Estimate ($M)	Change from Base Year Estimate ($M)
TOTAL:	**368.1**	**Under review**	**N/A**
Ground Systems	368.1	Under review*	N/A

**Pending review summer 2015.*

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

Project Management & Commitments

The SGSS Project Office at GSFC manages the project.

Element	Description	Provider Details	Change from Baseline
SGSS	Replace outdated and deteriorating ground systems at Space Network ground terminals	Provider: SGSS Project Office Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): Non-NASA US government partners	Under review*

**Pending review summer 2015.*

Project Risks

Risk Statement	Mitigation
If: SGSS operational delivery is delayed, Then: The Space Network will continue to use existing, high-risk ground systems that are costly to operate.	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.

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 planned.

MAJOR CONTRACTS/AWARDS

Element	Vendor	Location (of work performance)
SGSS	General Dynamics C4 Systems	Scottsdale, AZ

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

INDEPENDENT REVIEWS

NASA established an SRB to perform the independent reviews of the Space Network Ground Segment Sustainment project in accordance with NPR 7120.5.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
System Require-ments Review	SRB	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
KDP-B	SRB	Feb 2012	Determine if requirements definition and associated plans are sufficient to begin project implementation.	Complete	None
Technical Preliminary Design Review	SRB	Jul 2012	Determine if project is ready to proceed with detailed design of hardware and software elements.	Complete	None
KDP-C	SRB	Mar 2013	Determine if project is ready to proceed with formal development.	Complete	None
CDR	SRB	Aug 2013 and other dates TBD	Determine if project is ready to proceed with production of hardware and software elements.	Pending*	Pending*
Cost and Schedule Baseline Recertification	SRB	Summer 2015	Independent Review of SGSS replan.	Pending	N/A

**Pending review summer 2015 for budget and schedule. Technical CDR completed.*

SN GROUND SEGMENT SUSTAINMENT(SGSS)

Formulation	Development	Operations

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

Issues	Corrective Action Plan
Issue 1: While architecture and top level requirements approved by the SRB, lower level requirements, cost, and schedule was deemed inadequate for an assessment. 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.	Plan forward reviewed and accepted by Agency Program Management Council in November 2014; work is underway to achieve a new program baseline in summer 2015. In parallel, SGSS development continues on a work plan agreed to by SCaN and the prime contractor for FY 2015.

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**477.0**	**--**	**539.7**	**543.8**	**504.7**	**463.4**	**425.9**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

The 34-meter antenna at Deep Space Station 35 (DSS-35) in Canberra, Australia is readied to support Deep Space Network operations. SCaN networks provide support to NASA and other missions and have facilities located around the world. Teamed with other facilities around the world, DSS-35 supports deep space and interplanetary missions as part of NASA's Space Communications Networks.

The Space Communication and Navigation (SCaN) Program manages NASA's three space communications networks: the Space Network (SN), Near Earth Network (NEN), and Deep Space Network (DSN). 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 in order to continue providing proficiency at or above 95 percent for over 100 customer missions.

The Space Network provides continuous global coverage to NASA missions in low Earth orbit, during vehicle launch and ascent phase. It is the primary US communications link to the ISS, as well as for ground and balloon research in remote locations, such as the South Pole. The Space Network consists of NASA's TDRS system of communications satellites in geosynchronous orbit, a set of space-to-ground link terminals at NASA's White Sands Complex (WSC) in New Mexico, remote space-to-ground terminals in Guam, and, in the future, at Blossom Point, Maryland. Customer missions communicate with the TDRS spacecraft, which relay signals to and from the ground terminals. Modernizing this critical network is one of the Agency's top priorities. To accomplish this, SCaN's Space Network Ground Segment Sustainment (SGSS) project works to replace obsolete ground terminal equipment that is nearing the end of its life cycle.

NASA's current TDRS fleet consists of four first-generation satellites placed into orbit 19 to 24 years ago, three second-generation satellites that have provided services for more than a decade, and two new third-generation satellites. The four original first-generation satellites are well past their expected life cycle and are showing signs of age-related battery and electronics failures. Three new third-generation

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

satellites, TDRS-K, L, and M, are prepared to or have joined the fleet. TDRS-K and L are operating, and TDRS-M is in production.

The NEN provides space communications to 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 WSC, 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 DSN provides space communications capabilities to missions from outside low Earth orbit to those beyond the edge of the solar system, such as the Voyager spacecraft. The network's ground stations are spaced approximately 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 DSN Project Office at JPL manages operations, maintenance, and upgrades.

The DSN Aperture Enhancement effort modernizes and upgrades the DSN'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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

During the fiscal year, the Space Network supported over 25 missions, with over 175,000 hours of tracking and more than 145,000 passes. TDRS-L launch in FY 2014, followed by successful on-orbit testing, resulted in a transition to operations. SCaN successfully conducted the System Integration and Pre-Environmental Test Readiness Reviews for the TDRS-M spacecraft. Along with TDRS-K, these two spacecraft are critical to ensuring Space Network capacity and reliability to support NASA missions into the foreseeable future. The Space Network provided the primary US communications link with the ISS, and supported 14 launches, including NASA's Global Precipitation Measurement (GPM), Orbiting

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

Carbon Observatory – 2 (OCO-2), Mars Atmosphere and Volatile EvolutioN (MAVEN), and TDRS-L, as well as two Orbital Cygnus and two SpaceX Dragon missions to the ISS.

The NEN supported nearly 30 missions daily, with over 35,000 hours of tracking and more than 45,000 passes; support to customers included providing space communications capabilities to the Cygnus Orb-2 commercial cargo resupply spacecraft through the WSC. While attached to the ISS, the NEN also supported the Cygnus Orb-2 commercial cargo resupply spacecraft by providing a series of special commands, uplinked for spacecraft testing. In addition, the NEN completed the new Alaska Satellite 3 (AS3) antenna two months ahead of schedule, transitioning it to operations and successfully supporting launch of OCO-2. The new AS3 antenna is located at the Alaska Satellite Facility in Fairbanks, and will provide NEN coverage to collect data from NASA's polar orbiting satellites.

The DSN provided space communications capabilities to approximately 35 missions, with over 100,000 hours of tracking spread over more than 18,000 passes. The network supported the launch and early orbit phases of both the Indian Space Agency Mars Orbiter (ISRO) Mars Orbiter Mission (MOM) and MAVEN, with subsequent Mars orbit insertion several months later.

DSS-35, the first of two 34-meter DSN Aperture Enhancement Beam Wave Guide antennas at the Canberra Deep Space Communications Complex, transitioned to operations. These new antennas use state of the art equipment, and will provide space communications capabilities to missions from the Southern Hemisphere. DSS-35 will mitigate the lack of Southern Hemisphere assets necessary for 2014 to 2024, when many deep space satellites have similar mission views and are competing for limited Southern Hemisphere resources.

WORK IN PROGRESS IN FY 2015

The three space communications networks will provide a level of service similar to those provided in FY 2013 and FY 2014.This includes over 208,000 tracking passes, totaling more than 310,000 hours, while maintaining an extremely high level of proficiency (approximately 99.94 percent or higher), well above the 95 percent required by the SCaN Program Commitment Agreement.

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 addition, the networks support key human space flight programs, such as Orion's successful Exploration Flight Test-1 (EFT-1), as well as the ISS and its commercial cargo missions.

NASA will continue to replenish the networks by addressing ongoing obsolescent equipment. By continuing to upgrade and replace existing antennas at its communication complexes as part of the DSN modernization program, NASA will ensure necessary deep space communications required for its current and future deep space missions. 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 support operations at Canberra, and DSS-36 will continue with construction and assembly. These new antennas will transmit

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

and receive across a wide range of radio frequencies for deep space communication with interplanetary robotic spacecraft to provide required capabilities for the expected growth of deep space missions launching over the next decade.

The new TDRS-L and to-be-launched 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. Once all three spacecraft are accepted, the Space Network will have adequate capacity for its expected mission set until the second-generation TDRS begin retiring in the early 2020s. SGSS is undergoing a baseline replan to address past performance issues and align content, cost, and schedule with Space Network needs and available resources. NASA will submit the replan to Congress in the summer of 2015 for approval. (See SN Ground Segment Sustainment (SGSS section).

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The three space communications networks will continue to maintain network high proficiency levels and supportability for all NASA and non-NASA mission customers. The Space Network will focus attention on modernization of new ground station hardware and software under the SGSS project. Near the end of FY 2016, the Space Network will have its first opportunity to begin testing on new SGSS equipment. The DSN will accept the DSS-36 antenna at Canberra Deep Space Communications Complex for operations, and commence construction of the DSS-53 34-meter antenna at the Madrid, Spain complex.

All three networks will continue to identify and implement methodologies, processes, and equipment intended to help shape and achieve improvements over historical operational efficiencies and goals. System engineering planning and conceptual design options will be carried out by engaging representatives from all three networks, and will play an active role for communications and data transmission planning for future robotic and human space flight missions, including NASA Orion and SLS vehicle development.

Project Schedule

NASA's space communications networks provide ongoing services to Agency and customer missions, averaging about 600 tracking passes a day; providing this routine, daily service is their key function. Without these capabilities, customer missions like Hubble, ISS, New Horizons, Opportunity, and Voyager would fail. In order to assure continued functionality at expected levels, NASA is replenishing its networks, as noted below.

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

Date	Significant Event
Q1 FY 2015	DSS-35 antenna acceptance into the DSN for operational use
Q3 FY 2015	TDRS-M completed development and placed in storage
Q1 FY 2016	DSS-36 antenna acceptance into the DSN for operational use
Q1 FY 2016	Initial construction of DSS-53
Q3 FY 2016	Initial construction of DSS-56

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
NEN	Communication and navigation services to customer missions in low Earth, highly elliptical, and lunar orbits	Provider: NEN Project Office Lead Center: GSFC Performing Center(s): N/A Cost Share Partner(s): Non-NASA customers	N/A
DSN	Communication and navigation services to customer missions in deep space	Provider: DSN Project Office Lead Center: JPL Performing Center(s): N/A Cost Share Partner(s): Non-NASA customers	N/A
NASA Communications Services Office (CSO)	SCaN purchases ground communication services for NISN	Provider: CSO, through NASA Chief Information Officer Lead Center: NASA HQ Performing Center(s): MSFC, GSFC Cost Share Partner(s): N/A	N/A

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

Element	Description	Provider Details	Change from Formulation Agreement
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, as well as competitive procurements. NASA's JPL provides the management of the DSN.

MAJOR CONTRACTS/AWARDS

No major contracts or awards are planned for FY 2016.

Element	Vendor	Location (of work performance)
DSN	JPL	Pasadena, CA
Space Network Operations	Exelis	McLean, VA
NEN Operations	Exelis	McLean, VA
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
TDRS-L ORR/FRR	SRB	Nov 2013	Assess if all systems are operationally ready for the spacecraft and if the spacecraft is ready for flight	Passed	LRD

SPACE COMMUNICATIONS NETWORKS

Formulation	Development	Operations

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
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	SRB	Jun 2014	Assess if TDRS-L is ready to be accepted by the Government	Passed	
NASA Office of Inspector General Review	NASA OIG	Ongoing	Assess SCaN Program and Projects	Ongoing	Space Network complete; DSN in process

SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	61.5	--	92.7	115.9	111.9	134.2	150.5

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

This graphic depicts SCaN's optical communications technology development with the Lunar Laser Communications Demonstration (LLCD). During NASA's Lunar Atmosphere and Dust Environment Explorer mission, LLCD used a pulsed laser beam to transmit data across the 239,000 miles from the moon and Earth, at a record-breaking 622 megabits per second – about five times faster than ever before. LLCD is NASA's first system for two-way communication using a laser instead of radio waves, and it promises to provide the capacity needed for the growing data demands of telescopes, probes and rovers in the coming years.

NASA's SCaN program has a long history of service reliability and proficiency, but that success does not come easily. Maintaining a high level of performance requires the extensive planning, management, and technology efforts of the Space Communications Support project.

SCaN's architecture planning and systems engineering ensure that customer missions operate together with NASA networks by defining technical services, capacity, and performance to eliminate duplication across networks, minimize mission-unique requirements, and lower development and operations costs.

Like the technological advances that have so radically changed the way we communicate with each other, evolving space communication systems can transform NASA mission capabilities in ways we can only imagine today. SCaN's technology development effort invests in leading edge communications technology, and enables, improves, and matures available technologies to build systems and capabilities for ground-based and spacecraft communication and navigation use.

Operating in space requires significant international coordination. SCaN's standards development and management activity maintains a portfolio of internationally agreed upon interoperability standards that enable joint space missions with other nations. SCaN also promotes new technologies, and provides technical leaders and domain experts who ensure that appropriate space communication standards are available to NASA missions.

SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations

Amid soaring demand for wireless broadband, such as 3G and 4G mobile services, spectrum management has become more and more critical to the world's spacefaring nations. SCaN coordinates nationally and internationally to protect radio frequencies critical to NASA space missions. The SCaN team ensures that all Agency activities comply with rules and regulations applicable to the electromagnetic spectrum, and advocates for radio frequencies to remain available for NASA use.

Just as the Global Positioning System (GPS) receiver in your car or smartphone uses satellite and ground stations to pinpoint your location on the Earth, GPS systems provide precision positioning, navigation, and timing for vehicles in space. This allows NASA to maximize spacecraft autonomy, and enables precise space flight methods, such as formation flying. SCaN manages NASA's policy on GPS use and plays a major role on the international front, ensuring compatibility and interoperability among spacefaring nations, promoting common definitions and specifications, and mitigating threats to the GPS spectrum.

For more information, go to: https://www.nasa.gov/scan/.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

NASA's vision for the future SCaN network architecture is to build and maintain a scalable and integrated infrastructure, leveraging commercial service providers where possible, that provides comprehensive, robust, and cost effective space communications services at order-of-magnitude higher data rates to enable NASA's science and exploration missions. This infrastructure can readily evolve to accommodate new and changing technologies and will preserve current capabilities to support user mission critical events and emergencies.

As part of this evolution, SCaN conducted the systems requirements review for the Phase 2 network in FY 2014. This will provide customers an internationally interoperable unified interface, and a more integrated internal approach for NASA's networks. SCaN completed updates to the systems engineering management plan for implementing the unified network, and initiated studies focused on future mission needs through the 2030s, and Phase 3 architecture changes.

In April, SCaN completed the LLCD from aboard SMD's Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft in orbit around the Moon. This experiment demonstrated for the first time laser communications between the Earth and the Moon at data rates over six times higher than current radio frequency systems. LLCD achieved error-free operation during daylight, and continued the laser signal while moving between three ground stations. A first for NASA, LLCD downloaded science data from LADEE and streamed high-definition video to the Moon and back. This evolving laser communication technology will enable future missions to transmit at higher data rates, reducing mission costs and providing opportunities for new exploration and science missions, as well as commercial services for the nation's satellite communications industry.

SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations

The SCaN testbed aboard the ISS continued to mature software-defined radio technology, reducing risk to future missions using flight-proven software-based applications. The testbed provided approximately 2,000 hours of ISS utilization for science; extended the lifetime of communications infrastructure in space; supported over two dozen experiments; and engaged in partnerships with universities, other US government agencies, international space agencies, and private industry.

In collaboration with HEO's Advanced Exploration Systems, SCaN demonstrated antenna array data uplink with the high resolution Ka-Band Objects Observation and Monitoring (KaBOOM) system, developed to better track asteroids, comets, and orbital debris. Utilizing two antennas at the Goldstone DSN Complex in California, KaBOOM demonstrated real-time compensation of atmospheric twinkling, while transmitting a signal to the Mars Reconnaissance Orbiter. Signals were also uplinked to a commercial satellite using two KaBOOM antennas at KSC. Ultimately, NASA hopes this improved image resolution will enable radar images of near- Earth objects to see details as small as five centimeters, or the size of a golf ball. Today, NASA's best radar images are limited to 400 centimeters, or about the size of a bedroom.

WORK IN PROGRESS IN FY 2015

Continuing the evolution of NASA's space network architecture, in February SCaN will conduct a Phase 2 SDR for the future unified network, to update requirements and establish the technical baseline and management approach. Pre-formulation studies of future network capabilities for Phase 3 are underway, including the next generation of space-based near-Earth and deep space communications capabilities to support human deep space exploration and advanced robotic missions.

SCaN will leverage LLCD success at the Moon to continue developing the Laser Communications Relay Demonstration (LCRD) for near-Earth applications in partnership with NASA's Space Technology Mission Directorate (STMD), as well as commercial satellite providers and operators. The LCRD project will build two flight optical modules based on the flight-proven LLCD design, but with NASA-commercialized subcomponents. LCRD will develop a new high data rate modem, designed for use in geosynchronous Earth-orbit relay environments, and plans to commercialize the design.

SCaN has initiated a study to place a laser communications terminal, known as the low Earth orbit terminal, on the ISS in the 2019 timeframe. This unit will work with LCRD to demonstrate the laser-based analog of current radio frequency relays through NASA's TDRS. Additionally, SCaN will complete Deep Space Atomic Clock integration and environmental testing, and deliver results to the commercial host spacecraft provider in mid-FY 2015.

SCaN standards development and spectrum management activities will continue through FY 2015. Standards development and management will develop a proposal for international near-Earth and deep space laser communications standards, and work with the ISS program to provide a near-term radio frequency identification-encoding standard to support ISS requirements. The spectrum management effort will continue to protect GPS frequencies from introducing incompatible commercial mobile phone services into adjacent frequencies. NASA will submit analysis to the national regulators, the National

SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations

Telecommunications and Information Administration and Federal Communications Commission, to support a US decision on this issue.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Efforts will continue to advance NASA's space network architecture, concept of operations, requirements and cost estimating.

NASA will continue to utilize the SCaN testbed aboard the ISS to perform experiments with an operational software-defined radio. SCaN plans to provide international network interoperability with the National Space Study Center at France, as well as additional test support to TDRS and adaptive coding, and modulation capability for testbed users. Additionally, engineers will continue evaluating LLCD results and incorporate them into planning for an on-orbit laser communications relay demonstration.

The Deep Space Atomic Clock will launch on a commercial host spacecraft, with subsequent operations to demonstrate increased timing and accuracy for precision deep space navigation. By the end of the year, SCaN's Deep Space Optical Communications project will mature this technology for deep space missions.

SCaN will continue to advance standards for network management, network security, and data delivery, as well as complete foundation development for a space internetworking protocol to pave the way for space-based Internet. NASA will lead the effort to define a single, new, unified space link protocol for space communication.

Project Schedule

Date	Significant Event
Q2 FY 2015	SCaN Program Phase 2 SDR
Q3 FY 2015	Deep Space Atomic Clock ships to Commercial Spacecraft Host (Surrey)
Q4 FY 2015	Laser Communications Relay Demonstration CDR
Q2 FY 2016	Deep Space Atomic Clock Launch
Q4 FY 2016	ISS LEO Terminal PDR
Q4 FY 2016	All component designs of the Deep Space Optical Communications system are flight-qualified by ground testing (TRL 6) for selection on the Discovery 2014 mission

SPACE COMMUNICATIONS SUPPORT

Formulation	Development	Operations

Project Management & Commitments

The SCaN Program Office at NASA Headquarters manages Space Communications Support functions.

Element	Description	Provider Details	Change from Formulation Agreement
Space Communicat-ions Support	Provides critical communication and navigation architecture planning, systems engineering, technology development, standards development and management, spectrum management, and policy and strategic communications for NASA	Provider: NASA Responsible Center: HQ	N/A

Acquisition Strategy

Space Communications Support functions use multiple small contracted efforts, most of which are support services functions.

MAJOR CONTRACTS/AWARDS

NASA's LCRD plans to award the hosted payload integration contract to Space Systems Loral (SSL) in Mountain View, CA in FY 2016; SSL was selected in an earlier competition to provide hosted payload services to NASA.

INDEPENDENT REVIEWS

None.

HUMAN SPACE FLIGHT OPERATIONS

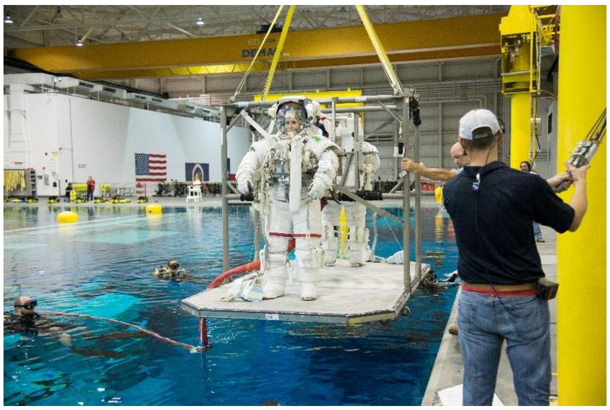
FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**106.5**	**--**	**108.5**	**110.2**	**110.5**	**110.5**	**111.6**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.



European Space Agency astronaut Samantha Cristoforetti, Expedition 42/43 flight engineer, is lowered into the Neutral Buoyancy Laboratory near NASA's Johnson Space Center. Divers assist Cristoforetti in this extravehicular activity rehearsal, which will prepare her for work on the exterior of the International Space Station.

Through more than 53 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 Project Mercury, the very core of human space exploration is the crew. Today, from anywhere with an Internet connection, people on Earth can watch NASA's skilled astronauts in high definition, engaged in daily life on the ISS. The Human Space Flight Operations (HSFO) program supports the training, readiness, and health of crewmembers prior to, during, and after each space flight mission to the ISS. All crews on board the Space Station have undergone rigorous preparation, which is critical to mission success. Within the HSFO program, the Space Flight Crew Operations (SFCO) element provides astronaut selection and training while the Crew Health and Safety (CHS) element manages all aspects of astronaut crew health.

At the next step in human space exploration, the Agency is developing the transportation system that will carry crew to destinations beyond Earth's orbit. NASA must also prepare the human system for living and working for extended periods in the hostile environment of space. As astronauts travel further from Earth, many questions come to mind. What health risks will astronauts face and how are they resolved? What kind of training will crews need to prepare for months of travel in the harsh space environment? How will they deal with medical emergencies or technical anomalies when Earth is no longer within reach? CHS, in collaboration with NASA's Office of Chief Health and Medical Officer and HEO's Human Research Program (HRP), answers these questions and others to ensure crew health, safety, and mission success. SFCO and CHS are responsible for astronaut training, readiness, and health while HRP funds development of human health and performance countermeasures, knowledge, and technologies that enable safe, reliable, and productive human space exploration.

HUMAN SPACE FLIGHT OPERATIONS

EXPLANATION OF MAJOR CHANGES IN FY 2016

Astronaut candidate class selections slipped from FY 2015, FY 2017, and FY 2019 to FY 2016, FY 2018, and FY 2020 to better align with ISS and Exploration manifest requirements.

ACHIEVEMENTS IN FY 2014

After medical evaluations demonstrated vision changes in some crewmembers, CHS convened a visual impairment/intra-cranial pressure (VIIP) panel, consisting of domestic and international experts. In response to the panel's recommendations, CHS is implementing new, targeted solutions and monitoring strategies to screen long-duration crewmembers for vision problems, support real time medical operations aboard the ISS, and monitor and rehabilitate returning crews. Personnel have also developed modified medical standards for a 12-month mission scheduled for 2015, based on NASA's improved understanding of the VIIP syndrome.

Another crew health concern for long-duration space exploration is loss of bone mass as high as ten times that of osteoporosis. Over a six-month period, a crewmember can experience as much as 10 percent mass loss in the femoral bone; recovery after returning to Earth can take three to four years or more. In order to determine effective countermeasures to reduce risk to crew health, CHS supported a second Bone Health Summit with the Research and Clinical Advisory Panel to identify potential areas for improvement in NASA's bone health program. The Astronaut Occupational Health Program is addressing expert-developed recommendations to review new methods of monitoring and mitigating long-term bone and muscle loss for application to longer missions.

Also in FY 2014, CHS provided crew surveillance during training and on-orbit activities associated with ISS rodent research, to identify and mitigate allergic responses or any injuries that may arise from animal exposure.

During the year, SFCO provided trained astronauts for crew rotations to the ISS and developed a "living-in-space" expeditionary training course to strengthen and better simulate the natural environment on board the ISS. This course will enhance crew effectiveness on orbit and simulate real ISS operations. SFCO also collaborated with Johnson Space Flight Center Mission Operations Directorate, the ISS Program, and international partners to shorten the 30-month crew training flow. This will reduce crew travel, curb cost, and improve crew training efficiency. SFCO continued direct crew return and mission support, transporting returning astronauts back to the US within 24 hours of landing. The project continued to evaluate and promote improved designs for the next generation assent and entry, and extravehicular activity space suits, including an extravehicular mobility unit upgrade needed to reduce astronaut injury and accommodate greater range of motion.

WORK IN PROGRESS IN FY 2015

In an ongoing effort to address crew health and safety concerns, CHS will implement new health-targeted solutions and monitoring strategies, aimed at supporting real-time medical operations aboard the ISS, while continuing to rehabilitate crew members returning to Earth. During FY 2015, CHS will continue to conduct its lifetime surveillance program, which involves monitoring retired astronauts for adverse health outcomes associated with being an astronaut. Analysis of data collected under the surveillance program benefits NASA by increasing understanding on the long-term health risks of human space flight.

CHS will work with and inform internal and external stakeholders, including the National Institutes of Health (NIH), and the National Academies concerning NASA progress towards remediating the adverse effects of long-duration space travel. This will enable the Chief Health and Medical Officer and NASA's international counterparts to develop medical standards and criteria for long-duration missions and, especially, prolonged radiation exposure. CHS will standardize medical and exposure data into a single integrated system for US and participating international crew, which will provide private and governmental researchers an opportunity to access astronaut health information accumulated over time. Crew health and safety information is needed for all domestic and international partners supporting crew clinical care, and vital data management for human research communities.

CHS will develop mitigation strategies, techniques, and clinical procedures, aimed at improving bone and muscle loss through an effective monitoring program, and will continue to characterize and develop mitigation strategies for VIIP risk through comprehensive monitoring and improved imaging techniques. CHS will also provide crew surveillance during training and on-orbit activities associated with animal research experiments. The goal is to develop a mitigation strategy regarding possible allergic responses or injuries that may arise from animal exposure.

Through NASA's Commercial Crew Program, NASA will begin ferrying astronauts to and from the ISS aboard US commercially built vehicles. In FY 2015, crew assignments and training will begin for FY 2017 and later flights to the ISS; the astronaut class of FY 2013 will be eligible for flight assignments during this time. To ensure mission success, HSFO will continue crew training, health monitoring, and safety during the transition from Russian Soyuz transportation to new US commercial crew vehicles.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, SFCO will begin preparations and conduct interviews to select a new astronaut class. As part of the selection process, new behavioral competencies and human skills assessment tools will screen astronaut candidates for non-technical skills necessary to support missions exceeding six months in duration. This is especially critical for missions beyond low Earth orbit, where crew will travel in smaller vehicles for longer durations without the benefit of real-time communication with the ground.

CHS will provide clinical services to the first NASA astronaut returning from the 12-month ISS mission. Clinical services will include reconditioning needed to return the crewmember to a health status suitable to resume post-mission activities. CHS will also provide clinical and behavioral support to ISS Expeditions 45 through 48, including pre-mission medical readiness assessments and treatments, in-flight clinical and behavioral support, and post-flight reconditioning.

Since the early days of human space flight, NASA has accumulated and archived crew health and safety data for use by the human health clinical research community. During FY 2016, CHS Data Management and Epidemiology teams will update crew health data architecture and analytics to guide CHS-hosted working groups. This will result in increased quantity and quality of crew health and safety data to research and clinical communities.

In FY 2016, HEO's HRP will transition the Integrated Medical Model 4.0 to CHS. This updated risk prediction tool will offer new capabilities, such as randomizing crew heath events throughout a mission and quantifying the impact of partial or alternative medical treatment options against adverse health outcomes. An updated Radiation Risk Model, employing a multiple exposure modeling capability, will become operational. This enhancement will refine radiation risk projections to astronauts, and take into account the dose effects of multiple space flight missions as well as non-space flight radiation exposure.

CHS will continue the lifetime surveillance program, monitoring retired astronauts for adverse health outcomes related to their service with NASA. Data collection under this surveillance program will continue to broaden our understanding of the long-term health risks of human space flight.

Program Elements

SPACE FLIGHT CREW OPERATIONS (SFCO)

SFCO provides trained astronauts for all NASA human space flight efforts. 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 that space flight readiness training requirements continue to support ongoing ISS operations, planned exploration, and commercial development.

SFCO is responsible for astronaut training, consistent with recommendations reported in the National Academies' report, Preparing for the High Frontier, released September 7, 2011. As part of its annual planning, the project ensures all astronaut training is consistent with ISS and Exploration manifest requirements. The minimum manifest requirement is based upon the number of spacecraft seats US astronauts must fill in the next five years to support the human space flight manifest and includes ISS via Soyuz, as well as projected Commercial Crew and Orion/SLS development flights. Today, it takes three years from the decision to select a new astronaut class until the process is completed. New astronauts must complete 12-18 months of training for eligibility and then 30 months of ISS training before a new astronaut reaches the ISS. Astronaut training activities, overseen by SFCO, include launch and landing operations, ability to respond in an emergency/high-stress environment, high performance aircraft operations skills, flight vehicle maintenance, payload and science experiment operator skills, extravehicular activities, Russian language skills, robotics (including free-flier capture), and ISS systems knowledge.

CREW HEALTH AND SAFETY (CHS)

CHS enables healthy and productive crew during all phases of space flight missions, implements a comprehensive astronaut occupational health care program, and works to prevent and mitigate negative long-term health consequences from exposure to the space flight environment. Using HRP research findings, CHS implements changes to astronaut occupational health protocols to ensure crew health and safety. CHS also medically assesses astronaut candidates as part of the selection process. In this collaboration, HRP concentrates on the research aspects of crew health, whereas CHS focuses on implementing the research results into occupational health 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.

CHS is also responsible for maintaining the health of active astronauts during non-mission periods, focusing on three aspects of health care: preventive care, risk factor management, and long-term health monitoring. CHS integrates and coordinates information relevant to the human health before, during, and after space flight. CHS documents and assesses all emerging health risks, such as visual impairment and intracranial pressure (VIIP) syndrome. CHS has continued to collaborate with a number of non-NASA organizations to include the National Academies, which recently delivered a report that provides a unique ethical framework for risk decisions associated with long duration and exploration missions. This report is entitled *Health Standards for Long Duration and Exploration Spaceflight: Ethics Principles, Responsibilities, and Decision Framework*.

Program Schedule

Date	Significant Event
Nov 2014	Astronaut Class of 2013 Group A training for long duration flight
Jan 2015	Gulfstream III Engine Hash Kit Installation (FAA Mandate)
Feb 2015	Astronaut Class 2013 Group B training for long duration flight
Aug 2015	Astronaut Class of 2013 graduation of Group A and B candidates
Jun 2016	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

Acquisition Strategy

The section below identifies the current contract(s) that support SFCO and CHS.

HUMAN SPACE FLIGHT OPERATIONS

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
Indepen-dent 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 National Academies' conclusions largely reinforced NASA decision making and approach to crew training.	N/A
Perform-ance	National Academies	Jul 2012	At the request of NASA, a National Academies committee reviewed NASA HRP's Scientific Merit Assessment Processes for directed research.	The 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

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Perform-ance	National Academies	Jul 2012	The National Academies' 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 provided a report to NASA March 2014. Ethical Considerations: Institutes of Medicine guidelines will be used in the future to advise any situation or standards where exposures may exceed current limits. Physiologic Risks: NASA has a multifaceted approach to identifying and mitigating risks to human physiology when exposed to the environment of space flight including health monitoring and assessment, review boards, Astronaut Occupational Health Program, and HRP.	N/A

LAUNCH SERVICES

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**80.9**	**--**	**86.7**	**88.0**	**89.1**	**89.1**	**90.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft soars from Space Launch Complex 41 at Cape Canaveral Air Force Station in Florida. After a 10-month journey to the Red Planet, MAVEN entered Mars orbit in September 2014 to study its upper atmosphere in unprecedented detail.

Utilizing commercially available domestic launch services, the LSP has provided affordable and reliable space access for science exploration, communication, weather, and technology development for over 16 years. NASA science and technology missions need these launch services to get into space and begin their critical work.

Acting as a technical expert broker, LSP matches science and communication spacecraft with commercially available launch services through a competitive process. Once the right launch vehicle is selected, the program purchases a “ride to space” for the customer. Starting with pre-mission planning and continuing through the spacecraft’s post-launch phase, LSP works with the customer and launch vehicle provider to maximize mission success. LSP provides NASA missions with access to a dependable and secure Earth-to-space bridge, launching spacecraft to orbit our planet or to venture into deep space.

LSP acquires and manages launch services, and ensures pricing is consistent and fair. Through launch-related contracts, the program provides the launch service, research and development, payload processing facility, and command and telemetry during ascent. Additionally, LSP offers insight into the commercial launch vehicle industry, tracks lessons learned to identify and mitigate risks for future managed launches, and certifies the readiness of new commercial launch vehicles for NASA and other civil sector agency spacecraft. The program also conducts engineering analyses and other technical tasks to maximize launch success for every NASA payload.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

LAUNCH SERVICES

ACHIEVEMENTS IN FY 2014

Three major payloads successfully launched utilizing LSP-acquired services:

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Nov 2013 CCAFS	Atlas V	MAVEN	Mars Atmosphere and Volatile EvolutioN	NASA SMD	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.
Jan 2014 CCAFS	Atlas V	TDRS-L	Tracking and Data Relay Satellite	NASA HEOMD	Provide NASA with crucial crosslink communications capability between control and data processing facilities on the ground, and Earth-orbiting spacecraft such as the Hubble Space Telescope, ISS, and dozens of unmanned scientific satellites.
Jul 2014 Vanden-berg AFB	Delta II	OCO-2	Orbiting Carbon Observatory 2	NASA Science Mission Directorate	Utilize remote sensing satellite to measure precise carbon dioxide levels in our planet's atmosphere. This enhanced understanding is essential for improving predictions of future atmospheric carbon dioxide increases and its impact on Earth's climate.

LSP's customer own and manage the payload mission objectives described above.

In addition, LSP continued efforts to expand the selection of available launch vehicles, working across industry to support commercial space sector growth by providing competitive opportunities to US providers.

The program acquired launch services for three future science missions:

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Mar 2016 Vanden-berg AFB	Atlas V	InSight	Interior Exploration using Seismic Investigations, Geodesy and Heat Transport	NASA SMD	Address fundamental issues of planet formation and evolution with a study of the deep interior of Mars.
Oct 2016 CCAFS	Pegasus XL	CYGNSS	Cyclone Global Navigation Satellite System	NASA SMD	Measure ocean surface winds throughout the life cycle of tropical storms and hurricanes, to facilitate better weather forecasting.

LAUNCH SERVICES

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Jul 2017 CCAFS	Atlas V	Solar Orbiter	Solar Orbiter	NASA SMD	Observe the Sun's atmosphere with high spatial resolution lenses and combine data with measurements taken in the environment surrounding the orbiter; also provide images and data covering the Sun's polar regions.

LSP's customer own and manage the payload mission objectives described above.

LSP also led the SpaceX Falcon 9 v1.1 launch vehicle flight readiness certification effort to support SMD's Jason-3 mission in 2015. In addition, LSP provided facility support, ground support equipment, communications and video capabilities, and computer modeling of the Orion vehicle's guidance, navigation, and control system for EFT-1.

NASA and LSP continued to partner 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 partnerships provide educational opportunities for students in science, technology, engineering, and mathematics disciplines, thereby strengthening the Nation's future workforce. NASA selected CubeSats from 29 states across the United States, with 32 launched and 22 manifested on NASA, National Reconnaissance Office, and US Air Force missions.

WORK IN PROGRESS IN FY 2015

LSP provides expertise and active launch mission management for over 40 NASA scientific spacecraft missions in various stages of development. In FY 2015, the program continues to acquire new launch services for future NASA missions. Three science missions are planned for launch in FY 2015:

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Jan 2015 Vanden-burg AFB	Delta II	SMAP	Soil Moisture Active Passive	NASA SMD	Provide global measurements of soil moisture and its freeze/thaw state to enhance understanding of processes to link the water, energy, and carbon cycles, and extend the capabilities of weather and climate prediction models.
Mar 2015 CCAFS	Atlas V	MMS	Magnetospheric Multiscale	NASA SMD	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 is important everywhere in the universe, known as magnetic reconnection.

LAUNCH SERVICES

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Mar 2015 Vandenburg AFB	Falcon 9	Jason-3	Jason-3	NASA, CNES, NOAA, NASA SMD	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.

LSP's customer own and manage the payload mission objectives described above.

As part of the Jason-3 launch activity, LSP leads the certification effort for the SpaceX Falcon 9 v1.1 launch vehicle. Falcon 9 v1.1 certification is vital to the US space program, as it adds to existing intermediate class capabilities, which enhances competition. Multiple providers enable launch cost reductions and increase the probability of a continuous manifest schedule.

In addition to full end-to-end launch service management, the program continues to offer 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 launching on SpaceX Falcon 9 and Orbital Sciences Antares launch vehicles;
- Orion Exploration Flight Test 1, which utilized the Delta IV heavy launch vehicle;
- Commercial Crew Program; and
- NOAA's Deep Space Climate Observatory (DSCOVR) mission.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The Launch Services Program is planning three civil sector missions for launch:

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Mar 2016 Vandenberg AFB	Atlas V	InSight	Interior Exploration using Seismic Investigations, Geodesy and Heat Transport	NASA SMD	Conduct a "check-up" of Mars, measuring its "pulse" or internal activity, temperature, and "reflexes."
Mar 2016 Vandenberg AFB	Atlas V	GOES-R	Geostationary Operational Environmental Satellite-R	NOAA, NASA SMD	First in a series of three satellites will provide continuous imagery and atmospheric measurements of Earth's Western Hemisphere and space weather monitoring.

Launch Date	Launch Vehicle	Payload	Mission Name	Customer	Mission Objectives
Sep 2016 CCAFS	Atlas V	OSIRIS-REx	Origins-Spectral Interpretation Resources Identification-Security-Regolith Explorer	NASA SMD	Visit an asteroid in 2016, perform six months of surface mapping, and use a robotic arm to collect samples to return to Earth. This data helps explain our solar system's formation and how life began, as well as improve understanding of asteroids that could impact our planet.

LSP's customer own and manage the payload mission objectives described above.

LSP will continue launch service acquisition activities necessary to support NASA and other approved government missions, and provide launch related mission support to over 40 NASA scientific spacecraft missions in various development phases.

Program Management & Commitments

Program Element	Provider
Expendable Launch Vehicle (ELV) Launch Services	Provider: United Launch Services (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 under the original NASA Launch Services (NLS) contracts for procuring ELV launch services from domestic commercial launch service suppliers. To meet the needs of science and technology customers who typically spend three to seven years developing a spacecraft mission, NASA created a contractual approach providing multiple competitive launch service options to cover small, medium, and intermediate-sized missions. 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 expires 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.

In 2013, LSP contracted one launch in the nanosatellite or CubeSat class. This firm fixed-price launch service contract to an emerging launch service provider, Generation Orbit Launch Services Inc., is a pathfinder for acquiring future launch services for low-cost and/or high-risk-tolerant payloads. If the contactor is successful, it could provide a cost effective launch option for small civil sector payloads who, due to orbital requirements, need a dedicated ride to space rather than a rideshare.

NASA has also made efforts to provide a complete launch service, including payload processing at the launch site. LSP uses 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 Operations (ASO) and Spaceport Systems International at Vandenberg AFB. In January 2013, NASA awarded the East Coast Commercial Payload Processing Facility contract to ASO in Titusville, Florida. ASO and Spaceport Systems International 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*	United Launch Services, LLC	Centennial, CO
NLS-II-A	Lockheed Martin Space Systems	Denver, CO
NLS-II-U	United Launch Services, LLC	Centennial, CO
NLS-II-S	SpaceX	Hawthorne, CA
NLS-II-O	Orbital Sciences Corporation	Dulles, VA
Payload Processing Facility	Astrotech Space Operations	Titusville, FL
Payload Processing Facility	Astrotech Space Operations	Vandenberg Air Force Base, CA
Integrated Processing Facility	Spaceport Systems International	Vandenberg Air Force Base, 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) will be scheduled in CY 2019.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
PIR	SRB	May 2014	Life Cycle Review	Board found that LSP is a successful program with a strong technical and management team representing NASA's core competency, demonstrating exceptional performance with a 97.4 percent launch success record. Standing Review Board recommends continuation of LSP operations as currently performed.	2019

Historical Performance

LSP managed ELV Missions from inception through FY 2014.

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	11	11	0
Delta II	Boeing Launch Services	26	26	0
	ULS	14	14	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 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	44.4	--	47.2	47.6	47.6	47.6	48.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The totals for the Exploration and Space Operations accounts in this document supersede the figures in the draft appropriations language.

Engineers and technicians install an Aerojet-Rocketdyne RS-25 engine into the A-1 test stand, to perform developmental and flight certification testing at Stennis Space Center, in Mississippi. Powered by a configuration of four RS-25 engines similar to the one shown above, NASA's Space Launch System will make its mark as the first rocket and launch system capable of powering humans, habitats, and support systems into deep space, providing new opportunities for human and scientific exploration far beyond low-Earth orbit.

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 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 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.

The Agency has designated RPT as the NASA representative for the National Rocket Propulsion Test Alliance (NRPTA) – an inter-agency collaboration with the Department of Defense 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 2016

None.

ACHIEVEMENTS IN FY 2014

During FY 2014, the RPT program safely performed 322 tests. Test time totaled over 493,000 seconds, with more than 26,800 seconds of hot fire combustion test of rocket engine and components at various levels of thrust.

In April, the final test of the J-2X engine was completed on test stand A-2 at Stennis Space Center (SSC), culminating with a 125-second test. The J-2X upper stage engine is the first human-rated liquid oxygen and liquid hydrogen rocket engine developed in 40 years. With completion of J-2X engine test effort, work began to prepare the A-2 test stand for mothball status in FY 2015. Throughout FY 2014, RPT performed facility modifications on the A-1 test stand to support RS-25 engine testing early in FY 2015. These engines will be used for the SLS core stage.

MSFC conducted SLS scale model acoustic testing to better understand the effects of sound during launch of the SLS vehicle. Several advanced rocket engine technologies were also tested, including components built using select laser melting construction technology; which, if proven successful, could lead to significant improvements in rocket engine development and manufacturing processes.

At SSC, Orbital Sciences Corporation and Aerojet Rocketdyne conducted test firings of the AJ-26 engine. The AJ-26 powered both successful launches of the Orbital Antares rocket from NASA's Wallops Flight Facility to support the ISS Commercial Resupply Services program. During AJ-26 testing, an engine component failed causing damage to the test stand, which Orbital Sciences Corporation paid to rebuild. Development testing continued for NASA's Morpheus lander, and began for SpaceX on a reimbursable basis. Refurbishment and repair activities continued for critical enabling infrastructure, including replacing the B-leg of the high-pressure industrial water system which supplies water to the test stands and refurbishing the B-2 test stand at SSC for SLS core stage testing.

At White Sands Test Facility (WSTF), engineers conducted tests to support the Missile Defense Agency engine and thruster program, the Peacekeeper safing project, and hot fire test and decontamination efforts for the Minuteman life extension program. Additionally, through a reimbursable agreement, Boeing Corporation tested their orbital maneuvering and reaction control system thruster as part of NASA's Commercial Crew program.

At Glenn Research Center Plum Brook Station (GRC-PBS), RPT performed tests in the B-2 facility to enable testing of large electric propulsion thrusters that could be used to enable extended duration space activities.

ROCKET PROPULSION TEST

WORK IN PROGRESS IN FY 2015

SSC will continue testing the RS-25 engine in support of the SLS program. Development testing will also continue for commercial companies seeking to test their engine systems on a reimbursable basis. Planned refurbishment and repair activities for critical enabling infrastructure include replacing the A and B-legs of the high-pressure industrial water system, repairing SSC's liquid oxygen and liquid hydrogen barges, upgrading high-pressure gas facility, and replacing the E-Complex data acquisition system. In addition to ongoing test programs, SSC will continue B-2 test stand refurbishment to prepare for SLS core stage testing.

The team at WSTF will conduct testing for the Missile Defense Agency and the US Air Force. Planning, design, and construction activities will take place to support future testing for the Boeing commercial crew service module (on a reimbursable basis) and the European Space Agency's (ESA) Orion service module development. In addition to test and construction activities, WSTF will begin refurbishment activities for the large altitude simulation system.

MSFC will continue testing on rocket engine components constructed using select laser melting and other additive manufacturing processes that could lead to significant improvements in construction of these complex machines.

At GRC-PBS B-2 facility, RPT will incorporate a 30,000-gallon liquid hydrogen tank into the system to support testing. The team will repair an11 foot vacuum isolation valve on the B-2 to enable lower vacuum pressures, electrical propulsion testing, and engine hot fire testing. RPT will also perform work to enable testing of electric propulsion thrusters to support exploration missions beyond low-Earth orbit.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Building on test results from previous years, RPT will provide valuable propulsion data to the SLS and Orion programs as they prepare for Exploration Missions 1 and 2. These tests will provide feedback on baseline designs, increasing confidence in technical performance, reducing risks, as well as assist in achieving launch readiness on schedule. This ongoing effort 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 SCC's A-1 test stand; eventually, four RS-25 engines will propel the SLS core stage upon launch.

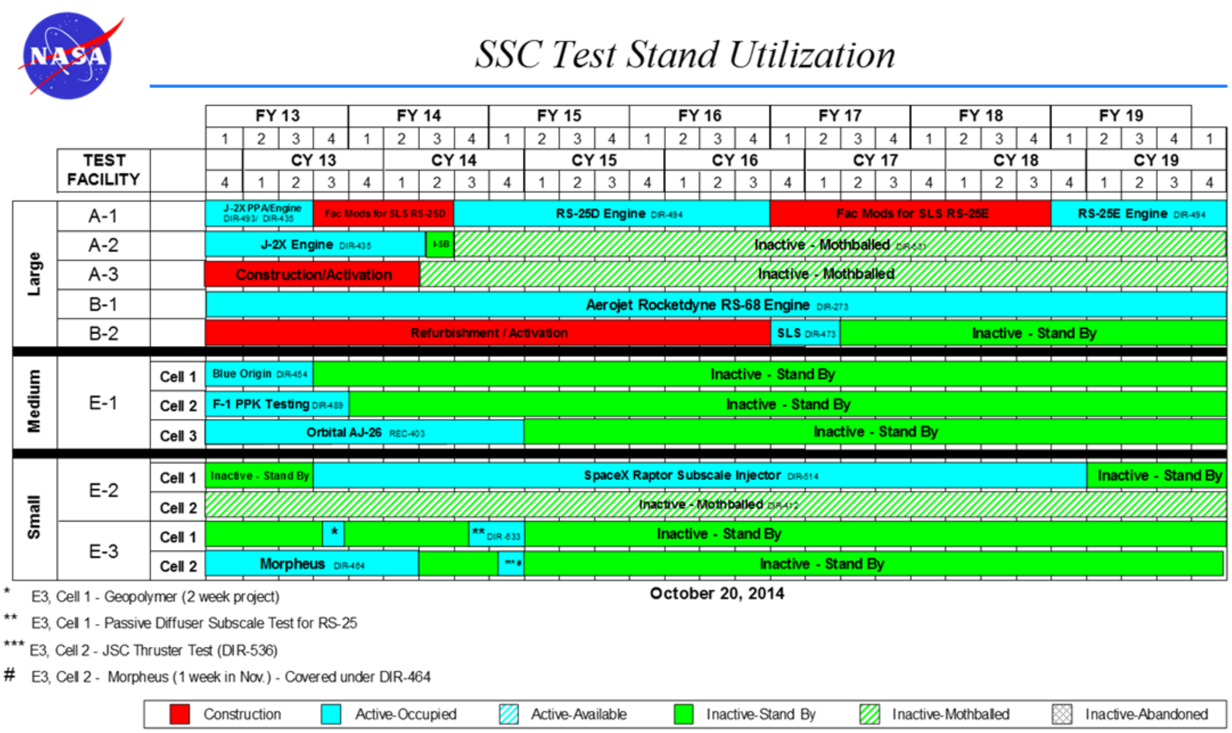
To prepare for future SLS integrated engine testing at SSC, RPT will continue refurbishment and construction activities, and initiate activation of the B-2 test stand, scheduled for completion in FY 2016. The program will continue facility preparations and construction activities to support Orion ESA Service Module and Boeing CST-100 Service Module FY 2017 test plans. RPT will complete refurbishing the large altitude simulation system at WSTF, which supports future space environment testing for the Orion service module, Boeing commercial crew vehicle, Missile Defense Agency, and US Air Force test articles.

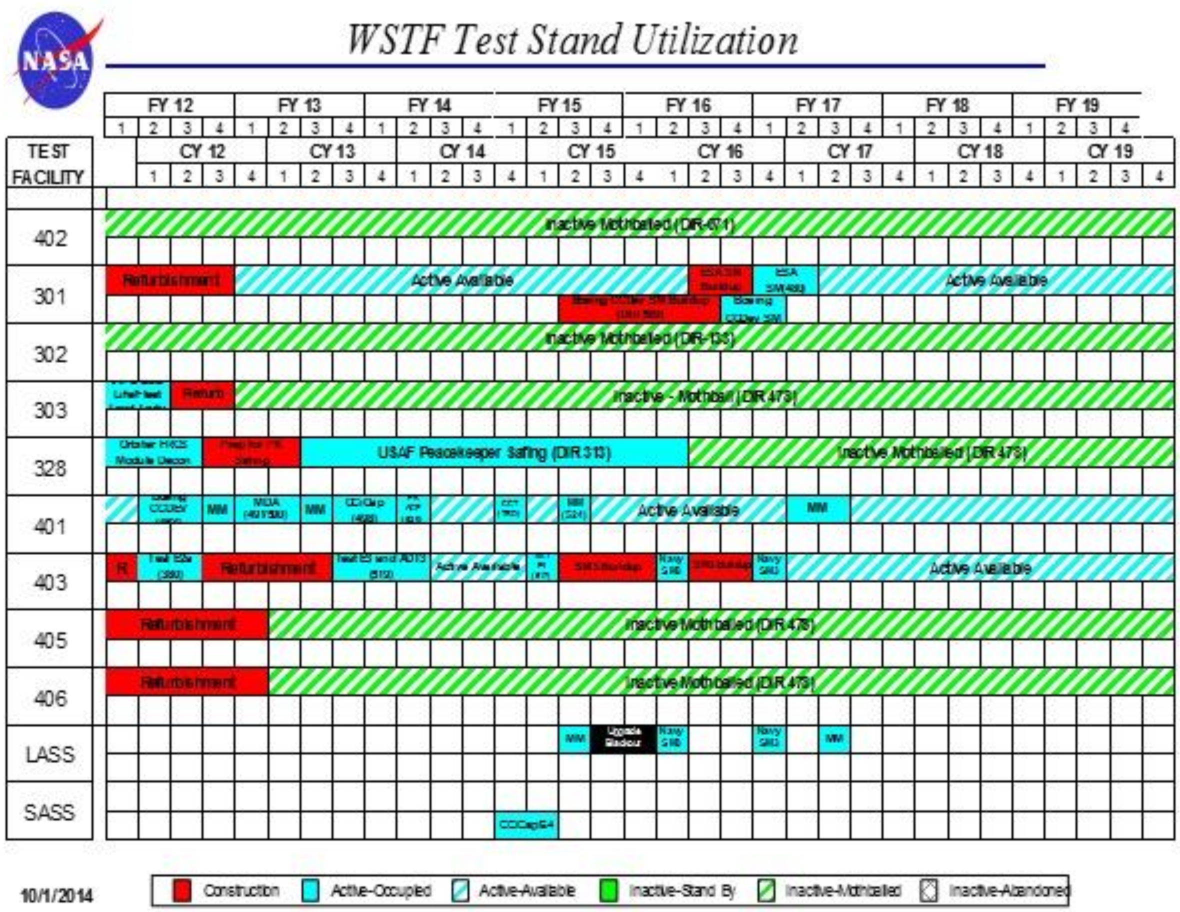
RPT will perform testing for the Aerojet Rocketdyne RS-68 engine, as well as testing for the US Air Force, SpaceX and other commercial engine developers. RPT will continue testing of hazardous hypergolic fuels at WSTF; these unique facilities are critical for testing future space vehicles in a simulated space environment and ambient conditions.

Program Schedule

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 refer 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 for FY 2016 and beyond.





Program Management & Commitments

Program Element	Provider
RPT	Provider: RPT Lead Center: N/A Performing Center(s): SSC, JSC/WSTF, GRC PBS, MSFC, KSC, WFF Cost Share Partner(s): Various other NASA programs, Department of Defense, and commercial partners

Acquisition Strategy

No major acquisitions identified for FY 2016.

ROCKET PROPULSION TEST

MAJOR CONTRACTS/AWARDS

No major contracts or awards planned for FY 2016.

INDEPENDENT REVIEWS

No reviews planned.

EDUCATION

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Aerospace Research and Career Development	58.0	58.0	**33.0**	33.0	33.0	33.0	33.0
STEM Education and Accountability	58.6	--	**55.9**	57.2	58.6	60.0	61.4
Total Budget	**116.6**	**119.0**	**88.9**	**90.2**	**91.6**	**93.0**	**94.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

EDUCATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Aerospace Research and Career Development	58.0	58.0	**33.0**	33.0	33.0	33.0	33.0
STEM Education and Accountability	58.6	--	**55.9**	57.2	58.6	60.0	61.4
Total Budget	**116.6**	**119.0**	**88.9**	**90.2**	**91.6**	**93.0**	**94.4**
Change from FY 2015			**-30.1**				
Percentage change from FY 2015			**-25.3%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The Native American Heritage Program held at Marshall's official visitor center, the US Space and Rocket Center, a Smithsonian affiliate, supported nearly 800 local underrepresented and underserved fifth grade students through groups such as Girl Scouts, Native Americans, 4-H Clubs, Head Start students, and the visually-and hearing-impaired.

Bolstering American science and innovation is central to the Administration's strategy for strengthening the economy and increasing opportunities for Americans to secure high-paying jobs. As a result, the Administration has placed a high priority on Science, Technology, Engineering, and Mathematics (STEM) education, making significant commitments to improve the quality of STEM education at all levels, including by preparing 100,000 new and effective STEM teachers and producing an additional one million STEM undergraduates over the next decade.

NASA Education's vision advances high quality STEM education using NASA's unique capabilities, assets and expertise. This vision aligns to ***Objective 2.4: Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets*** in the Agency's 2014 Strategic Plan. NASA Education programs will continue to develop and execute strategic collaborations and partnerships with intergovernmental, academic, industrial, entrepreneurial, and international communities to achieve NASA's values, mission, and vision.

NASA Education programs provide opportunities for educators, learners and institutions that are consistent with the goals, objectives, and strategies of the Five-Year Federal Strategic Plan on STEM Education, Committee on STEM (CoSTEM). NASA Education collaborates with other federal agencies in the key areas identified by CoSTEM to: 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 experiences for tomorrow's STEM workforce. The FY 2014 CoSTEM

Progress Report can be viewed here: http://www.whitehouse.gov/sites/default/files/microsites/ostp/STEM-ED_FY15_Final.pdf.

In FY 2016, NASA Education will build on the Administration's efforts to establish a stronger and more cohesive federal infrastructure for delivering STEM education and leveraging existing resources to improve the reach of the Agency's assets. The Office of Education (OE) supports a coherent framework for engaging STEM education learners, educators, and institutions; while reducing program fragmentation and ensuring that the OE, Centers and Mission Directorates implement a strategically integrated education portfolio. NASA Education gives priority to two kinds of activities: activities that use evidence to guide program design and implementation and activities that build evidence about what works in STEM education, using appropriate metrics and improving the measurement of outcomes. NASA Education also continues to use competitive processes for allocating resources and ensuring that the most effective STEM education activities are supported.

NASA's STEM education expertise, as well as the Agency's unique missions and assets, makes profound contributions to the Nation's STEM education portfolio. The FY 2016 request for NASA Education is $88.9 million. Additionally, the Budget provides $20 million to NASA's Science Mission Directorate to compete and fund meritorious science educational activities that meet the Nation's STEM education goals. NASA continues to consolidate the education functions, assets, and efforts of the Mission Directorates, Offices, and Centers into the coordinated STEM Education and Accountability Projects (SEAP) under the auspices of NASA Education. A SEAP competition conducted in FY 2015 identified and prioritized NASA-unique assets and content for implementation in FY 2016 by NASA Education and in support of other Federal agencies STEM efforts. FY 2016 activities will continue to capitalize on the excitement of NASA's missions of scientific inquiry and exploration through innovative solutions, approaches, and tools that inspire educator and learner interest and proficiency in STEM.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

NASA Education made significant strides in developing and executing strategic collaborations and partnerships with other Federal entities and non-profit organizations to accomplish the Administration's vision for STEM. The OE signed a Space Act Agreement with Destination Imagination, Inc., a nonprofit organization providing project-based educational programs in the United States and abroad, to foster creativity and innovation among K-12 students that enables adding NASA space exploration and innovation content to Destination Imagination's programs and activities. Additionally, NASA Education formalized a long-standing collaboration on 4-H, the nation's largest youth development organization, with the Department of Agriculture's National Institute for Food and Agriculture. In collaboration with the nonprofit 4-H Council, the first activity in this five-year agreement helped prepare and launch the 2014 National Youth Science Day on October 8, 2014. Hundreds of thousands of youths in the United States and abroad participated in this youth-led science experiment as part of 4-H National Youth Science Day. The University of Arizona Cooperative Extension designed the Rockets to the Rescue experiment that challenged youth to build an aerodynamic craft designed to deliver a payload of food to natural disaster victims.

EDUCATION

In a novel collaboration between Federal agencies, NASA and the Department of Education entered into a reimbursable Space Act Agreement that ran from fall 2013 through winter 2014. The agreement aligned with near-term CoSTEM priorities to increase and sustain youth and public engagement in STEM. The partnership supported STEM objectives and activities within Department of Education's 21st Century Community Learning Center (21CCLC) program. NASA customized online STEM challenges and associated curriculum materials aligned to 21CCLC objectives and implemented them in Colorado, Michigan, and Virginia. NASA and the Department of Education are using the results from this pilot activity to draft a framework for other federal collaborations with 21CCLC.

WORK IN PROGRESS IN FY 2015

NASA continues to align its STEM education activities with the priorities identified by CoSTEM. NASA and the Department of Education entered into a second reimbursable Space Act Agreement that follows up on the earlier 21CCLC pilot. The second agreement also aligns to the near-term CoSTEM priority of increasing and sustaining youth and public engagement in STEM. The partnership continues to support STEM objectives within ED's 21CCLC program and is conducting a comprehensive evaluation study to collect evidence of the pilot's effectiveness. NASA will continue to customize its online STEM challenges and associated curriculum materials aligned to 21CCLC objectives.

NASA Education is continuing to cultivate strategic partnerships with non-governmental entities to accomplish its vision. NASA Education is revising its NASA Announcement for High-Impact and National Strategic STEM Education Partnerships [EDUCATION01SP13] to reflect the CoSTEM Plan and the NASA Strategic Plan. OE has already signed a Space Act Agreement with US Satellite Laboratory to provide NASA STEM-based educator professional development through a series of online, university-level STEM education courses for pre- and in-service teachers. Through this strategic effort, NASA and US Satellite Laboratory advance the CoSTEM priority investment area to improve STEM instruction.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA Education will continue to actively contribute to Federal-wide efforts to advance collaboration among government agencies to deliver compelling STEM content through CoSTEM. In FY 2015 NASA was named co-chair with Smithsonian Institution for the STEM Engagement interagency working group and was active in sessions for the other four priority STEM education investments. In FY 2016 NASA OE will continue its dedication to the interagency working group-created infrastructure, policies and practices.

NASA Education will continue to use competitive processes to identify the most effective, 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.

Programs

AEROSPACE RESEARCH AND CAREER DEVELOPMENT

The Aerospace Research and Career Development (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's Mission Directorate research needs and further 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. These programs are intended to 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 ARCD program are the National Space Grant College and Fellowship Program (Space Grant) and the Experimental Program to Stimulate Competitive Research (EPSCoR).

STEM EDUCATION AND ACCOUNTABILITY

The STEM Education and Accountability (SEA) program provides unique NASA assets, including its people, resources and facilities to support the Nation's STEM education priorities. The projects within the SEA program are Minority University Research and Education Program (MUREP) and the STEM Education and Accountability Projects (SEAP).

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 the education and research, academic, and technology capabilities of Historically Black Colleges and Universities (HBCU), Hispanic-Serving Institutions (HSI), Tribal Colleges and Universities (TCU), 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 to identify and eliminate potential duplication of effort across NASA's education portfolio. NASA also actively participates in the National Science and Technology Council (NSTC)'s CoSTEM and co-chairs the Federal Coordination in STEM Education Subcommittee. 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

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
National Space Grant College and Fellowship Project	40.0	40.0	**24.0**	24.0	24.0	24.0	24.0
Experimental Project To Stimulate Competitive Research (EPSCoR)	18.0	18.0	**9.0**	9.0	9.0	9.0	9.0
Total Budget	**58.0**	**58.0**	**33.0**	**33.0**	**33.0**	**33.0**	**33.0**
Change from FY 2015			**-25.0**				
Percentage change from FY 2015			**-43.1%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Benjamin Martins, supported by the California Space Grant Consortium, worked with several NASA mentors and developed flexible wing concept technologies at the Aeronautics Academy at NASA's Armstrong Flight Research Center.

ARCD will continue national STEM efforts through Space Grant and 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 had not previously 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.

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 2016

None.

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**40.0**	**40.0**	**24.0**	**24.0**	**24.0**	**24.0**	**24.0**
Change from FY 2015			**-16.0**				
Percentage change from FY 2015			**-40.0%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Community college students attended a one-week research academy where they were introduced to laboratory research supported by the California Space Grant Consortium. This was the first time these students had conducted university lab research.

Space Grant is a competitive grant opportunity that enables the active involvement 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 900 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 experience 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 NASA projects, including those conducted by NASA Mission Directorates and Centers. Space Grant also supports student participants in internship experiences at NASA Centers.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations

ACHIEVEMENTS IN FY 2014

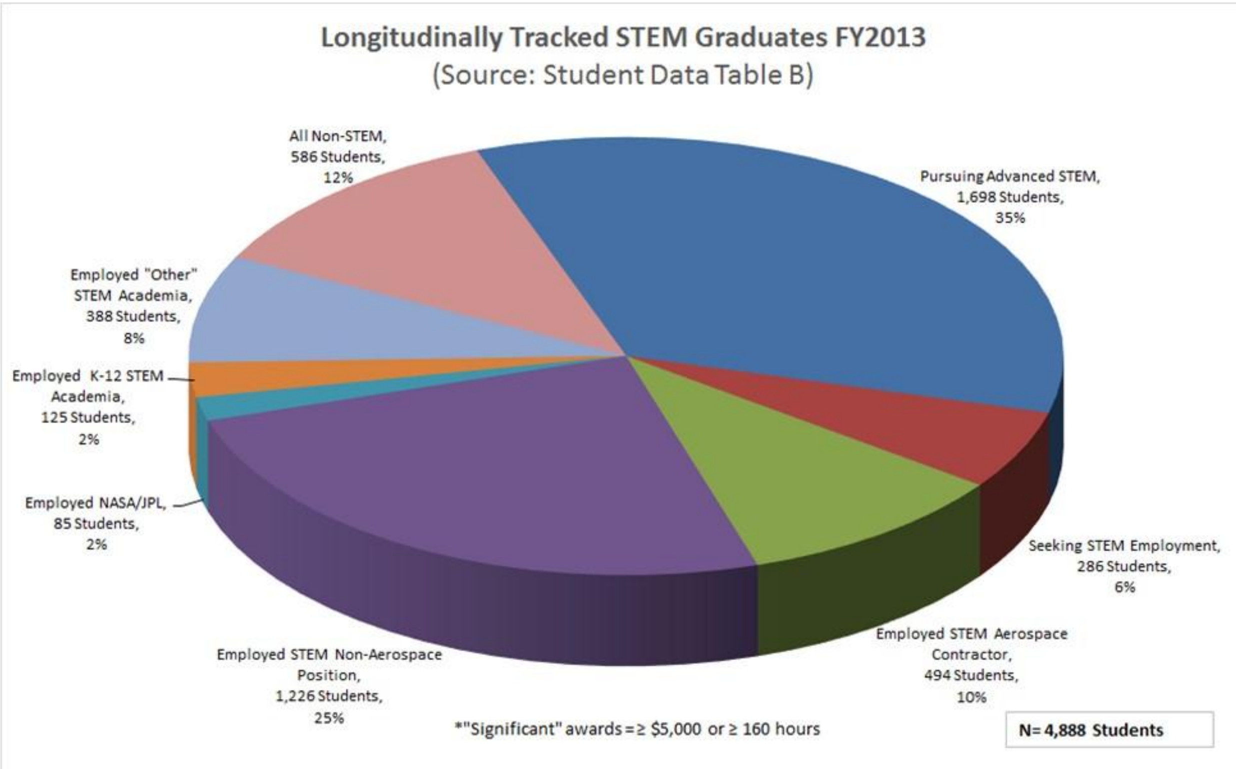
Thirty-five Space Grant consortia received more than $17 million in competitively awarded funds to increase student and faculty engagement in STEM at community colleges and technical schools across the US. Each award has a two-year performance period and a maximum value of $500,000. The winning proposals outlined ways to attract and retain more STEM students from community and technical colleges through competitive STEM scholarships, development of distance learning STEM courses for students and faculty, and internship opportunities at NASA Centers. For instance, the California Space Grant Consortium proposed to enhance STEM preparation at 12 State community colleges and improve opportunities for approximately 300 students to transfer to either the University of California or the California State University system. This multi-faceted program includes development of a distance learning STEM course for faculty and students that fosters education and training in topics such as: programmable microcomputers, near-space ballooning, small satellites, and autonomous ground robots. For more information on the 35 community colleges and technical schools awards, visit: http://go.nasa.gov/1svsrWD.

Space Grant provided student awards for more than 4,100 undergraduate and graduate students through scholarships, fellowships, internships and authentic hands-on research and engineering challenges. Diversity is a key component within the Space Grant project, achieving 28 percent participation among underrepresented students and 41 percent participation among female students in Space Grant activities. This year more than 16,000 educators participated in NASA Space Grant activities. Space Grant also targets elementary and secondary students through NASA informal education activities, web-based activities, and other instructional and enrichment activities; reaching more than 113,000 precollege students. The Agency conducts longitudinal tracking of higher education students receiving significant investments.

The figure below shows the status of Space Grant's 4,888 students who were tracked in 2013 and received awards in excess of $5,000 or had 160 or more contact hours. As noted below, of those students, 1,698 or 35 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



FY 2013 data is the most current data. FY 2014 Data is not available until June 2015.

Space Grant consortia received funding to continue efforts outlined in their five-year strategic plans. All activities conducted by the 52 consortia are in alignment with Agency goals, the OE lines of business, and the NSTC CoSTEM priority areas. Space Grant awards consist of scholarships, fellowships, or internships in support of higher education, Research Infrastructure, Precollege, and Informal Education. Space Grant consortia also supported flight project activities led by student teams. Some of those flight activities included, but are not limited to:

- Rock-on Workshop
- Rock-Sat-C
- Rock-Sat-X
- DemoSat
- High Altitude Student Platform (HASP)

WORK IN PROGRESS IN FY 2015

Space Grant consortia are currently implementing 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

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations

the next multi-year training grant solicitation, a three-year NASA STEM competitive opportunity focusing on key CoSTEM priorities and enhancing STEM endeavors. NASA is also implementing activities identified in the Community College and Technical Schools proposals awarded in FY 2014.

The Space Grant program office at NASA Headquarters continues to prepare for an independent external evaluation of the national program. OE will incorporate results from the external evaluation into strategic planning for the Space Grant program.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The program budget will continue to support base awards for the 52 consortia to do the following:

- Provide hands-on experiences for US 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.

Project Schedule

Date	Significant Event
Q1 FY 2016	Release of Solicitations for Space Grant
Q2 FY 2016	Proposal Due and Review Process (Space Grant)
Q3 FY 2016	Selection and Awards (Space Grant)
Q4 FY 2016	Prior Fiscal Years' 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

NATIONAL SPACE GRANT COLLEGE AND FELLOWSHIP PROJECT

Formulation	Development	Operations

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 multi-year.

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.

INDEPENDENT REVIEWS

The OE Evaluation Manager and the Space Grant Program office are engaged in community consultation and planning to support the next evaluation.

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Indepen-dent/ External	TBD	TBD	To provide an independent review by an external organization to assess the accomplishments and strategy of the Space Grant program	TBD	2015

EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

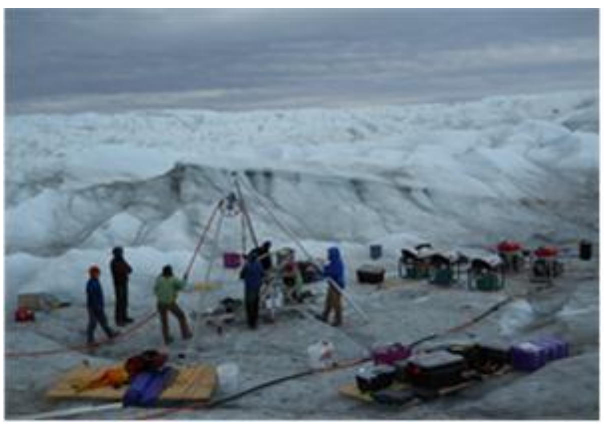
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**18.0**	**18.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**
Change from FY 2015			**-9.0**				
Percentage change from FY 2015			**-50.0%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Researchers from the University of Montana gather data in the field that is paired with NASA Goddard's IceBridge mission airborne radar measurements to create simulations of ice sheet motion. These simulations help researchers project the future response of ice sheets to climate change.

The 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 capacity of that State or region. The program strives to improve a region's research infrastructure, which in turn has the potential to contribute to its research and development 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 (NSF)) 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCOR)

Formulation	Development	Operations

ACHIEVEMENTS IN FY 2014

There are indications that NASA-funded academic research in the EPSCoR has provided benefits in the following three areas: a) increased competitive research capacity within targeted jurisdictions, b) the generation of advanced technology as evidenced by the awarding of patents, and c) research productivity demonstrated through distribution of research accomplishments (e.g., scientific publications and professional presentations).

- EPSCoR was originally conceived in response to the observation that certain jurisdictions were not as successful in competing for Federal research and development funding as some other jurisdictions. EPSCoR programs were developed to, as the program title suggests, stimulate competitive research. A clear indication of the success of NASA EPSCoR is reflected in the fact that three States (Utah, Iowa, and Tennessee) graduated from the NASA EPSCoR program because they demonstrated the ability to secure sufficient non-ESPCOR funding for sustainability.
- Two patents were awarded to the following EPSCoR jurisdictions in FY 2014:
    - Researchers from the University of Puerto Rico patented a cost effective nanotechnology approach to forming diamonds for commercial use. (Patent #: US 8608850 B1–Issue Date – Dec. 17, 2013).

Abstract: Diamond thin films were deposited on copper substrate by the Vapor Solid (VS) deposition method using a mixture of fullerene C60 and graphite as the source material. The deposition took place only when the substrate was kept in a narrow temperature range of approximately 550-650° C. Temperatures below and above this range results in the deposition of fullerenes and other carbon compounds, respectively.

Researchers from Utah State University Research Foundation patented devices, systems, and methods for dispersive energy imaging. (Patent#: US 8809771– Issue Date – August 19, 2014).

Abstract: Devices, systems, and methods for dispersive energy imaging are disclosed. The full three-dimensional velocity distribution function of a flowing particle stream may be measured and properties of the particle stream characterized. In some devices, an aperture system controls the entry of a stream of particles into the sensor where an electrostatic deflector separates the stream of particles into different species, and a detector system senses the separated species.

A total of 796 faculty and postdoc researchers funded by EPSCoR demonstrated research productivity through the following metrics:

- 406 peer reviewed publications accepted or published;
- 212 other publications accepted or published; and
- 685 talks/presentations at professional meetings.

EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCOR)

Formulation	Development	Operations

WORK IN PROGRESS IN FY 2015

EPSCoR will make new research awards based on availability of funding. Each funded proposal will establish research activities with the potential to 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 EPSCoR jurisdiction.

EPSCoR, in cooperation with the ISS Program Office, will continue to provide ISS Flight Opportunities for the EPSCoR jurisdictions. Additionally, EPSCoR will continue its collaboration with the Space Technology Mission Directorate (STMD) to provide workshops aimed at increasing the States' knowledge of NASA's unique and innovative capabilities, resources and facilities.

In support of the Federal EPSCoR Interagency Coordinating Committee (EICC), NASA EPSCoR is identifying and providing 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 review panels.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA EPSCoR will issue a competitive call for extramural Research Infrastructure Development (RID) and ISS Flight Opportunity proposals, and support STMD/EPSCoR workshops. NASA EPSCoR will continue to be an 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 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
Q1 of FY 2016	Release of Solicitations for Research and RID Opportunities
Q2 of FY 2016	Proposal Due and Review Process (Research and RID Opportunities)
Q3 & Q4 of FY 2016	Selection and Awards (Research and RID Opportunities)

EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

Formulation	Development	Operations

Project Management & Commitments

The program manager for NASA EPSCoR resides at NASA Headquarters and is responsible for overall administrative duties of this national project. The project manager is located at Kennedy Space Center and provides management responsibility for day-to-day operations. Contractor staff and 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 as required throughout the year 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's 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 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.

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's and NASA's Strategic Plans 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.

EXPERIMENTAL PROJECT TO STIMULATE COMPETITIVE RESEARCH (EPSCoR)

Formulation	Development	Operations

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Indepen-dent	National Academy of Sciences	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 incorporated the findings of the November, 2013 report of the National Academy of Sciences on the EPSCoR program into its FY 2016 budget request. NASA will continue to participate in the Federal EICC, meetings in FY 2016.	N/A

STEM Education and Accountability

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Minority University Research Education Project	30.0	--	**30.0**	30.0	30.0	30.9	30.0
STEM Education and Accountability Projects	28.6	--	**25.9**	27.2	28.6	29.1	31.4
Total Budget	**58.6**	--	**55.9**	**57.2**	**58.6**	**60.0**	**61.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

NASA supports the nation's STEM education priorities through its collaborations with internal and external partners and using NASA-unique assets, people, resources and facilities. Dr. James Garvin, Chief Scientist, NASA Goddard Space Flight Center, speaks to 4-H National Youth Science Day participants.

The SEA program provides unique NASA assets, including people, resources, and facilities to support the Nation's STEM education priorities; leveraging programs from the ED, NSF, and the Smithsonian Institution. Through the competitive award of federal domestic assistance funds and collaboration with other Federal agencies, the program provides students and educators with 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 exciting and compelling content emanating from NASA's scientific discoveries, aeronautics research, and exploration endeavors.

NASA provides multi-year grants and cooperative agreements to the Nation's Historically Black Colleges and Universities (HBCU), Hispanic Serving Institutions (HIS), Tribal Colleges and Universities (TCU), and other Minority-Serving Institutions (MSI) through the 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.

Explanation of Major Changes in FY 2016

None.

MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

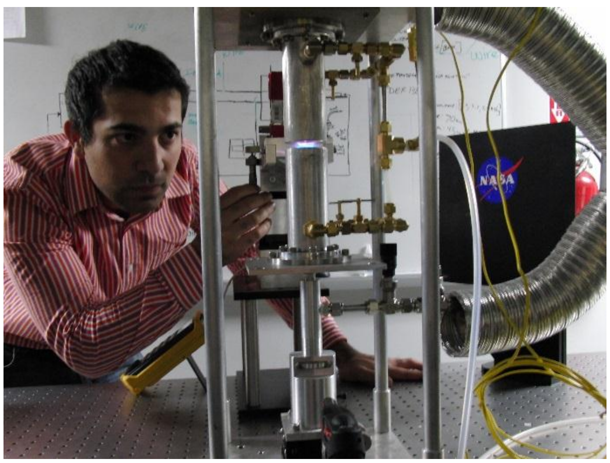
Formulation	Development	Operations

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	30.0	--	30.0	30.0	30.0	30.9	30.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



The NASA MUREP Institutional Research Opportunity (MIRO), project is designed to achieve a broad-based, competitive aerospace research capability among the nation's minority institutions. Here, Mazdak Kebria, a student at California State University, Los Angeles, conducts an experiment related to bio-fuel combustion temperature profile data extraction of counter-flow flame. The MIRO awards 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 (HBCU), Hispanic Serving Institutions (HSI), Asian American and Native American Pacific Islander-Serving Institutions (AANAPISI), Tribal Colleges and Universities (TCU) and eligible community colleges. The Administration recognizes the valuable role that these institutions play in educating our citizens, as reflected in the four Minority-Serving Institutions (MSI) Executive Orders signed by the President. These institutions recruit and retain underrepresented and underserved students, including women and girls, and persons with disabilities into 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 that are 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 MSIs. Multi-year grants awarded to MSIs assist faculty and students in research and authentic STEM engagement pertinent to NASA missions. These competitive awards provide NASA specific STEM knowledge, skills, and abilities to underrepresented and underserved learners through research, internships, scholarships, and fellowships at NASA Centers. Awards also provide opportunities for minority institutions to improve the quality of their faculty preparation programs and thereby better serve groups historically underrepresented in STEM.

MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

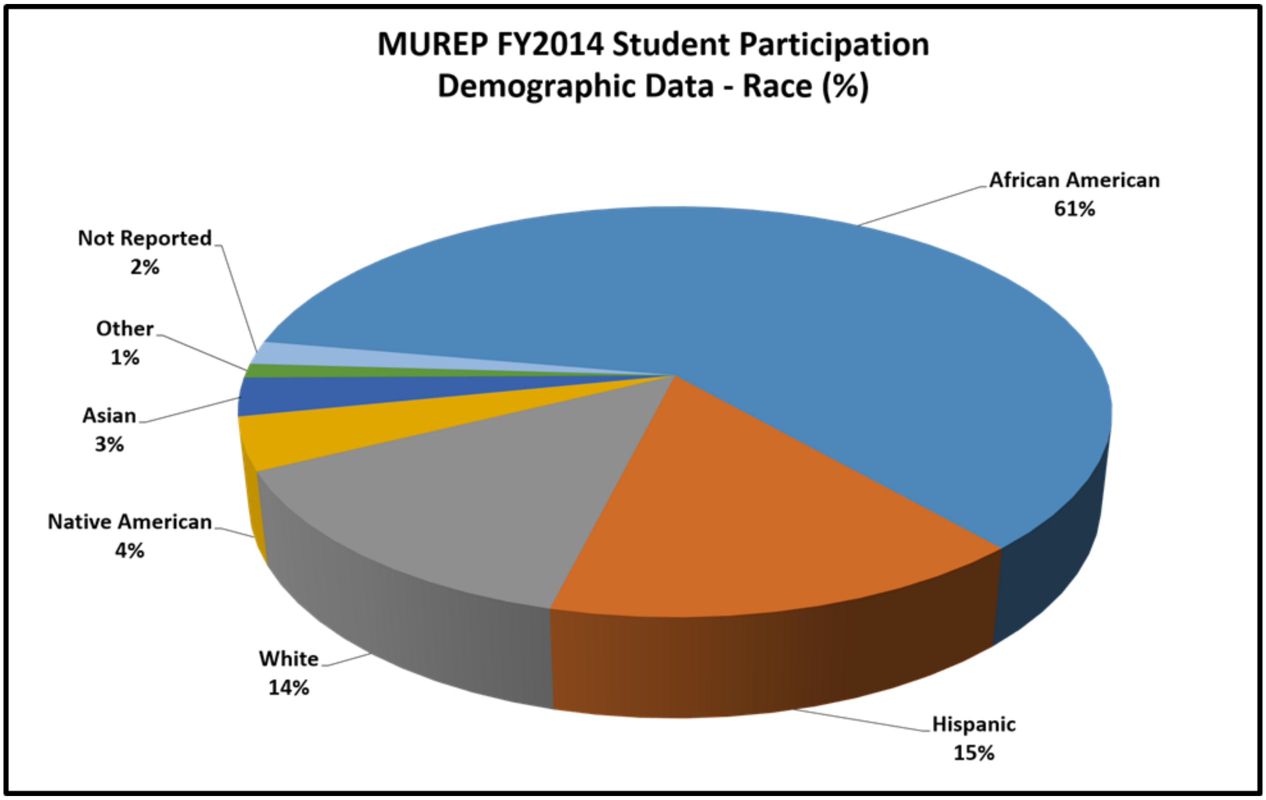
Formulation	Development	Operations

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

Financial support and research experiences have been shown to increase the retention and completion rates of students pursuing STEM degrees in an effort to improve tracking of student outcomes without overburdening institutions, NASA has set a reporting threshold based on "significant investment" by the agency. For MUREP, NASA defines significant investment as a student receiving 160 or more contact hours or $3,000 or more student stipend. MUREP's FY 2014 reporting reflects support of over 1200 postsecondary students with a significant investment. Forty percent of those students were females and 93 percent were students from historically underrepresented and underserved groups, which includes women and persons with disabilities.



MUREP funded graduate fellowships and undergraduate scholarships to increase the number of minority, disadvantaged, or underrepresented groups in NASA specific STEM fields and to increase diversity in NASA's workforce. Only 43 percent of students entering as a STEM major in a four-year public college or university graduate with a STEM degree. Approximately 14 percent of community college students who declare a STEM major on entry are still in a STEM field at the time of their last enrollment (CoSTEM 5-Year Strategic plan, pg. 10). In FY 2014, MUREP supported 25 undergraduate scholars

MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation	Development	Operations

where 52 percent of those scholars were females, 8 percent were persons with disabilities, 4 percent had former military service and 16 percent attended community colleges. The MUREP funded undergraduate scholarship focuses on underserved and underrepresented students in the STEM disciplines, thereby addressing the critical shortage of qualified STEM professionals across the nation.

MUREP 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. The goal of these competitive fellowships and scholarships is to address the Agency's mission-specific workforce needs of increased diversity and targeted areas of national need in minority STEM representation. In FY 2014, MUREP supported 26 graduate fellows where 69 percent were female, 4 percent were persons with disabilities, and 8 percent had former military service.

MUREP Institutional Research Opportunity (MIRO) provides a broad-based competitive NASA-related research capability among MSIs that fosters new aerospace science and technology concepts. In FY 2014, MIRO grantees authored 568 NASA-related research papers, publications, and presentations with three patents granted. There were also 43 students who received their Bachelors, 47 who received their Masters, and nine who received their Ph.D. In addition, grantees had a total of 47 proposals funded by federal, State, and community organizations to leverage and sustain their research work implemented via MIRO funding. Three students were also reported as being hired by NASA in FY 2014. Please take note of the highlighted accomplishments listed below.

MIRO contributions to notable NASA projects:

- NASA Beltsville Center for Climate System Observation at Howard University was selected for the NASA Discover AQ project team in 2010 and continues to provide significant support during the current reporting period.
- NASA Center for Radiation Engineering and Science for Space Exploration at Prairie View A&M University participated with Johnson Space Center in the University Research (UR-1) mission launch to the International Space Station aboard the third SpaceX Dragon capsule flight.
- Student and faculty at the NASA Optical Sciences Center for Applied Research received the NASA Group Achievement award for their contribution to the ChemCam Team's work on the Mars Curiosity Rover mission.
- The NASA center for Aerospace Devices Research and Education at North Carolina Central University acquired nanotechnology project funding from the NSF ($75,000), Department of Defense ($630,000), and Department of Energy ($540,000).
- The Science, Engineering, Mathematics and Aerospace Academy at Morgan State University enabled three students to complete STEM degrees and begin three STEM companies entitled, I Turn Research into Empowerment and Knowledge (I-trek), Liquid Off, and DLR Technologies.

WORK IN PROGRESS IN FY 2015

MUREP will continue to fund efforts in the OE aligned with the LOB which focus on MSIs and minority-serving community colleges to help prepare historically underrepresented and underserved students in NASA specific STEM disciplines and careers. In addition, MUREP will compete and award an agreement for a MUREP Educator Institute (MEI). The work of this agreement will advance high quality STEM

MINORITY UNIVERSITY RESEARCH EDUCATION PROJECT

Formulation	Development	Operations

education using NASA's unique capabilities by conducting summer institutes for pre-service teachers at the 10 field Centers. The majority of MUREP funding will be used to continue to maintain active agreements and awards for HBCUs, HSIs, TCUs, AANAPISIs, other MSIs, and non-profit organizations that contribute to the Agency's workforce diversity and MUREP's goals. Some institutions and organizations could potentially receive 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 2016

MUREP will continue to provide competitive funding opportunities to MSIs through an omnibus solicitation called Educational Opportunities in NASA STEM (EONS). EONS can be located at the NASA Solicitation and Proposal Integrated Review and Evaluation System website. For more information go to: http://nspires.nasaprs.com.

Project Schedule

MUREP implements a consolidated investment through the NASA Research Announcement Education Opportunities in NASA STEM (EONS). A new EONS opportunity will be offered no later than the last quarter of FY 2016 with a rolling schedule of opportunities through FY 2018.

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 2014, the current MUREP elements are as follows:

Element	Description	Provider Details	Change from Formulation Agreement
MIRO	MIRO is designed to establish significant, multi-disciplinary, scientific, engineering, and/or commercial research centers at the host Minority-Serving Institution, that contribute substantially to the programs of one or more of the NASA Mission Directorates as described in the 2014 NASA Strategic Plan.	Provider: All NASA Centers Lead Center: Armstrong Flight Research Center 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
MUREP Community College Curriculum Improvement (MCI)	MCI is designed to strengthen STEM curricula and curricular pathways at two-year minority institutions (MIs); Strengthen and diversify the STEM pipeline through high school partnerships.	Provider: All NASA Centers Lead Center: Headquarters Performing Center(s) All NASA Centers: Cost Share Partner(s): N/A	
MUREP NASA Internship, Fellowship, and Scholarship (NIFS)	Intentional and consistent efforts are needed along the STEM trajectory in order to increase the number of individuals from groups traditionally underrepresented in STEM that graduate and are well-prepared with STEM degrees, because members of these groups leave STEM majors at higher rates than others. MUREP NIFS provides historically underrepresented groups in STEM fields and students at MSIs the opportunity to use NASA facilities and assets to provide work experiences and research and educational opportunities to improve retention in STEM and prepare students for employment in NASA STEM jobs.	Provider: All NASA Centers Lead Center: Johnson Space Center, Ames Research Center Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
MUREP for American Indian and Alaskan Native STEM Engagement (MAIANSE)	MAIANSE provides opportunities for TCU students, faculty and staff; and high school students who are likely to matriculate to TCUs, to engage in NASA-related STEM scientific research and engineering activities.	Provider: All NASA Centers Lead Center: Goddard Space Flight Center 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
MUREP Educator Institutes	MEI is designed to develop, promote, or utilize new, innovative, and replicable approaches to improving STEM learning and instruction; Provide experiences and activities that are grounded in education research or use evidence-supported approaches, techniques, and tools; and build linkages and connections to and from secondary education, elementary education, middle school education, and higher education.	Provider: All NASA Centers Lead Center: Stennis Space Center Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
MUREP STEM Engagement (MSE)	MSE gives MSIs the opportunity to design, develop, and implement a NASA-related STEM challenge targeted for MSI and community college STEM-enrolled student. All challenges align with the NASA mission and a specific NASA program or project. MSIs develop and implement processes to capture the impact of activities and strategies implemented through this challenge participation.	Provider: All NASA Centers Lead Center: Kennedy Space Center Performing Center(s): All NASA Centers Cost Share Partner(s): N/A	
Earth Systems, Technology and Energy Education for MUREP (ESTEEM)	ESTEEM is designed to increase the level of climate literacy and engagement of the United States public; advance the understanding of how to effectively teach global climate change concepts; and Create a diverse, highly skilled, and motivated future workforce in climate-related sciences.	Provider: All NASA Centers Lead Center: Langley Research Center 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
MUREP Aerospace Academy (MAA)	MAA is designed to Educate students using a STEM curriculum that meets national math, science and technology standards aligned to NASA's Mission Directorates.	Provider: All NASA Centers Lead Center: Glenn Research Center 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, 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

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**28.6**	**--**	**25.9**	**27.2**	**28.6**	**29.1**	**31.4**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

A competing team, Team Lore, listens in the audience as NASA Administrator Charles Bolden speaks at the event to announce the winner of the Exploration Design Challenge. Team Lore was one of the semi-finalists in the challenge. The goal of the Exploration Design Challenge is for students to research and design ways to protect astronauts from space radiation. The winner, Team ARES from Hampton VA, of the challenge was announced on April 25, 2014 at the USA Science and Engineering Festival at the Washington Convention Center in Washington, DC.

NASA continues to integrate and consolidate its STEM Education projects and activities into a more focused portfolio, consistent with Congressional and Administration direction to streamline and consolidate STEM education programs within NASA. Specifically, NASA continues internal consolidation of education functions, assets, and efforts of the Mission Directorates into the coordinated SEAP. SEAP-funded assets are critical and unique components that NASA can make available to the NSF, Smithsonian Institution, and ED, on a reimbursable basis, as they facilitate federal STEM education activities through the Administration's Committee on STEM process for agency coordination.

Working in collaboration with other Federal agencies, NASA continues 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 provides opportunities to educators and learners, including women, minorities, and persons with disabilities. NASA continues to review and consider appropriate ways to incorporate the most meritorious education functions, assets, and efforts of the Aeronautics Research Mission Directorate and Human Exploration and Operations Mission Directorate into SEAP. SEAP will enhances 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 makes its people, resources, facilities, and discoveries available to key stakeholders and strategic partners, such as educational organizations and science museums.

STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

Approximately 1 million elementary and secondary students participated in NASA instructional and enrichment activities. Of those students, NASA engaged more than 62,000 through the Summer of Innovation pilot project, launched in 2010 to support the President's Educate to Innovate campaign.

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. There were a total of 12 final selections, using FY 2014 funds, for awards at children's museums, NASA Visitor centers, and a planetarium and science center based in a public school system, and science museums. Thirty-six institutions that had active projects from prior awards during FY 2013 attended a reverse site visit cohosted at Marshall Space Flight Center's visitor center the US Space and Rocket Center in Alabama, the NASA Shared Services Center, and Jet Propulsion Laboratory.

Through the One-Stop Shopping Initiative, more than 7,000 undergraduate, graduate, and high school students applied for NASA-unique internship, fellowship, and scholarship opportunities. From this pool of exceptional talent, NASA Education was able to award 3,317 students with NASA-unique fellowship, internship, and scholarship opportunities.

WORK IN PROGRESS IN FY 2015

SEAP continues to fund a mix of new and old grants, contracts, and cooperative agreements highlighted in Project Management and Commitments below. The Educator Professional Development, STEM Engagement and Institutional Engagement lines of business have started to plan a joint STEM Facilitation & STEM Interagency Coordination Pilot Projects Competition to further advance NASA Education restructuring. The Summer of Innovation pilot project will complete implementation, and lessons learned activities, including from its collaboration with 4-H that are already available for implementation by Federal and non-federal STEM education stakeholders.

NASA has begun an internal criteria-based competition across the Mission Directorates and NASA Centers to identify the most meritorious education activities eligible for SEAP funds. Potential applicants and recipients for this funding include:

- Informal STEM Education and roughly 40 other NASA activities reported as part of the March *2014 Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (CoSTEM) Education*;
- Projects and activities not previously funded in prior years and would be new in FY 2015; and

STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations

- 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.

Internal competition ensures that SEAP funding is made available to the most effective and highest priority education activities across the agency. Demonstrated results and a plan for performance measurement, including assessment of progress toward pre-established goals, are among the criteria being used to judge merit. Additionally, SEAP investments are structured (or, if new, will be structured) to use or build on evidence of effectiveness or need. For example, research suggests that many pre-service teachers take required STEM courses in their first two years of college, either at a community college or at a four-year college or university, and these classes are often the last STEM classes that these future K-12 teachers take. SEAP supports a community of practice via the Museum Alliance comprising of educators, science centers, and museums to facilitate educators' access to the latest science knowledge being generated by NASA missions and programs. As of December 2014, professors, lecturers and planetarium directors at more than 150 higher education institutions in 43 States had signed up for this free-of-charge NASA STEM content facilitation service.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

SEAP will continue to support the most effective and highest priority STEM projects and activities identified in the FY 2015 competition and will begin planning for a FY 2017 competition. Since the internal competition results won't be known before the end of the third quarter of FY 2015, specific details about planned achievements are not currently available. Based on the process and criteria established for the internal competition, the Administration fully expects that the winners of the competition will reflect the best that NASA has to offer to the Nation's STEM enterprise.

Project Schedule

Consistent with the NSTC 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 worked with the CoSTEM to finalize criteria for success, develop common evidence standards, evaluation and research toolkits, and identify efficiencies and collaborative opportunities.

In years three 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 NSTC 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 2016	NSTC Committee on STEM Meetings

STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations

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 2016, NASA will make new commitments based on the competitive acquisition strategy described below. NASA Centers, including Jet Propulsion Laboratory, or other previously selected awardees may be eligible to compete for SEAP funding. 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: Universities Space Research Association 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 STEM education in Cleveland, NASA Headquarters in Washington, and other NASA Centers, as necessary.	Provider: Paragon-TEC, Inc. of Cleveland Lead Center: Glenn Research Center Performing Center(s): All Cost Share Partner(s): Not Applicable	No Change Contract expires March 2018 Performance start date: April 2013

Acquisition Strategy

In FY 2015 NASA conducted an internal, criteria-based competition across Mission Directorates and NASA Centers to identify the highest priority STEM projects and activities. 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 when necessary. External and internal experts base selections in part on peer reviews. The Education Coordinating Council also makes recommendations to the Associate Administrator for Education on any funding allocated to activities implemented directly by NASA Centers, including Jet Propulsion Laboratory.

MAJOR CONTRACTS/AWARDS

None.

STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations

INDEPENDENT REVIEWS

NASA's approach to independent reviews is informed by the Government Accountability Office report (GAO-14-374) STEM Education: Assessing the Relationship between Education and the Workforce (Published: May 8, 2014. Publicly Released: Jun 9, 2014) and reports from the NSTC CoSTEM (Progress Report on Coordinating Federal Science, Technology, Engineering, and Mathematics (STEM) Education, March 2014). (For more information, go to: http://www.whitehouse.gov/sites/default/files/microsites/ostp/STEM-ED_FY15_Final.pdf). NASA embeds evaluation and accountability requirements within SEA activities as appropriate for performance monitoring. Although the final schedule for completion of these reviews is not yet established, in October 2014 the NASA Office of Inspector General launched two studies related to measuring the performance of NASA Education. Audit of NASA's Education Program and Activities (Assignment No. A-14-015-00) has a dual objective to assess NASA's implementation of 1) its strategic education objective and 2) Federal STEM education priorities. The Office of Inspector General initiated a Review of NASA-funded Institutes (A-15-001-00) focused on NASA's institutional investments with the overall objective of identifying and examining the various institutes that receive funding from NASA for the advancement of the Agency's mission and goals.

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.	No further action due to pilot conclusion
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 for the stand-alone program model developed and implemented by Abt Associates in 2013 and 2014; reports available online at: http://www.nasa.gov/offices/education/performance/#.VGvlYvnF-Ag	No further action due to pilot conclusion

The contractor, Paragon TEC, conducted a pilot study of the collaboration between NASA and the ED in FY 2014 as explained below. This study's publication (forthcoming) is accessible at: http://www.nasa.gov/offices/education/performance/index.html#.VJCehCvF-Ah.

STEM EDUCATION AND ACCOUNTABILITY PROJECTS

Formulation	Development	Operations

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Implemen-tation evaluation study	Paragon TEC	Jan – May 2014	Conduct study to assess the implementation of NASA STEM Challenges within ED's 21CCLC program	Department of Education used the implementation study report to expand a second pilot beyond NASA to include other Federal agencies, e.g., the Institute for Museums and Library Services and the National Park Service.	Follow-on Implementation and outcome study of NASA's participation in the the multi-agency pilot begun in FY 2015.

SAFETY, SECURITY, AND MISSION SERVICES

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Center Management and Operations	2041.5	--	**2075.2**	2105.0	2136.6	2168.6	2201.0
Agency Management and Operations	751.5	--	**767.9**	780.7	792.5	804.4	816.5
Total Budget	**2793.0**	**2758.9**	**2843.1**	**2885.7**	**2929.1**	**2973.0**	**3017.5**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

SAFETY, SECURITY, AND MISSION SERVICES

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Center Management and Operations	2041.5	--	**2075.2**	2105.0	2136.6	2168.6	2201.0
Agency Management and Operations	751.5	--	**767.9**	780.7	792.5	804.4	816.5
Total Budget	**2793.0**	**2758.9**	**2843.1**	**2885.7**	**2929.1**	**2973.0**	**3017.5**
Change from FY 2015			**84.2**				
Percentage change from FY 2015			**3.1%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

NASA's Security Operations Center provides a coordinated operational and technical approach to ensuring the protection of the Agency's information assets.

Safety, Security, and Mission Services (SSMS) 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.

SSMS 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 4,400 buildings and structures on 330,000 acres across the Agency's Centers and facilities.

Missions rely on SSMS 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 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.

SAFETY, SECURITY, AND MISSION SERVICES

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

NASA is working to instill a culture of innovation in its workforce by recognizing and rewarding innovative performance; engaging and connecting the workforce to make it easy for employees to collaborate, network, and innovate; and creating an environment in which leaders view developing innovative employees as a productive and vital use of their time. SSMS activities provide the facilities, tools, and services needed to conduct NASA's missions safely and effectively. For example, in FY 2014, NASA:

- Demonstrated its commitment to workforce innovation by increasing its Innovation Index score from 77.2 percent in FY 2013 to 78.0 percent in FY 2014, as determined through three innovation-related questions in the annual Federal Employee Viewpoint Survey;
- Generated 7.6 percent of its electricity from renewable energy sources, exceeding the target of 7.5 percent; and
- Assured the safety and health of its activities. NASA's Total Case Rate and Lost Time Case Rate were under the injury/illness goals established in the President's Protecting Our Workers and Ensuring Reemployment (POWER) initiative.

WORK IN PROGRESS IN FY 2015

SSMS 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:

- Initiating 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;
- Conducting safety reviews and independent technical assessments of NASA's missions; and
- Improving NASA's Information Technology (IT) network security with an enterprise approach to perimeter control and maintenance. Work includes implementation of an Enterprise Firewall and Web Content Filter, deployment of a Network Access Control system inside NASA's networks, and replacement of Center Virtual Private Networks with and enterprise-enabled solution.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

In FY 2016, SSMS programs will continue to enable program and institutional capabilities to conduct NASA's aeronautics and space activities. SSMS programs will:

- Continue to improve the Agency's information security posture and assure the Agency's IT systems and networks support NASA's critical missions;

- Implement key findings and recommendations from National Research Council study (Limiting Future Collision Risk to Spacecraft: An Assessment of NASA's MMOD Programs) on micrometeoroid and orbital debris;
- Assess high pressure layered pressure vessels to evaluate material fracture properties, vessel analysis methodologies, and inspection techniques, to ensure that unsafe vessels are identified in time to prevent excessive risk to personnel;
- Operate and maintain NASA Centers and major component facilities to ensure a safe, healthy, and environmentally responsible workplace;
- Provide essential operations such as Center security, environmental management, safety services, and facility maintenance;
- Support the workforce with utilities, IT, legal, occupational health, equal employment opportunity, financial management, and human resources services;
- Provide the technical facilities, workforce expertise and skills, equipment, and other resources required to implement the program at the Center; and
- Ensure engineering and safety oversight of NASA's programs.

Themes

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

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 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Center Institutional Capabilities	1591.9	--	**1627.4**	1644.1	1667.5	1692.0	1714.4
Center Programmatic Capabilities	449.6	--	**447.8**	460.9	469.1	476.6	486.6
Total Budget	**2041.5**	--	**2075.2**	**2105.0**	**2136.6**	**2168.6**	**2201.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

NASA Centers across the country provide the institutional and programmatic capabilities required to support the missions. Here, Security Officers at JSC White Sands Test Facility are conducting a perimeter check of the facility.

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 2016

None.

ACHIEVEMENTS IN FY 2014

NASA continued to improve operations to enable the Agency to conduct its day-to-day technical and business operations more effectively. For example:

- Glenn Research Center (GRC) reduced the number of printers and copiers by consolidating the delivery of services;
- Marshall Space Flight Center (MSFC) converted 119 acres of maintained space to a natural state to save grounds maintenance costs;

- Armstrong Flight Research Center (AFRC) implemented real-time data visualization of remote flight testing to allow project personnel from other Centers to monitor testing data without travel to AFRC; and
- Kennedy Space Center (KSC) improved video surveillance at all access gates to enhance safety and protection of assets and workforce.

To provide for early detection and correction of facility maintenance issues, Centers increased reliability-centered maintenance and condition-based monitoring activities. New differential pressure sensors installed on air handlers at Stennis Space Center (SSC) and similar activities Agency-wide will reduce maintenance requirements and facilitate correction of maintenance problems before costly failures occur.

WORK IN PROGRESS IN FY 2015

In FY 2015, Centers are providing the essential day-to-day technical and business operations required to conduct NASA's aeronautics and mission activities. Activities encompass the services, tools, and equipment required 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. Efforts underway include:

- Partnering with local utility providers to assess and improve energy and water use;
- Consolidating activities into fewer, more efficient facilities to reduce energy usage and maintenance requirements;
- Installing radio-frequency identification (RFID) tagging systems to improve the efficiency and accuracy of real property inventory and management activities; and
- Replacing aging IT equipment and systems to improve security and effectiveness.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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 2016, CMO will support:

- Facility maintenance and operations; including: utility and custodial support of approximately 4,400 buildings and structures with a current total replacement value of $34 billion (83 percent of NASA's assets by value are beyond their design life);
- 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 16,100 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;
- 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 Centers, 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 42,500 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.

Center Programmatic Capabilities provide a key component of NASA's overall system of checks and balances. 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

CENTER MANAGEMENT AND OPERATIONS

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. They concur based on the technical merits of each case and agreement that the risks are acceptable. This assures that NASA conducts its mission activities safely in accordance with accepted standards of professional practice and applicable NASA requirements.

Engineering Technical Authorities

$ in millions	**FY 2016**
Ames Research Center	$8.5
Armstrong Flight Research Center	$7.2
Glenn Research Center	$11.9
Goddard Space Flight Center	$12.7
Johnson Space Center	$22.4
Kennedy Space Center	$15.6
Langley Research Center	$17.1
Marshall Space Flight Center	$38.6
Stennis Space Center	$3.7
Grand Total	**$137.7**

Figure 1: Engineering Technical Authorities provide for independently funded engineering assessment of programs

CENTER MANAGEMENT AND OPERATIONS

Safety and Mission Assurance Technical Authorities

$ in millions	FY 2016
Ames Research Center	$2.6
Armstrong Flight Research Center	$4.1
Glenn Research Center	$2.4
Goddard Space Flight Center	$10.4
Johnson Space Center	$6.9
Kennedy Space Center	$8.6
Langley Research Center	$3.1
Marshall Space Flight Center	$8.3
Stennis Space Center	$2.0
Grand Total	**$48.2**

Figure 2: Safety and Mission Assurance Technical Authorities provide for independently funded safety assessment of programs

AGENCY MANAGEMENT AND OPERATIONS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Agency Management	384.0	--	**395.4**	402.6	408.7	414.8	421.0
Safety and Mission Success	179.0	--	**166.6**	169.1	171.7	174.3	177.0
Agency IT Services (AITS)	161.5	--	**179.0**	181.7	184.4	187.2	190.0
Strategic Capabilities Asset Program	27.0	--	**26.9**	27.3	27.7	28.1	28.5
Total Budget	**751.5**	**--**	**767.9**	**780.7**	**792.5**	**804.4**	**816.5**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

At Cape Canaveral Air Force Station's Space Launch Complex 37, NASA Administrator Charlie Bolden, along with other agency and contractor officials talk to members of the news media in front of the United Launch Alliance Delta IV Heavy rocket with NASA's Orion spacecraft mounted atop.

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 meet 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 consists of four programs: Agency Management, Safety and Mission Success (SMS), Agency Information Technology Services (AITS), and Strategic Capabilities Asset Program (SCAP).

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 President's Budget includes funding to build a Digital Service team that will focus on transforming the agency's digital services with the greatest impact to citizens and businesses so they are easier to use and more cost-effective to build and maintain. Increased funding will enable the Agency to implement the Digital Accountability and Transparency Act, which includes the disclosure of all Federal spending and standardization of spending data. To strengthen NASA's oversight of procurement spending, NASA will modify the Agency's IT systems related to procurement spending and management as well as increase the acquisition workforce. This modification to establish a uniform procurement identification is vital to support the move to electronic invoicing, shared financial services, and implementation of the Digital Accountability and Transparency Act.

ACHIEVEMENTS IN FY 2014

NASA was recognized as the Best Place to Work in the Federal Government among large agencies during 2014, including being ranked first in leadership, innovation, support for diversity, and teamwork. For the fourth consecutive year, the Agency received a clean (unmodified) audit opinion of its accounting and financial systems.

NASA signed a lease with Planetary Ventures, LLC (PV) to manage Moffett Federal Airfield and rehabilitate historic Hanger 1 located at Ames Research Center in California.

NASA implemented 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 improve NASA’s IT security and address concerns from NASA’s Inspector General (IG report numbers IG-11-017 and IG-13-001), as well as aid NASA in meeting the Office of Management and Budget Cross-Agency Priority (CAP) goals.

WORK IN PROGRESS IN FY 2015

As part of a renewed lease and associated building renovation, NASA’s Headquarters office building will achieve Leadership in Energy and Environmental Design (LEED) Gold certification by the end of FY 2015.

The Office of Safety and Mission Assurance program is performing safety reviews and independent technical assessments of NASA missions.

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 15 projects including 12 NASA missions, three multi-agency missions (National Oceanic and Atmospheric Administration (NOAA)/NASA), and seven NASA Centers.

NASA will continue to 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 applications business systems to improve performance, reduce costs, and retire risks associated with running obsolete systems.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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 National Agency Check (NAC) systems inside NASA's networks, and replacement of Center VPNs with an enterprise Personal Identity Verification (PIV)-enabled solution.

Collaborative efforts between the Office of Safety and Mission Assurance (OSMA), OCE, and OCHMO will continue to strengthen the Agency's Technical Authority capability. 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 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.

STRATEGIC CAPABILITIES ASSETS PROGRAM

SCAP ensures the essential Agency 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 supported within SCAP are thermal vacuum chambers, simulators, and the Arc Jet Facility.

AGENCY MANAGEMENT

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Total Budget	**384.0**	**--**	**395.4**	**402.6**	**408.7**	**414.8**	**421.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

NASA Headquarters in Washington D.C. provides overall planning and policy direction for Headquarters and the corporate management for all of its field Centers, which includes approximately 50,000 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 2016

Agency Management activities will enable an ongoing focus on security and other services to support mission operations. Agency Management includes funding to build a Digital Service team to meet the requirements of the Digital Accountability and Transparency Act. NASA will modify the Agency's IT systems related to procurement spending and management as well as increase the acquisition workforce.

AGENCY MANAGEMENT

ACHIEVEMENTS IN FY 2014

In FY 2014, the Agency received a clean (unmodified) audit opinion of its accounting and financial systems for the fourth consecutive year. The auditor's opinion of an unmodified financial statement asserts the Agency's financial statements accurately represent its financial position and operations.

The Partnership for Public Service recognized NASA as the Best Place to Work in the Federal Government among large agencies based on the 2014 Employee Viewpoint Survey results. This includes ranking first in leadership; innovation; support for diversity; teamwork; and first among women, African Americans, people with disabilities, and veterans. The Office of Personnel Management conducted this survey.

As part of a renewed lease, the Headquarters completed its office building renovation in 2014. This renovation increased energy and workplace efficiency and created a more collaborative work environment. The replacement of the Heating, Ventilating, and Air Conditioning (HVAC) system and the transition to a Light-Emitting Diode (LED) lighting system increased the energy efficiency of the building. Floor plans were also revamped to 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. The new energy efficient LED lighting reduced overall energy usage by 20 percent, and the installation of a Variable Air Volume HVAC system increased energy efficiency by 15 percent. Overall, the project resulted in increased energy efficiency of over 35 percent while providing natural daylight to 75 percent of building occupants.

WORK IN PROGRESS IN FY 2015

As part of a renewed lease and associated building renovation, NASA's Headquarters office building will achieve Leadership in Energy and Environmental Design (LEED) Gold certification by the end of FY 2015.

NASA is expanding the pilot for the PMF-STEM track program to provide for seven more participants across the Agency.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

The Agency will continue to refine and improve NASA's Insider Threat Program. The goal is to enhance NASA's ability to gather, integrate, centrally analyze, and respond to key threat-related information, deploy improved monitoring capabilities for classified and unclassified networks, provide insider threat awareness training, and protect the civil liberties and privacy of all NASA personnel.

The success rate of government digital services is improved when agencies have digital service experts on staff with modern design, software engineering, and product management skills. To ensure the Agency can effectively build and deliver important digital services, Agency Management includes funding to build a Digital Service team that will focus on transforming the agency's digital services with the greatest impact to citizens and businesses so they are easier to use and more cost-effective to build and maintain.

AGENCY MANAGEMENT

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:

- IT 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; and 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
- 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 for functional leadership of administrative and mission support activities at Headquarters and Centers perform this diverse set of activities on behalf of the Agency.

Mission Support activities include:

- Execution and management of the Agency's financial and budget processes and systems. This includes overseeing 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.

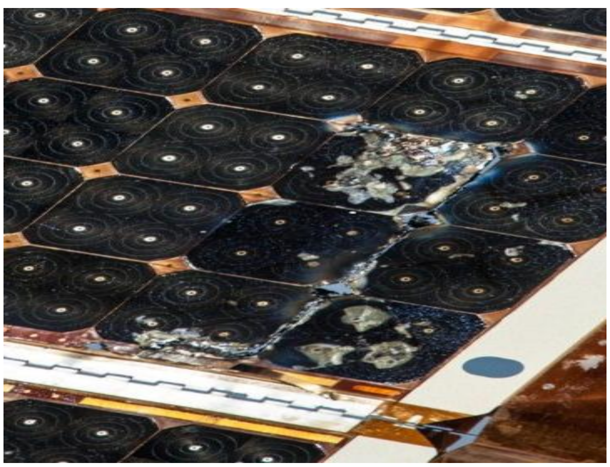
SAFETY AND MISSION SUCCESS

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Safety and Mission Assurance	48.7	--	**50.1**	50.8	51.6	52.4	53.2
Chief Engineer	87.0	--	**83.4**	84.7	86.0	87.3	88.6
Chief Health and Medical Officer	4.2	--	**4.2**	4.3	4.3	4.4	4.5
Independent Verification and Validation	39.1	--	**28.9**	29.3	29.8	30.2	30.7
Total Budget	**179.0**	**--**	**166.6**	**169.1**	**171.7**	**174.3**	**177.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.



Understanding the risk to spacecraft from Micrometeoroids and Orbital Debris (MMOD) helps spacecraft designers to better protect their spacecraft. This Figure shows an area of damage on the photovoltaic cells of the ISS 3A solar array wing. A 7-millimeter-sized MMOD perforation of the solar array panel broke a bypass diode. Major overheating of the solar array occurred in the vicinity of the MMOD impact damage due to the broken bypass diode, causing a nearly 36-centimeter-long U-shaped burn or tear in the Kapton backing.

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 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.

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 required by the technical authorities to develop authoritative decisions related to the application of requirements on programs and projects.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

SMS conducted 17 formal, stringent Safety and Mission Success Reviews. These reviews are the culmination of the identification and mitigation of all potential Safety and Mission Assurance (SMA) problems for launches and high criticality events. Substantive participation in Directorate Program Management Council (DPMC), Flight Planning Boards, Key Decision Points reviews, and scores of lower level reviews and assessments collectively enable effective governance and successful mission implementation.

OSMA provided policy direction, functional oversight, and assessment for all Agency safety, reliability, maintainability, and quality engineering and assurance activities. This office served as the principal advisory resource for the Administrator and other senior officials on matters pertaining to safety and mission assurance. In FY 2014, OSMA successfully executed these functions and enhanced its efforts to assess and communicate the health of safety and mission assurance throughout the Agency in support of NASA's strategic goals and governance approach.

OSMA updated seven Agency-level directives/standards. Significant changes included the addition of a policy to promote a healthy safety culture, the formal adoption by NASA of a pre-tailored version of Air Force payload safety requirements, and clarifications of mission classification related to a review of Cat 3/Class D mission requirements. OSMA updated and vetted each document to ensure requirements were clear, necessary, and supported NASA's mission.

NASA's IV&V Program provided software expertise to 18 projects and 7 NASA Centers. The IV&V Program uses a rating system for issues identified in software artifacts. The issue ratings range from 1 to 5. A '1' indicates that if the issue were to manifest itself during spacecraft or system operations, NASA could experience loss of life, physical injury, and/or mission failure. In FY 2014, the IV&V Program documented 64 issues with a rating of 1. The resolution of these issues is critical for the safety and mission success of these projects.

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 Occupational Safety and Health Administration (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 and focus health promotion efforts.

SAFETY AND MISSION SUCCESS

The OCE-led NASA Technical Standards Program developed and published 10 NASA Engineering Standards and Handbooks, while the use of the Web has resulted in over 104,000 technical standards products being downloaded by the Agency. The NASA Engineering and Safety Center accepted 54 requests for independent technical assessment and support activities in FY 2014.

WORK IN PROGRESS IN FY 2015

The SMA program continues to conduct safety reviews and independent technical assessments for NASA missions, including any newly selected projects. The SMA program will continue to 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. The SMA program will also continue to advance its program to detect, track, catalog, and reduce the number of counterfeit electronic parts in the NASA supply chain. The SMA program will continue to enhance its portfolio of requirements and technical guidance documents and its suite of SMA training.

NASA and the Air Force Research Laboratory (AFRL) are collaborating to place a wide field-of-view, 1.3-meter aperture telescope on Ascension Island for space debris research.

OCHMO is continuing its implementation of the 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 research and technology (R&T) programs and projects; and NASA-unique occupational and environmental health requirements that are not mandated by OSHA or the Environmental Protection Agency. In cases where there is no NASA-unique or federally-mandated health/medical requirement or standard, 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, 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 15 projects, including 12 NASA missions and 3 multi-agency missions (NOAA/NASA), and across 7 NASA Centers.

OCE, including the NASA Engineering and Safety Center (NESC), continues to remain vigilant in supporting the achievement of the Agency's major priorities. Through the Agency technical reviews, OCE maintains Technical Authority caucuses to ensure full integrity and to ensure all dissenting and divergent opinions had been fully heard and appropriately considered. The NESC plans to conduct over 50 independent assessments of NASA's highest risk challenges maintaining prioritization on the ISS, Commercial Crew, Orion/Space Launch System (SLS), James Webb Space Telescope (Webb), and Space Technology. OCE continues to be an active participant in the Agency's Technical Capability Assessment Team efforts and provides leadership for a number of discipline-related assessments.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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; (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.

In FY 2016, OSMA will increase efforts to examine layered pressure vessel material properties, analysis methodologies, and inspection techniques. OSMA will also develop assurance methodologies for the emerging fields of additive manufacturing and 3D printing.

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, 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 FY 2016, 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.

Collaborative efforts between OSMA, OCE, and OCHMO will continue to strengthen the Agency's Technical Authority capability. The offices will continue to work together, conducting safety reviews and independent technical assessments of NASA's missions, including ISS, Commercial Crew, Orion/SLS, Webb, 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 as well as for 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

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 NESC, 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, the NESC performs independent testing, analysis, and assessments of NASA's high-risk projects to ensure safety and mission success. SMS funding provides for the core NESC organization of senior engineering experts from across the Agency, including the NASA Technical Fellows and technical discipline teams. As an Agency-wide resource with a reporting path that is independent of the Mission Directorates and independently funded from OCE, the NESC 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. The NASA Engineering Network is 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. Annual certified continuing medical education activities and flight surgeon education support ongoing medical and health discipline professionalism and licensure. To maintain clinical currency, OCHMO sponsors university-based physician training programs. NASA's biomedical research programs, in support of human space flight, are guided by NASA-developed health and medical standards.

SAFETY AND MISSION SUCCESS

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 reducing the cost to develop the software. IV&V identifies software problems as early as possible, therefore 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. 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 formulating software development improvement recommendations to the Agency.

IV&V performs independent testing of critical system software as a state-of-the-art 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; and
- Training and education for workforce and students.

INDEPENDENT REVIEWS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Safety	Aerospace Safety Advisory Panel	Jan 2015	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: http://oiir.hq.nasa.gov/asap/	Apr 2015

SAFETY AND MISSION SUCCESS

Review Type	Performer	Date of Review	Purpose	Outcome	Next Review
Program Audit	NASA Office of the Inspector General	Audit announced on Sep 2, 2014	Audit of NASA's Pressured Vessels and Systems Program	Anticipating recommendations to the NASA Administrator	On-going Audit

AGENCY IT SERVICES (AITS)

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
IT Management	14.9	--	**13.2**	18.2	19.2	20.3	21.4
Applications	55.5	--	**60.6**	59.4	61.7	64.1	66.1
Infrastructure	91.1	--	**105.2**	104.1	103.5	102.8	102.5
Total Budget	**161.5**	--	**179.0**	**181.7**	**184.4**	**187.2**	**190.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

NASA's IT Infrastructure Integration Program (I3P) transformed NASA's IT Infrastructure services from a Center-based model to an enterprise-based management and provisioning model. The scope of I3P is entailing consolidation and central management of IT services in the areas of service desk and ordering, Web services and technologies, enterprise business and management applications, integrated network/ communications services, end user services, and data center services.

The AITS program provides the Agency's information technology services, including IT security policy and incident monitoring, Web services for the Agency's Web sites, 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 in achieving mission success. The program also improves citizen access to NASA scientific data and increases citizen participation in NASA activities.

The AITS program provides an enterprise model for infrastructure and business applications. The Infrastructure Integration Program (I3P) improves security, efficiency, and standardizes services across the Agency. AITS develops 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 Web sites and services that facilitate the Agency's statutory requirement to disseminate information concerning its activities and missions results. The NASA Web 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. It also 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 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

ACHIEVEMENTS IN FY 2014

In alignment with the 2014 NASA Strategic Plan, NASA published the 2014 Information Resources Management Strategic Plan. The three Information Resource Management goals and underlying objectives focus the NASA IT community on providing mission-enabling IT capabilities, risk-based cyber security, and a sustainable management approach to support NASA's diverse mission needs.

NASA implemented a CDM and ISCM strategy, which improved real-time or near real-time situational awareness of its IT Security state. NASA continued to increase initiatives related to IT Security. Examples include: (1) transformation and expansion of continuous monitoring capabilities; governance, risk, and compliance; and penetration testing; (2) deployment of intrusion detection systems across mission, corporate, and research networks; (3) expansion of Web application security scanning; (4) continued implementation of PIV capability on Windows-based systems; and (5) implementation of intrusion prevention systems at Trusted Internet Connection (TIC) locations. These activities improved NASA's IT Security and addressed concerns from NASA's Office of Inspector General, as well as aided NASA in meeting OMB's CAP goals.

NASA's IT Security Enterprise Data Warehouse (ITSEC-EDW) continued to provide continuous monitoring status for detailed scans of hardware/software inventory, security controls, and network vulnerability data. ITSEC-EDW also added the capabilities to correlate the Risk Management Framework data into the Agency IT Security dashboard. The dashboard provides information at the Agency, Center, and security plan levels.

NASA capitalized 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. NASA expanded the Web Application Security Program (WASP) in FY 2014 and implemented an automated scanning process to identify security vulnerabilities, prioritize criticality of vulnerabilities, and coordinate with Centers to mitigate the related issues. In addition to WASP, NASA continued to conduct in-depth penetration testing at individual Centers. These penetration-testing activities drove corrective actions for 195 discovered vulnerabilities. In support of OMB's CAP goal for cyber security, NASA achieved 75 percent compliance for strong authentication using PIV authentication for Windows systems. The Agency also procured and deployed Intrusion Detection Systems (IDS) and Intrusion Prevention Systems (IPS) on the NASA Mission and Research Networks.

AGENCY IT SERVICES (AITS)

NASA worked closely with the General Services Administration (GSA) to ensure NASA data was accessible, machine-readable, and available on Data.gov. The Open Innovation Program coordinated the third annual Internal Space Apps Challenge, which featured challenges within six mission focus areas: robotics, human spaceflight, Earth watch, planet watch, space technology, and asteroids. In this third-annual challenge, more than 8,000 volunteers in 95 cities and 70 countries participated in 40 challenges. In three years, nearly 2,000 solutions have resulted in crowd-sourced methods to monitor air, water, and urban pollution, track environmental mishaps, alert citizens of weather or health-related disasters, and track the stars.

NASA continues leveraging the Cloud to reduce operational costs by transitioning Web applications to a centralized cloud platform thereby reducing operations and maintenance (O&M) costs through the Web Services Program. NASA migrated over 150 Web applications into the production cloud environment. Following these migrations, NASA's focus shifted to the consolidation and decommissioning of applications and Web sites when practical to reduce costs. NASA decommissioned 45 applications that were no longer relevant for their programs or were consolidated into other existing Web sites and applications. These efforts resulted in a $3million per year cost avoidance for O&M as compared to the FY 2013 expenses. Furthermore, the migration of NASA Headquarters' applications to the centralized environment reduced the Headquarters' data center footprint by 60 percent.

WORK IN PROGRESS IN FY 2015

NASA is increasing 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 is replacing outdated applications business systems to improve performance, reduce costs, and retire risks associated with running obsolete systems. In addition, NASA is deploying network Data Loss Prevention (DLP) capabilities in FY 2015, which will help the Agency identify sensitive data, determine its location, and assign policies for access control.

NASA is investing cybersecurity resources to manage risk and mitigate cyber threats. The Agency continues to improve on cybersecurity activities such as preventing malicious cyber activity, including the protection of Federal systems; detecting, analyzing, and mitigating intrusions, including investigating and prosecuting cyber criminals; and shaping the cybersecurity landscape.

NASA is providing Instructor-Led Training (ILT) and Computer-Based Training (CBT) for Web Programming Techniques for Vulnerabilities. These training efforts will improve effectiveness of the NASA IT Security Program and reduce the number of Web related programming incidents.

The Agency continues to re-architect NASA's Wide Area Networks (WANs) to establish a defensible Agency network perimeter, including improving its network security with an enterprise approach to perimeter control and maintenance, (e.g. planning and development of an Enterprise Firewall and Web Content Filter), planning to deploy NAC systems inside NASA's networks, and designing an enterprise PIV-enabled remote access system to replace Center VPNs. These activities greatly enhanced NASA's security posture. Efficiencies are being 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 augmented the WAN backbone maintaining mission critical service levels, to accommodate growing requirements more efficiently and securely, enabling the consolidation of NASA's mission and corporate WANs backbones, and reducing transport costs.

NASA will complete and publish the target IT architecture in FY 2015 for the Work from Anywhere (WFA) implementation, with specific portfolio roadmaps and details to identify viable alternatives to support federal and Agency mobility goals for NASA employees to work away from the office.

Under the goal of Smarter IT Delivery, NASA will increase the adoption of cloud computing throughout the infrastructure and mission, by deploying an enterprise managed cloud infrastructure. This will simplify the compliance portions of cloud for all NASA users, as well as create a sandbox environment for NASA users to benchmark their applications and test out available cloud constructs as they consider whether cloud is the right platform for new applications and applications at a modernization point.

NASA currently operates two separate backbone infrastructures: one for critical spacecraft/science operations and one for Agency corporate services. Under the goal of Network Transformation, NASA will optimize these backbone infrastructures, reducing cost and improving service delivery. In FY 2015, the Mission Next Generation Architecture (MngA) will implement the new Mission network architecture required to support emerging and upcoming mission concepts and requirements, using the backbone infrastructure wherever possible to reduce the overall cost of wide area Mission network services.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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.

Also in FY 2016, NASA will continue to transform the network by transitioning to a single NASA enterprise network and effectively utilize the bandwidth of the Communications Services Office backbone for both corporate and mission data, enabling more efficient use of available capacity, while improving performance with no degradation to mission services. These efficiencies will allow reinvestment of savings into the continued improvement of the network. In addition, NASA currently operates two entirely separate backbone infrastructures: one for critical spacecraft/science operations and one for Agency corporate services. The goal is to drive efficiencies by consolidating the operation of the end- to-end NASA network and optimize the backbone infrastructures to reduce cost and improve service delivery. NASA will complete the Consolidated Network Operations System Project, which will standardize network operations processes and procedures across Communications Services Office Corporate Networks into Center Operations and Processes This standardization ensures operational efficiencies by using Enterprise best practices to consolidate network services and reduce duplication of effort, while improving overall end-to-end visibility of Communications Services Office managed networks and improved IT security. NASA's mission services will begin transitioning to the new communications backbone, allowing for decommission of legacy transport services, resulting in cost avoidances. Capacity increases to this backbone will support additional Space Communications and Navigation requirements.

AGENCY IT SERVICES (AITS)

Under the goal of Smarter IT Delivery, NASA will continue to support the Administration's mandate of "Cloud First" when making new (or life cycle) investments.

STRATEGIC CAPABILITIES ASSET PROGRAM

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	27.0	--	26.9	27.3	27.7	28.1	28.5

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The Z1 space suit and Suit Port testing was conducted in vacuum at Chamber B, located at NASA's Johnson Space Center, Houston, TX. Chamber B is the largest known human-rated space environmental simulation facility at 35 feet diameter and 43 feet high. NASA's unique Space Environment Simulation Capabilities has enabled and contributed to areas of spacecraft integration, space power, in-space propulsion, and space suit development for 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 that SCAP supports include: 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 2016

None.

ACHIEVEMENTS IN FY 2014

SCAP ensured and sustained that the asset capabilities identified as essential by the Agency were maintained in a state of readiness. SCAP maintained the skilled workforce and performed essential preventative maintenance necessary to keep these asset capabilities available to meet current and future program requirements.

SCAP's Ames Arc Jet Complex supported testing for Orion, SMD, STMD, Department of Defense (DoD), and commercial test programs.

SCAP and the Space Environmental Testing Assets Group (SETAG) completed an inventory update of large space environmental testing assets with the Agency.

SCAP assets continued to support the development, testing, verification, and validation for NASA, DoD, NOAA, Federal Aviation Administration (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, enhanced stall modelling and other ongoing development and testing;
- Thermal vacuum and acoustic chambers: Orion, James Web Space Telescope, Deep Space Climate Observatory, Joint Polar Satellite System, Satellite Servicing Capabilities Office, Atlas, Solar Probe Plus, Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-Rex), 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 2015

SCAP's JSC Chamber A will finalize preparations for the initial test series for Webb. SCAP's Chamber B will support Z2 space suit testing.

SCAP's GRC Space Power Facility will support Orion and other commercial companies in thermal vacuum and acoustic testing.

SCAP plans to review and identify high-risk areas for the thermal vacuum capability at MSFC to assess the condition and health of the assets.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

SCAP will continue to sustain the strategic technical capabilities needed by NASA to achieve successful missions.

SCAP's GRC Space Power Facility will continue to support Orion EM-1 and commercial companies in thermal vacuum and acoustic testing.

Program Elements

SCAP maintains the skilled workforce and performs the maintenance required to keep essential NASA assets available to meet program requirements.

STRATEGIC CAPABILITIES ASSET PROGRAM

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 Magnetospheric Multi-Scale (MMS), 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

	Actual	Enacted	Request		Notional		
($ in millions in full cost)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
Aeronautics Research	6.8	6.8	7.1	7.3	7.1	7.2	7.4
Human Exploration and Operations	25.0	24.7	24.7	26.4	27.1	27.9	28.6
Science	27.2	28.6	29.8	30.7	31.4	32.4	33.2
Space Technology	4.8	4.7	4.3	5.0	5.1	5.3	5.4
Mission Directorates	**63.8**	**64.8**	**65.9**	**69.3**	**71.1**	**73.2**	**75.0**
Office of the Administrator	8.4	8.2	8.4	8.5	8.7	8.8	8.9
Office of Evaluation	16.1	16.0	17.7	17.8	18.0	18.2	18.3
Chief Engineer	4.4	4.2	4.4	4.5	4.6	4.8	4.9
Chief Financial Office	24.8	24.3	28.4	28.9	29.3	29.8	30.3
Chief Health and Medical Office	1.7	1.7	1.7	1.8	1.8	1.9	1.9
Chief Information Office	8.0	7.0	7.3	7.5	7.7	7.9	8.1
Chief Scientist	1.4	1.4	1.4	1.4	1.5	1.5	1.5
Chief Technologist	1.4	1.4	1.4	1.4	1.5	1.5	1.6
Communications	14.4	12.9	14.1	14.5	15.1	15.0	15.3
Diversity and Equal Opportunity	4.2	4.0	4.1	4.2	4.3	4.3	4.4
Education	2.9	2.8	2.9	3.0	3.1	3.2	3.2
General Counsel	9.1	8.7	9.3	9.8	10.0	10.3	10.5
International and Interagency Relations	12.4	11.7	12.2	12.4	12.7	12.9	13.2
Legislative and Intergovernmental Affairs	3.7	3.6	3.9	4.0	4.1	4.2	4.3
Safety and Mission Assurance	6.5	6.4	6.7	6.8	7.0	7.2	7.4
Small Business Programs	1.8	1.7	1.8	1.8	1.8	1.9	1.9
Staff Offices	**121.3**	**116.0**	**125.7**	**128.5**	**131.1**	**133.4**	**135.6**
NASA Management Office at JPL	8.5	8.2	8.3	8.4	8.6	8.7	8.8
Human Capital Management	15.7	16.8	18.8	18.0	17.9	17.1	17.0
Headquarters Operations	113.5	105.2	108.5	109.6	111.6	114.0	115.2
Strategic Infrastructure	15.4	14.6	15.0	15.3	15.6	15.9	16.1
Internal Controls and Management Systems	1.9	1.9	2.0	2.0	2.1	2.1	2.2
Procurement	11.6	10.8	21.0	21.2	21.3	21.5	21.7
Mission Support Directorate Front Office	2.1	1.8	1.9	1.9	2.0	2.0	2.0

HEADQUARTERS BUDGET BY OFFICE

	Actual	Enacted	Request	Notional			
($ in millions in full cost)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
NASA Shared Services Center	13.5	7.2	6.7	6.9	7.2	7.4	7.6
Protective Services	16.8	18.6	21.6	21.3	20.3	19.6	19.7
Mission Support	**198.9**	**185.3**	**203.9**	**204.7**	**206.5**	**208.3**	**210.4**
Total, Agency Management	**384.0**	**366.0**	**395.4**	**402.6**	**408.7**	**414.8**	**421.0**

HEADQUARTERS TRAVEL BUDGET BY OFFICE

HEADQUARTERS TRAVEL BUDGET BY OFFICE

	Actual	Enacted	Request
($ in millions in full cost)	**FY 2014**	**FY 2015**	**FY 2016**
Aeronautics Research*	0.4	0.5	0.5
Human Exploration and Operations*	2.6	2.6	2.6
Science*	2.1	2.3	2.3
Space Technology*	2.0	2.0	2.0
Mission Directorates	**7.1**	**7.4**	**7.4**
Office of the Administrator	0.8	0.9	0.9
Office of Evaluation	0.5	0.5	0.5
Chief Engineer	0.7	0.7	0.7
Chief Financial Office	0.3	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	0.1	0.1	0.1
Chief Technologist	0.2	0.2	0.2
Communications	0.2	0.2	0.2
Diversity and Equal Opportunity	0.1	0.1	0.1
Education*	0.1	0.3	0.3
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
Staff Offices	**4.3**	**4.6**	**4.6**
NASA Management Office at JPL	0.2	0.2	0.2
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	0.2	0.3	0.3
Mission Support Directorate Front Office	0.1	0.1	0.1
Protective Services	0.2	0.2	0.2
Mission Support	**1.7**	**1.9**	**1.9**
Total, Agency Management	**13.0**	**13.9**	**13.9**

** 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 SSMS Agency Management program account).*

HEADQUARTERS WORKFORCE BY OFFICE

HEADQUARTERS WORKFORCE BY OFFICE

	Actual				Enacted				Request			
	FY 2014				FY 2015				FY 2016			
	FTE	SES	NC*	WYE	FTE	SES	NC*	WYE	FTE	SES	NC*	WYE
Aeronautics Research	38	8		10	38	9		13	38	9		13
Human Exploration and Operations	137	12	1	62	137	14	1	60	131	18	1	62
Science	143	19	1	73	153	20	1	64	153	20	1	64
Space Technology	26	2		11	26	2		11	23	3		11
Mission Directorates	**343**	**41**	**2**	**202**	**353**	**45**	**2**	**148**	**345**	**50**	**2**	**149**
Office of the Administrator	25	7	6		25	6	7		25	6	7	
Office of Evaluation	29	4	1	16	32	4	1	9	37	4	1	4
Chief Engineer	22	5	1	15	22	7	1	16	22	9	1	16
Chief Financial Office	99	9	2	33	99	9	2	33	99	9	2	33
Chief Health and Medical Office	10	1		1	10	1		1	10	1		3
Chief Information Office	43	5		23	39	6		43	39	7		43
Chief Scientist	5	2	1		5	3	1		5	3	1	
Chief Technologist	7	1	1		7	1	1		7	1	1	
Communications	49	2	3	28	49	2	3	28	49	3	3	28
Diversity and Equal Opportunity	17	3		3	17	3		3	17	3		3
Education	14	2		13	14	2		18	14	3		18
General Counsel	41	6	2		41	6	2		41	6	2	
International and Interagency Relations	50	8	1	9	51	8	1	7	51	8	1	7
Legislative and Intergovernmental Affairs	26	3	3	3	26	3	3		26	4	3	
Safety and Mission Assurance	34	6		7	34	6		4	34	6		4
Small Business Programs	5	1		3	5	1		4	5	1		4
Staff Offices	**478**	**65**	**21**	**150**	**478**	**68**	**22**	**165**	**453**	**74**	**22**	**161**
NASA Management Office at JPL	25	1		2	25	1		2	25	1		2
Human Capital Management	33	5		17	34	5		15	34	5		15
Headquarters Operations	98	4		350	98	4		319	98	4		319
Strategic Infrastructure	54	4		2	54	6		2	54	7		2
Internal Controls and Management Systems	9			1	9			1	9			1
Procurement	33	4			33	4			33	4		
Mission Support Directorate Front Office	8	2			8	3			8	3		
Protective Services	44	1		9	46	1		6	46	2		6
Mission Support	**304**	**21**	**0**	**380**	**307**	**24**	**0**	**344**	**307**	**26**	**0**	**344**
Total, Agency Management	**1,125**	**127**	**23**	**685**	**1,138**	**137**	**24**	**657**	**1,134**	**150**	**24**	**654**

**NC is Non-Career*

CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Construction of Facilities	455.9	--	**374.8**	344.3	349.3	354.6	359.9
Environmental Compliance and Restoration	66.1	--	**90.5**	91.8	93.3	94.7	96.1
Total Budget	**522.0**	**419.1**	**465.3**	**436.1**	**442.6**	**449.3**	**456.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Construction and Environmental Compliance and Restoration

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Construction of Facilities	455.9	--	**374.8**	344.3	349.3	354.6	359.9
Environmental Compliance and Restoration	66.1	--	**90.5**	91.8	93.3	94.7	96.1
Total Budget	**522.0**	**419.1**	**465.3**	**436.1**	**442.6**	**449.3**	**456.0**
Change from FY 2015			**46.2**				
Percentage change from FY 2015			**11.0%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Demolition of unneeded facilities helps reduce the Agency's footprint and operating costs. The 2014 demolition of the iconic Space Shuttle Mate-Demate Device at AFRC included recycling of 585 tons of steel.

NASA designs and implements its 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. Aging, infrastructure is inefficient and costly to maintain and operate. To address these challenges, NASA's CoF program focuses on reducing and modernizing NASA's infrastructure into fewer, more efficient, and sustainable facilities.

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 2016

None.

CONSTRUCTION AND ENVIRONMENTAL COMPLIANCE AND RESTORATION

ACHIEVEMENTS IN FY 2014

During FY 2014, NASA:

- Completed the demolition of 107 structures at various sites. 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 Shuttle Mate, Demate Facility at Armstrong Flight Research Center (AFRC);
    - Twenty-eight storage facilities built in 1942 totaling 54,684 square feet and the Plum Brook K-Site Test Building, a 15,835 square foot test facility built in 1958 at Glenn Research Center (GRC); and
    - The administrative office Building 1229 at Langley Research Center (LaRC).
- Began construction of the following projects:
    - Central Campus Phase 1, Construct Replacement Shared Services and Office Building, (KSC); and
    - Site preparation for Marshall Space Flight Center (MSFC) Building 4221.
- Completed construction of the following projects:
    - Parking Structure, Jet Propulsion Laboratory (JPL);
    - Repair by Replacement Facility Support Center, AFRC;
    - Construct Replacement Engineering Building 4220, MSFC; and
    - Repair by Replacement Central Office Building, GRC.
- Continued work at Santa Susana Field Laboratory (SSFL):
    - Issued the Final Environmental Impact Statement for the Proposed Demolition and Environmental Cleanup Activities and Record of Decision for Demolition;
    - Completed field work for characterization of the soils;
    - Continued comprehensive characterization of groundwater source areas by well drilling and sampling to investigate seeps, faults, and source zone areas, and to refine flow models;
    - Continued operation and expansion of the Groundwater Extraction and Treatment System, 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 2015

Exploration CoF activities in FY 2015 focus on meeting the requirements of the Space Launch System program. Projects include restoration of the B-2 test stand at Stennis Space Center (SSC).

To support Space Operations activities, work continues on the 21st Century Launch Complex at KSC and the 34-meter Beam Wave Guide (BWG) antenna systems at Canberra, Madrid, and Goldstone.

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. Work is underway to replace a deteriorated, high maintenance MSFC administrative building with a more efficient facility. Other work in progress includes installation of environmental compliance hardware, refurbishment/replacement of helium compressors, and continuation of projects to replace the high pressure industrial water systems at SSC. Energy Savings Investments projects underway include work to install a chilled water thermal energy storage system at KSC.

NASA's ECR program includes 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 and soils, and demolition of facilities at SSFL in accordance with the State of California consent order reflect this Agency priority.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Construction activities planned include:

- Major repair and replacement projects at LaRC that will correct deficiencies noted by the National Research Council and support core NASA research efforts;
- Construction of the Measurement Systems Laboratory (MSL) complex that 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;
- Repairs to the Wallops Flight Facility (WFF) airfield;
- 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 to eliminate obsolete facilities; and
- Construction for Space Operations activities to support Space Communication and Navigation.

ECR activities planned include:

- Continuing cleanup of ground water contamination and investigation of soil contamination at White Sands Test Facility (WSTF), 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;
- 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;
- Operating and maintaining systems to clean up contaminated groundwater emanating from JPL and continued operations of the Lincoln Avenue and Monk Hill drinking water treatment systems;
- Continuing cleanup of contaminated groundwater and soil removal, operations of groundwater treatment systems, and continued long term monitoring of the groundwater at SSFL in accordance with the consent order with the State of California;
- Beginning cyclotron decommissioning at GRC;

- Continuing cleanup activities and long-term monitoring at Ames Research Center (ARC), MSFC, and Michoud Assembly Facility (MAF); and
- Continuing operations of treatment systems and monitoring at AFRC, GRC, Goddard Space Flight Center (GSFC), LaRC, SSC, and WFF.

CONSTRUCTION OF FACILITIES

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Institutional CoF	283.4	--	**338.6**	344.3	349.3	354.6	359.9
Exploration CoF	139.3	--	**10.0**	0.0	0.0	0.0	0.0
Space Operations CoF	30.2	--	**26.2**	0.0	0.0	0.0	0.0
Science CoF	3.0	--	**0.0**	0.0	0.0	0.0	0.0
Total Budget	**455.9**	--	**374.8**	**344.3**	**349.3**	**354.6**	**359.9**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The newly constructed Mission Integration Center at GRC received Leadership in Energy and Environmental Design (LEED) Gold certification in 2014. NASA's inventory of sustainable facilities now exceeds 2.3 million square feet.

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 specialized capabilities in testing and development that directly support NASA's current missions. These projects modify NASA facilities to provide critical technical requirements to manufacture, test, process, or operate hardware for NASA programs.

Minor revitalization and construction projects are those with initial cost estimates between $1 and $10 million. Discrete construction projects refer to those with initial cost estimates of $10 million or greater. Centers accomplish routine day-to-day facility maintenance and repair activities with estimates of $1 million or less within program and Center Management and Operations budgets.

EXPLANATION OF MAJOR CHANGES IN FY 2016

The FY 2016 request for CoF includes funding transferred from Exploration and Space Operations accounts to achieve Space Launch System, and Space Communications and Navigation (SCaN) requirements. Funding associated with all program designs and out-year programmatic construction activities remains in program accounts.

INSTITUTIONAL COF

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**283.4**	**--**	**338.6**	**344.3**	**349.3**	**354.6**	**359.9**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Projects such as the Institutional Power Systems Safety and Reliability Upgrade at KSC replace aging infrastructure with safer, more reliable systems.

NASA's Institutional CoF program includes projects to reduce risk and increase sustainability.

CoF projects that repair and/or improve NASA's existing facilities reduce facility-related risks to mission success, property, and personnel. NASA prioritizes these projects using a risk-informed process. Projects to increase sustainability and environmental friendliness support NASA's core capabilities within a smaller, more efficient footprint. These 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 flexible so they can address programmatic requirements, both known and still evolving over the next 40 years.

NASA's demolition program eliminates obsolete, unneeded infrastructure to improve efficiency and eliminate safety and environmental risks.

NASA's recent Institutional CoF program efforts are beginning to demonstrate the intended results. By the end of FY 2013, NASA reduced energy intensity in select facilities by 26.4 percent compared to the FY 2003 baseline. 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.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

INSTITUTIONAL COF

ACHIEVEMENTS IN FY 2014

During FY 2014, NASA:

- Began construction of the following projects:
  - Replacement of Asbestos Siding (Buildings 4619 and 4755), MSFC; and
  - Upgrade Systems, Industrial Area Chiller Plant, KSC.
- Completed construction of the following project:
  - Renovation of the Administration Support Office Building, GSFC.
- Initiated Energy Savings projects:
  - Installation of Utility Metering, Primarily Gas and Steam, Various Centers;
  - Greening of Building 1100, SSC;
  - Energy Efficiency Improvements, LaRC; and
  - Installation of Lighting and Occupancy Sensors, GRC.

WORK IN PROGRESS IN FY 2015

NASA is replacing the Electrical Distribution System at Wallops Island in support of launch and vehicle processing, and the Central Air Compressors at GRC providing compressed air for research throughout the campus.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

NASA will initiate several projects to repair and revitalize its aging infrastructure. These include electrical and mechanical projects that support NASA research facilities such as Replace Unitary Planned Wind Tunnel Auxiliaries 1000 kVA Transformers and Replace Arc Jet Aerodynamic Heating Facility Heat Exchanger at ARC; Revitalize Radar & Telemetry Infrastructure and Repair Research Aircraft Integration Facility at AFRC; A-Complex Test Control Center Heating, Ventilation, and Air Conditioning Refurbishment at SSC; and Revitalize Building Electrical Systems, Building 4755, Revitalize Building Electrical Systems, Building 4711, and Revitalize Building Mechanical Systems, Building 4619 at MSFC.

NASA will complete several infrastructure repair projects, including reliability improvement modifications to island communications hub, Building X-75, and Replace Island Primary Electrical Feeder, WFF; Upgrade/Repair Critical 16.5 KV Electrical Distribution System at JPL; and Replace High Voltage Electrical Feeders and Switches, Site Utility Tunnel, Johnson Space Center (JSC).

Institutional Discrete Construction of Facility Projects

Discrete construction of facilities projects have initial cost estimates of $10 million or greater.

INSTITUTIONAL COF

INSTITUTIONAL POWER SYSTEMS SAFETY AND RELIABILITY UPGRADE, PHASE 2 OF 4

Location: KSC, Merritt Island, FL

FY 2016 Estimate: $10.0 million, Total Project FY 2015 to FY 2017 is $51.0 million

Scope/Description

This is the second of a four-phase project to upgrade and increase the reliability and safety of the KSC institutional power system. Phase 2 is to install electrical system modifications and refurbish KSC's Orsino Substation (13.2 kilovolt) air insulated bus structure to restore structural integrity, improve critical system maintainability, and replace degraded and obsolete power cables, duct banks, switchgear, and transformers at various locations. This project will also modify KSC's C5 and Orsino Substations to reduce arc-flash energy within KSC manholes, refurbish Launch Complex 39 Area Emergency Power Plant generator control and load bank systems, and repair and rehabilitate the C5 Substation bus structures.

The multi-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 and serves all vehicle processing, payload processing, ground support processing, and administrative facilities. System failure can result in injury or death, loss of workforce productivity, and impact to spacecraft processing or Center operations. Arc-flash safety requirements have drastically increased the complexity and cost of KSC power system work. De-energizing cables within manholes to improve work safety often results in widespread KSC power outage impacts. Modifications to KSC's Orsino and C5 Substations to reduce arc-flash energy will significantly improve worker safety and reduce operation, maintenance, and construction costs. The corroded/rusted structure that supports energized and uninsulated electrical bus at the Orsino and C5 Substations is a safety and mission schedule risk. Due to the substation's 50-year age, coastal proximity, criticality, and lack of alternate power sources, necessary power outages to perform structural work have not been feasible. Due to KSC's proximity to the coast, corrosion is a major contributor to deterioration of all exterior electrical equipment, and this project will replace, repair, and improve future maintainability of deteriorated or obsolete switchgear, transformers, and primary substation air bus structures at various KSC locations. This project will also replace obsolete and deteriorated equipment at the KSC Launch Complex 39 Area Emergency Power Plant, which provides emergency back-up power to mission essential loads. Sections of Paper Insulated Lead Covered and Cross-Linked Polyethylene cable installed between 1960 and 1980 remain on KSC's system. The cables are submerged in water, and moisture migration through the cable insulation is a failure factor. Delays in implementation of this project will lead to increased unscheduled outages and continue to significantly impact costs associated with construction and maintenance activities. System failure can result in injury or death, loss of workforce productivity, and impact to spacecraft processing or Center operations. The electrical system serves Launch Complex 39, Vertical Assembly Building, Launch Control Center, Rotation Processing Surge Facility, Booster Fabrication Facility, Logistics Facility, Propellants North, Electrical Maintenance Facility, Orbiter Processing Facilities (1-3), Administrative Office Buildings (OSB 1, OSB 2, and Headquarters), 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 and replacing power systems to provide safe, reliable, and cost-effective power to KSC facilities.

Other Related Costs	Amount
Studies/Design	$1.2M
Related Equipment	N/A
Activation	$0.8M
Other	N/A

Estimated Schedule	Start	Complete
Design	Sep 2013	Sep 2015
Construction	Jan 2016	Mar 2018
Activation	Jan 2018	Mar 2018

REPAIR BY REPLACEMENT MEASUREMENT SYSTEMS LABORATORY

Location: LaRC, Hampton, VA

FY 2016 Estimate: $93.7 million

Scope/Description

I MSL will provide the Agency with a premier research and development facility enabling advancements in the technical areas of optics and laser/Light Detection and Ranging (LIDAR), advanced sensors, electromagnetics, electronics, and software intense flight systems. MSL will integrate technical groups and functions from the Research Directorate and Engineering Directorate, facilitating systems engineering solutions that span concept-to-flight. 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. MSL will utilize high-density office solutions 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. MSL will incorporate features to pursue a certification level of “Silver” in accordance with the United States Green Building Council LEED green building certification 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.

Basis of Need

MSL is a primary technical facility of the LaRC 20-Year Revitalization Plan, aimed at consolidating and modernizing existing aging facilities in the sprawling campus into a smaller, energy-efficient, state-of-the-art, core campus environment. This project corrects deficiencies identified by the Aerospace Safety Advisory Panel 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. In addition, the major existing facilities housing the laboratories are old and lack state-of-the-art equipment and services, and maintenance is ever increasing. The new facility will provide state-of-the-art lab facilities supporting research and development initiatives unique to the Agency in support of all mission directorates. As a key element in the LaRC 20-Year Revitalization Plan, 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).

Other Related Costs	Amount
Studies/Design	$8.1M
Related Equipment	N/A
Activation	$9.7M
Other	N/A

Estimated Schedule	Start	Complete
Design	Oct 2012	Nov 2014
Construction	Apr 2016	May 2018
Activation	May 2018	Feb 2019

REPAIR CENTRAL COMPRESSED AIR EQUIPMENT, PHASE 2 OF 3

Location: GRC, Cleveland, OH

FY 2016 Estimate: $11.0 million, Total Project estimate is $29.2 million

Scope/Description

This project is the second phase of a three-phase project that will repair existing central compressed air systems at various locations throughout GRC's Lewis Field campus. Phase 2 includes the following components: replace the York dehydrator; rebuild the C-4 compressor gearbox to avoid future failure; replace the combustion and service air malfunctioning, broken, and obsolete valve actuators with new actuators for reliable and safe operation to meet the research needs on time; rewind exhauster E46 motor drives; replace start run switchgear for compressors C4 and C5; apply rust prevention coating to all CA-40 compressors and cooler piping interiors; replace compressors surge and pressure controllers; replace exciter controllers; and replace the Input/Output for the Delaval synchronous condensers.

Basis of Need

Multiple test facilities at GRC rely on this 70-year old Combustion Air System. The centrally located compressed air system includes hundreds of valves and relief valves that are up to 50 years old. Unreliable valves delay research and cause system isolation issues. The C-4 compressor gearbox is overdue for rebuilding. The gearbox is becoming noisy and is taking longer to build up the oil pressure; indicating considerable wear. The E-46 exhauster motor drives an exhauster powered by one 1950's vintage motor. The motor on line test data has shown a declining trend in several categories tending to indicate a failure is imminent and the vibrations have been getting worse. The start and run switchgear feeds the critical 450 pound compressors C4 and C5. It is no longer manufactured and reliable spare parts are no longer available. It has been exposed to numerous water and drain line leaks causing the enclosure to rust and deteriorate. Failure of this gear could interrupt the 450 services for at least three to six months. Rust prevention will extend the system life to avoid costly repairs and system down time. Replacing the exciter controllers will increase reliability and prevent unexpected outage of one of the large synchronous motors for several weeks. Delaval Synchronous Condensers are used to maintain Power Factor of Unity on GRC Power Grid as recommended by the Utility. The Condensers use antiquated I/O System to control and monitor the machine performance. The I/O cannot be repaired due to the unavailability of compatible parts.

Other Related Costs	Amount
Studies/Design	$1.3M
Outfitting	N/A
Activation	N/A
Other	N/A

Estimated Schedule	Start	Complete
Design	May 2013	Jun 2014
Construction	Mar 2016	Oct 2017
Activation	N/A	N/A

REPAIR DOMESTIC WATER MAIN, PHASE 2 OF 2

Location: GRC, Cleveland, OH

FY 2016 Estimate: $12.0 million, Total Project FY 2013 to FY 2016 is $23.0 million

Scope/Description

This project is the second of two planned phases for repairing the domestic water distribution system at GRC. The domestic water main is over 60 years old and has had numerous major failures. The scope of work incudes replacement of the 12-inch diameter Walcott Road main from Taylor Road to Moffett Road, replacement of the 6-inch diameter service supply line to Building 102, and the relocation of the service supply line to Building 49. In addition, this project replaces the currently non-functional 24-inch diameter main isolation valve north of Building 101 and abandons the leaking supply line to Building 140. The project will reduce the risk of costly emergency repairs and building evacuations caused by unexpected systems failures. It will also reduce leaks and help meet water reduction goals.

Basis of Need

The GRC city water piping mains and fire hydrants are 60 years old and have experienced numerous failures in recent years. Since many of the existing main isolation valves are non-functional, piping failures require shutdown of large sections of the mains resulting in loss of water service to many buildings. The locations of many of the mains and branch lines to the building are inaccessible (i.e., under sidewalks, roads, and drives) making leaks expensive to repair. Relocation of the mains and branch lines to tree lawns will allow for better access for repair and maintenance.

Several deficiencies were identified with the city water distribution system during the Energy and Water Functional Review and the Environmental Functional Review of 2010. The environmental review identified excessive chlorine in wastewater discharge as a top Center challenge, which is symptomatic of city water system leaks. Also the Energy and Water Functional review cited significant leaks in the distribution system requiring repairs as a top risk to mission. Further, in order to comply with Energy and Independence Security act of 2007 annual water intensity reduction mandates, eliminating system leaks is a first order priority. This project addresses all the cited deficiencies.

Other Related Costs	Amount
Studies/Design	$1.2M
Related Equipment	N/A
Activation	N/A
Other	N/A

Estimated Schedule	Start	Complete
Preliminary Engineering Report	N/A	N/A
Design	Jun 2013	Aug 2014
Construction	May 2016	Jul 2018

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 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. The focus is on projects that reduce building square footage or eliminate excess building systems, provide long-term savings, and reduce the Agency's maintenance backlog. During the year, planned projects may change to accommodate changing priorities.

MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, $144.7 MILLION

ARC, $17.3 million

Replace Unitary Planned Wind Tunnel Auxiliaries 1000 kilovolt-ampere Transformers
Replace Arc Jet Aerodynamic Heating Facility Heat Exchanger
Replace Roofs, Life Research Laboratory, Building N239
Restore Reliability of Vertical Motion Simulator, Building N243

AFRC, $15.4 million

Repair Aircraft Hangar B4802 Heating, Ventilation, and Air Conditioning Systems
Revitalize Radar & Telemetry Infrastructure
Repair Research Aircraft Integration Facility

GRC, $8.9 million

Repair Exterior of Engine Research Building West Wing, Building 23
Repair Water Intrusion and Institutional Plumbing, Engineering Research Building

GSFC, $17.0 million

Repair Exterior of Engine Research Building West Wing, Building 23
Repair Water Intrusion and Institutional Plumbing, Engineering Research Building

JPL, $17.4 million

Energy Management System Upgrade
T-1722 and T-1723 Consolidation

JSC, $10.9 million

Repair Mechanical Systems, Planetary and Earth Sciences Laboratory, Building 31
Repair Central Heating and Cooling Plant Compressed Air System, Building 24
Upgrade Water Wells and Distribution System, WSTF

LaRC, $25.3 million

Steam System Upgrades
Electrical Distribution System Upgrades, Phase 3 of 6
Potable Water Supply Upgrades, Phase 2 of 2
Renovate Building 1230 for Avionics Systems Laboratory

MSFC, $18.1 million

Revitalize Building Electrical Systems, Building 4755
Revitalize Building Electrical Systems, Building 4711
Revitalize Building Mechanical Systems, Building 4619

SSC, $14.4 million

A-Complex Test Control Center Heating, Ventilation, and Air Conditioning Refurbishment
Site-wide Hazard/Fire Detection System
Repair/Replace Electrical Switchgear and Mitigation of Electrical Risk Site-wide
Repair Bascule Bridge

Energy Savings Investments

FY 2016 Estimate: $12.0 million

Energy Savings Investments funds enable NASA to implement projects focused on reducing the utilities cost and consumption of facilities and operations. The projects that comprise this request are of the highest priority based on expected return on investment or contribution to Federal energy mandates. During the year, planned projects may change to accommodate changing priorities.

JSC
Implement Energy Conservation Measures & Retro-Commissioning, Various Buildings

GSFC
Replace Obsolete Utility Control System

KSC
Upgrade Lighting, Various Buildings

Demolition of Facilities

FY 2016 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 2016 Estimate: $34.2 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 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**139.3**	**--**	**10.0**	**0.0**	**0.0**	**0.0**	**0.0**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The moveable platforms in High Bay 3 of the VAB at KSC will support stacking and vehicle integration of the Space Launch System.

Exploration CoF provides construction required to achieve Space Launch System (SLS), Orion, 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 2016

Request for FY 2016 funding is 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 construction and installation of the platforms in High Bay 3 of the Vehicle Assembly Building (VAB) at KSC.

ACHIEVEMENTS IN FY 2014

During FY 2014, NASA made tremendous progress as it continued transitioning from the Space Shuttle and Constellation programs to Exploration. At KSC, construction continued in the VAB and at Launch Complex 39B (LC-39B). In addition to the ongoing VAB demolition work, construction started on building the access platforms in High Bay 3 to support SLS launch vehicle integration. At LC-39B, major construction efforts began on the mobile launcher interfaces, upgrading the Apollo-era Heating, Ventilation and Air Conditioning (HVAC) systems, making necessary modifications to the ignition over-pressure sound suppression system, and making the necessary modifications to the environmental control systems to support SLS and Orion. In addition to the construction efforts of Ground Systems Development and Operations in the VAB and the LC-39B, the Orion program completed the second phase of a three-phase project at the KSC Launch Abort System Facility, formerly known as the KSC Canister Rotation Facility. The project modified the existing high bay doors to accommodate the height of Orion service and crew modules stack with the attached launch abort system.

The SLS program continued progress on the SSC B-2 Test Stand restoration in preparation for SLS Green Run testing. As part of work packages 1 and 2, SLS completed the refurbishment of the Rolling Deck, Level 7, Level 8, Level 11, and parts of the Flame Bucket. The SLS team also completed all design packages for Work Package 3, which included the mechanical piping, Main Propulsion Test Article (MPTA) structure rollback, Battleship refurbishment, liquid oxygen and liquid hydrogen piping, and refurbishment of the soft and hard core structures. The program released Work Package 3 for bid, awarded the contract, and began construction during FY 2014. Work Package 3 included moving a 1.2 million pound super structure used for the Space Shuttle Program more than 20 feet to accommodate the larger size of the SLS Core Stage. SLS also designed and released Work Package 4, which includes the electrical and mechanical build-out for bid

The SLS program completed several critical construction projects at the MAF in FY 2014 including construction at Building 131 Cells M, N, and P for external cleaning, priming, and thermal protection system application in support of the SLS launch vehicle. The program also completed construction in Building 110 Cells B and C for the Vertical Assembly Center, where large segments of the SLS core stage will be welded and vertically assembled. The program also completed modifications for Cell E and Cell F in Building 110 for tank internal cleaning liquid oxygen (LOX) hydrostatic proof load testing. Additionally, the program completed construction to lengthen Building 451 for proof testing.

At MSFC, SLS commenced construction of the two structural test stands to support SLS Core Stage Qualification Testing. Work began on both stands in May 2014 shortly after contract award. Test Stand 4693 will be used for structural testing on the Core Stage Liquid Hydrogen Tank. Test Stand 4693 is being built on the foundation of the demolished Test Stand 4696. The first element of the Test Stand 4693 construction project was the demolition and clean-up of Test Stand 4696. SLS also started construction of Test Stand 4697 for structural testing of the SLS LOX Tank and Forward Skirt. The program made significant progress on this project as well, including: site excavation, installation of production pilings, and the initial concrete pour.

WORK IN PROGRESS IN FY 2015

Exploration CoF activities in FY 2015 focuses on meeting the requirements of the Exploration program. At KSC, Exploration projects will continue in the VAB and at LC-39B. Orion will initiate the third, and final, phase project at KSC to modify the Launch Abort System Facility to support launch abort system integration to the Orion crew module.

At MSFC, Construction of Test Stand 4693 continues with the initial mass concrete pour of the reaction slab, which occurred in October 2014. New work includes placing the next level of rebar and anchor rods. Following completion of the foundation and reaction slab work, construction of the primary towers will commence. Similarly, the reaction slab mass concrete pour for Test Stand 4697 is planned to occur in December 2014. Following this milestone, the Test Stand 4697 tower structures will be erected. Both test stands are scheduled to be completed by the end of FY 2015.

The B-2 Test Stand Work Package 4 will be awarded in early FY 2015. Work Package 4 includes modifications and upgrades to the electrical, mechanical, and structural systems. Full completion and operation of the main derrick crane is also scheduled for completion in the first quarter of the year. Work Package 3 and Work Package 4 are on track for completion in FY 2015. SLS also plans to design, release, and award the final work package (Work Package 5), which will include the Tarmac rebuild, Environmental Control System installation, and Test Stand Control System improvements.

EXPLORATION COF

At MAF, construction will continue in Building 103 for the launch vehicle Final Assembly and Integration area with a planned completion date in early FY 2015. Other MAF projects include improvements to the levee, roadways, and barge dock to accommodate the Core Stage transit, which is scheduled for completion in Spring 2015.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Exploration projects in FY 2016 at KSC include the final phase of the discrete project to modify the KSC VAB for SLS vehicle integration and the minor project to replace the roof of the launch equipment shop. Additionally, SLS is planning three minor constructions projects at MAF to support SLS manufacturing.

Exploration Discrete Construction of Facility Projects

Discrete projects are construction projects with initial cost estimates greater than $10 million. The FY 2016 Exploration CoF request for discrete projects includes $5 million to complete the outfitting and activation for the Repairs and Modifications to VAB project at KSC. Construction of this project began in FY 2012. Total project cost from FY 2012 to FY 2016 is $142.3 million.

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 meet new building, fire, and accessibility codes.

MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, $5.0 MILLION

MSFC, $5.0 million

Rehabilitate Production Waste Water, MAF Phase 3
Rehabilitate B-103 Fan House, MAF Phase 1
Replace Substations 63 and 64, MAF

SPACE OPERATIONS COF

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	30.2	--	26.2	0.0	0.0	0.0	0.0

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

The 34-meter antenna under construction at the Canberra DSCC in Australia is part of NASA's worldwide Deep Space Network.

Space Operations CoF provides construction to support SCaN, 21st Century Launch Complex, and Launch Services Program.

EXPLANATION OF MAJOR CHANGES IN FY 2016

FY 2016 funds are higher than previous years because construction of a new antenna will begin in FY 2015. The new antenna is designated as Deep Space Station (DSS)-56 and construction of facilities and site identification and preparation begins in FY 2015. Additionally, construction of DSS-36, the antenna at Canberra DSCC will continue, with completion anticipated in FY 2016.

ACHIEVEMENTS IN FY 2014

During FY 2014, the Deep Space Network (DSN) completed construction of and commissioned the DSS-35 34-meter BWG Antenna at Canberra, Australia. FY 2014 was a big year for DSS-36. The foundation and pedestal construction, which supports the Azimuth Track and upper steel structure, was completed. The pedestal is now ready for installation of the Azimuth Track and steel structure.

The 21st Century Launch Complex completed the design for the modifications and repairs to building X-75, the relocation of Pad 1, and replacement of the island primary electrical feeder at Wallops Flight Facility.

WORK IN PROGRESS IN FY 2015

The SCaN project to construct DSS-36, a 34-meter antenna in Canberra, Australia, will continue, with expected completion in FY 2016. SCaN will also begin construction of a multi-year funded discrete project to construct two new 34-meter BWG DSS Antennas 56 then 53 at the Madrid DSCC.

On-going work includes the repairs and modifications to building X-75 to construct a new second story to the existing structure. The second story will provide an elevated and protected housing for critical island communications systems. Additionally, work on relocating, the MLAS (100K) Launch Pad and the (50K) Large Sounding Rocket Launch Pad and Range Infrastructure at Wallops will take place. The infrastructure upgrades include improvements of access roads, utility systems, launch pad concrete base and associated infrastructure. Finally, work will begin to provide reliable power to the Northern Areas of the Island, including the Payload Processing Facility, by replacing the existing electrical feeder and installing a conduit and feeder in a loop layout for redundancy. A fiber optic conduit system will also be installed to facilitate future fiber requirements.

KEY ACHIEVEMENTS PLANNED FOR FY 2015

The SCaN discrete project to construct 34-meter antennas in Canberra, Australia will be completed by the end of the year. SCaN will also continue construction of a multi-year funded discrete project to construct two new 34-meter BWG DSS Antennas 56 then 53 at the Madrid DSCC. At KSC, the ISS program will complete the design, award the contract, and begin construction to replace the roof on Space Shuttle Processing Facility.

Space Operations Discrete Construction of Facilities 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 (DSCC, Canberra, Australia.

FY 2016 Construction Estimate: $1.7 million, Total Project FY 2010 to FY 2019 is $55.0 million.

Scope/Description

This project constructs two new 34-meter BWG antennas at Canberra DSCC. The basic contract provides for the initial construction of DSS-35 and DSS-36.

The project is divided into three contracts: excavation and roads, site infrastructure, and antenna-related facilities. The funding for FY 2016 is $1.7 million of the total $55 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.

SPACE OPERATIONS COF

Basis of Need

The construction of these antennas is planned as Phase 1 of the SCaN DSN Aperture Enhancement Project. Analysis of outer planet declinations reveals a growing bias toward the southern declination well into the 2020s. By 2015, NASA projects spacecraft mission needs in the southern hemisphere will begin to overload capacity at the Canberra DSCC. This project is necessary to allow BWG antennas to add resilience in the southern hemisphere for DSN. Additionally, the 70-meter antennas at each Complex are closer to end of service. This project 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, Madrid, Spain

FY 2016 Construction Estimate: $14.4 million, Total Project FY 2015 to FY 2019 is $57.75 million.

Scope/Description

This project constructs two new 34-meter BWG antennas at Madrid DSCC, 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 FY 2016 is $14.4 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

Phase 2 of the SCaN DSN Aperture Enhancement Project was originally scheduled to begin after completion of a third antenna at Canberra. However, two existing antennas at Madrid are now showing considerable concrete degradation in their pedestals; therefore, a decision was made to begin construction of the two 34-meter antennas at Madrid in FY 2015. This decision reduces future long-term maintenance downtimes of the existing 70-meter and 34-meter antennas at Madrid.

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 meet new building, fire, and accessibility codes.

MINOR REVITALIZATION AND CONSTRUCTION PROJECTS BY CENTER, $10.1 MILLION

JPL, $1.5 million

Fire Detection Upgrade, Goldstone

KSC, $8.6 million

Replace Roof –Launch Equipment Shop
Replace Roof –Space Station Processing Facility

ENVIRONMENTAL COMPLIANCE AND RESTORATION

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	FY 2017	Notional FY 2018	FY 2019	FY 2020
Total Budget	**66.1**	**--**	**90.5**	**91.8**	**93.3**	**94.7**	**96.1**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

Large Diameter Auger soil mixing with thermal treatment and iron at KSC to remove Chlorinated Volatile Organic Compounds. Crane with a containment shroud shown.

NASA's 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 2016

None.

ACHIEVEMENTS IN FY 2014

In FY 2014, NASA continued to execute restoration activities at all NASA Centers and facilities. Most notably, the following restoration activities were accomplished in FY 2014:

- At SSFL, the ECR program issued the Final Environmental Impact Statement for the Proposed Demolition and Environmental Cleanup Activities and Record of Decision for Demolition; completed field work for characterization of the soils; continued comprehensive characterization of groundwater source areas by well drilling and sampling to investigate seeps, faults, and source zone areas, and to refine flow models; continued operation and expansion of the Groundwater Extraction and Treatment System, 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.
- MSFC continued cleanup activities at the former Stauffer Chemical Plant site and began design activities for the cleanup of petroleum-contaminated sites at the Center.
- WSTF continued to operate the plume front and mid-plume front treatment systems to capture and treat contaminated groundwater. They also continued source area investigations and closure activities of the sewage lagoon.
- KSC installed several new groundwater treatment systems, completed extensive contaminated soil removal at various sites, continued sampling of over 400 monitoring wells, and continued operations of existing groundwater cleanup systems.
- At JPL, the program continued to operate and maintain systems to clean up contaminated groundwater emanating from JPL, as well as operations of the Lincoln Avenue and Monk Hill drinking water treatment systems. JPL also completed the Proposed Plan for its Record of Decision on final cleanup.

WORK IN PROGRESS IN FY 2015

Major restoration project achievements planned for FY 2015 include:

- Investigate and clean up contaminated groundwater and soil at SSFL in accordance with the consent order with the State of California and begin implementing demolition of facilities;
- Continue operations and maintenance of systems to clean up contaminated groundwater emanating from JPL, install two new recovery wells, connect existing backwash system to the treatment facility, and continue operations of the Lincoln Avenue and Monk Hill drinking water treatment systems;
- Continue investigation and cleanup of groundwater and soil contamination at KSC in accordance with State of Florida requirements. Actions 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;
- Continue cleanup of ground water contamination and investigation of soil contamination at WSTF, to comply with the facility permit issued by the State of New Mexico. Key achievements include closure activities, implementation of source area facility investigations, and continued operation of the plume front and mid-plume ground water treatment systems; and
- Complete the Federal Facilities Agreement and continue cleanup studies, investigations, and design of the cleanup of the peninsula solid waste disposal site at ARC.

KEY ACHIEVEMENTS PLANNED FOR FY 2016

Key projects and achievements in the FY 2016 request include:

- $37.0 million for cleanup of contaminated groundwater and soil removal, operations of groundwater treatment systems, and continued long term monitoring of the groundwater at SSFL in accordance with the consent order with the State of California;
- $11.0 million for continued cleanup of ground water contamination and investigation of soil contamination at WSTF, to comply with the facility permit issued by the State of New Mexico.

ENVIRONMENTAL COMPLIANCE AND RESTORATION

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;

- $10.1 million for 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, 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; and
- $7.3 million to operate and maintain systems to clean up contaminated groundwater emanating from JPL and operations of the Lincoln Avenue and Monk Hill drinking water treatment systems.

Program Elements

RESTORATION

Restoration projects address cleanup liabilities at all NASA Centers and component facilities. As of the start of FY 2015, 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 2016 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 AND FUNCTIONAL LEADERSHIP

Environmental Compliance and Functional Leadership 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.

INSPECTOR GENERAL

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**37.5**	**37.0**	**37.4**	**38.0**	**38.5**	**39.1**	**39.7**

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

INSPECTOR GENERAL

FY 2016 Budget

Budget Authority (in $ millions)	Actual FY 2014	Enacted FY 2015	Request FY 2016	Notional FY 2017	FY 2018	FY 2019	FY 2020
Total Budget	**37.5**	**37.0**	**37.4**	**38.0**	**38.5**	**39.1**	**39.7**
Change from FY 2015			**0.4**				
Percentage change from FY 2015			**1.1%**				

FY 2014 reflects funding amounts specified in the June 2014 Operating Plan per P.L. 113-76.

FY 2015 reflects only funding amounts specified in P.L. 113-235, the Consolidated and Further Continuing Appropriations Act, 2015.

For FY 2016, the NASA Office of Inspector General (OIG) requests $37.4 million to support the work of 192 auditors, investigators, analysts, specialists, lawyers, and support staff located at NASA Headquarters in Washington, DC 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 operational offices are the Office of Audits (OA) and the Office of Investigations (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 (DOJ) for criminal prosecution and civil litigation or to NASA management for administrative action. Through its investigations, OI develops recommendations 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 that involve NASA employees who place private gain before public service.

EXPLANATION OF MAJOR CHANGES IN FY 2016

None.

INSPECTOR GENERAL

ACHIEVEMENTS IN FY 2014

In FY 2014, the OIG issued 26 audit products and identified approximately $124 million in potential savings for NASA. Audit products included reports examining NASA's:

- Efforts to Extend the Operational Life of the International Space Station;
- Management of the Commercial Crew program;
- Use of Award Fee Contracts;
- Efforts to Identify and Mitigate Near-Earth Object Hazards;
- Web Application Security Program; and
- Use of Space Act Agreements.

In FY 2014, 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 $29 million in criminal, civil, and administrative penalties and settlements. More than $4.5 million of these funds were returned directly to NASA. Overall, OI's efforts in FY 2014 resulted in 38 indictments, 18 convictions, 2 civil settlements, 23 administrative actions, and 18 suspensions and debarments.

Examples of OI's work over the past year include:

- The sentencing of a former executive of a personnel services company to five years in prison and two years of supervised release. The executive was also ordered to pay a fine of $12,500 and forfeit $2.9 million in ill-gotten gains. Previously, the executive pled guilty to one count of major fraud for misrepresenting his firm as a disadvantaged small business in order to secure more than $2.4 million in NASA security contracts;
- The conviction of a former Boeing procurement official for taking bribes from companies seeking to sell parts for military aircraft to Boeing in exchange for providing them with a competitor's confidential bid information. The official admitted to three counts of mail fraud, one count of wire fraud, and one count of currency structuring for his role in the scheme;
- The indictment of two scientists on conspiracy to commit wire fraud, aggravated identity theft, and falsification of records. According to the indictment, the scientists fraudulently obtained approximately $10 million in research contracts from NASA and other Federal agencies; and
- The sentencing of an Estonian National for his role in a cybercrime scheme that caused millions of computer systems worldwide, including scores used by NASA, to be infected with malicious software. The subject was sentenced to four years in prison and agreed to forfeit $7 million.

WORK IN PROGRESS IN FY 2015

During FY 2015, 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. Some of the projects on which our auditors are currently working are NASA's efforts to manage health and human performance risks for space exploration, challenges to international cooperation in space programs, and the Agency's management of its Pressure Vessels and Systems Program and the Deep Space Network.

INSPECTOR GENERAL

KEY ACHIEVEMENTS PLANNED FOR FY 2016

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. In a November 2014 report, we listed those challenges as:

- Managing NASA's Human Space Exploration Programs: the International Space Station, Commercial Crew Transportation, and the Space Launch System
- Managing NASA's Science Portfolio
- Ensuring the 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
- Ensuring the Integrity of the Contracting and Grants Processes and Proper Use of Space Act Agreements

The FY 2016 request is $37.4 million, including:

- $31.0 million (83 percent) for personnel and related costs, including salaries, benefits, monetary awards, 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;
- $1.0 million (3 percent) for travel, per diem, and related expenses;
- $3.0 million (8 percent) to fund the required annual audit of NASA's financial statements;
- $2.4 million (6 percent) for equipment, training, government vehicles, special equipment for criminal investigators, transit subsidies, and information technology equipment unique to the OIG.[1]

[1] *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.*

Supporting Data

FUNDS DISTRIBUTION BY INSTALLATION

FUNDS BY MISSION BY NASA CENTER

Budget Authority ($ in millions)	FY 2016*
Science	204.2
Aeronautics	130.1
Space Technology	50.5
Exploration	59.6
Space Operations	21.6
Education	0.9
Safety, Security, and Mission Services	204.5
Construction and Environmental Compliance and Restoration	18.0
Ames Research Center (ARC) Total	**689.3**
Science	71.9
Aeronautics	58.0
Space Technology	14.2
Exploration	5.6
Education	0.9
Safety, Security, and Mission Services	63.7
Construction and Environmental Compliance and Restoration	15.9
Armstrong Flight Research Center (AFRC) Total	**230.2**
Science	26.9
Aeronautics	109.6
Space Technology	103.0
Exploration	46.3
Space Operations	60.9
Education	1.0
Safety, Security, and Mission Services	214.7
Construction and Environmental Compliance and Restoration	39.2
Glenn Research Center (GRC) Total	**601.5**
Science	2,187.1
Space Technology	67.8
Exploration	3.5
Space Operations	304.0
Education	1.4
Safety, Security, and Mission Services	415.1
Construction and Environmental Compliance and Restoration	17.9
Goddard Space Flight Center (GSFC) Total	**2,996.8**

FUNDS DISTRIBUTION BY INSTALLATION

Budget Authority ($ in millions)	FY 2016*
Science	1,058.6
Space Technology	36.9
Exploration	25.2
Space Operations	180.9
Education	1.9
Safety, Security, and Mission Services	16.7
Construction and Environmental Compliance and Restoration	24.9
Jet Propulsion Laboratory (JPL) Total	**1,345.2**
Science	20.3
Space Technology	23.4
Exploration	1,249.6
Space Operations	2,892.3
Education	1.1
Safety, Security, and Mission Services	360.7
Construction and Environmental Compliance and Restoration	27.0
Johnson Space Center (JSC) Total	**4,574.3**
Science	338.8
Space Technology	10.7
Exploration	1,612.8
Space Operations	168.9
Education	1.0
Safety, Security, and Mission Services	376.4
Construction and Environmental Compliance and Restoration	20.3
Kennedy Space Center (KSC) Total	**2,528.9**
Science	189.9
Aeronautics	173.9
Space Technology	29.8
Exploration	32.5
Space Operations	0.5
Education	1.1
Safety, Security, and Mission Services	281.3
Construction and Environmental Compliance and Restoration	120.3
Langley Research Center (LaRC) Total	**829.2**

FUNDS DISTRIBUTION BY INSTALLATION

Budget Authority ($ in millions)	FY 2016*
Science	131.8
Space Technology	30.0
Exploration	1,290.6
Space Operations	178.5
Education	2.2
Safety, Security, and Mission Services	390.7
Construction and Environmental Compliance and Restoration	61.4
Marshall Space Flight Center (MSFC) Total	**2,085.1**
Science**	1,057.8
Aeronautics	99.9
Space Technology**	356.9
Exploration	145.7
Space Operations	161.6
Education	76.4
Safety, Security, and Mission Services	464.9
Construction and Environmental Compliance and Restoration	105.0
Office of Inspector General	37.4
NASA Headquarters (HQ) and Inspector General (IG) Total	**2,505.7**
Science	1.4
Space Technology	1.5
Exploration	34.6
Space Operations	34.5
Education	1.1
Safety, Security, and Mission Services	54.4
Construction and Environmental Compliance and Restoration	15.4
Stennis Space Center (SSC) Total	**142.9**
Total	**18,529.1**

**Totals may not add due to rounding.*

***Funds will not be fully distributed to Centers until after final acquisition decisions are made. Thus, Center FY 2016 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 2016 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 where appropriate, and a leaner fiscal environment. A civil service workforce is critical for conducting mission-essential work in research and technology. As NASA continues to balance its workforce to meet requirements, some reduction to workforce levels is necessary. NASA will reduce the size of the civil service workforce by almost 200 full-time equivalents from FY 2015 to FY 2016, bringing the civil service workforce to approximately 17,200 full-time equivalents.

The Agency will apply the civil service workforce to 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. NASA will also continue to explore opportunities across the Agency to insource work.

CIVIL SERVICE FULL-TIME EQUIVALENT DISTRIBUTION BY CENTER

	Actual	Estimate	Request	Notional			
	FY 2014	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
ARC	1,192	1,178	1,165	1,165	1,165	1,165	1,165
AFRC	544	549	538	538	539	539	539
GRC	1,596	1,565	1,546	1,542	1,546	1,546	1,546
GSFC	3,288	3,281	3,265	3,271	3,269	3,271	3,271
JSC	3,048	3,035	2,979	2,974	2,976	2,975	2,975
KSC	2,011	1,992	1,976	1,977	1,967	1,967	1,967
LaRC	1,861	1,845	1,821	1,819	1,819	1,819	1,819
MSFC	2,413	2,364	2,334	2,334	2,339	2,338	2,338
SSC	311	318	314	308	309	309	309
HQ	1,126	1,141	1,136	1,147	1,147	1,147	1,147
NSSC	127	138	138	138	138	138	138
NASA Total*	**17,518**	**17,406**	**17,211**	**17,213**	**17,214**	**17,214**	**17,214**
OIG	197	213	213	213	213	213	213

**Totals may not add due to rounding*

All actuals and estimates include direct-funded and reimbursable FTE

CIVIL SERVICE FULL-TIME EQUIVALENT DISTRIBUTION

FY 2015 FTE DISTRIBUTION BY ACCOUNT BY CENTER

	Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Safety, Security, and Mission Services	Reimbursable / Working Capital Fund**	NASA-Funded Total	Agency TOTAL
ARC	136	235	98	100	24	6	545	22	1,143	1,165
AFRC	114	162	13	14	0	5	214	15	523	538
GRC	79	362	135	178	168	7	614	3	1,543	1,546
GSFC	1,157	0	122	21	161	7	1,573	224	3,041	3,265
JSC	31	0	72	875	1,135	7	859	0	2,979	2,979
KSC	1	0	55	689	351	7	860	14	1,962	1,976
LaRC	233	489	112	127	3	8	834	15	1,806	1,821
MSFC	131	0	102	890	190	7	1,014	0	2,334	2,334
SSC	7	0	6	67	39	5	152	39	275	314
HQ	12	0	1	0	0	0	1,123	0	1,136	1,136
NSSC	0	0	0	0	0	0	0	138	0	138
NASA Total*	**1,900**	**1,248**	**715**	**2,961**	**2,070**	**60**	**7,788**	**470**	**16,742**	**17,211**
OIG	0	0	0	0	0	0	0	0	0	213

**Totals may not add due to rounding*

***Includes 143 FTE funded by Working Capital Fund; and 327 FTE funded by reimbursable customers*

WORKING CAPITAL FUND

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 FY 2014	Estimate FY 2015	Request FY 2016
NSSC	82	72	85
SEWP	8	15	15
I3P	297	366	335
Total Spending Authority	**387**	**453**	**435**
Unobligated Brought Forward, Oct. 1	7	11	14
Recoveries of Prior Yr. Unpaid Obligations	1	4	0
Total Budgetary Resources	**395**	**468**	**449**
NSSC	77	74	85
SEWP	9	14	14
I3P	298	366	335
Total Obligations	**384**	**454**	**434**
Unobligated Balance (end-of-year)*	**11**	**14**	**15**

**Unobligated balance end-of-year is budgetary resources less obligation*

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 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 reduces duplicative efforts and increases cost efficiencies.

NSSC's revenue streams include funding from the NASA Centers, mission directorates, and various NASA mission support offices. During FY 2016, NSSC will continue to offer similar services as in FY 2015 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 more 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 2015, SEWP quotes have a 24- 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 0.39 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 2015, the Federal Government is projected to save about $7.5 million in service fees (based on the difference between General Service Administration and SEWP surcharge fees) and $51 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 initiatives and to increase visibility into NASA's IT budget and expenditures. Under I3P, NASA has consolidated 19 separately managed contracts into 4 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.
- 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 2016 anticipated funding level, the I3P WCF will continue to offer similar services as in FY 2015.

BUDGET BY OBJECT CLASS

FY 2016 Estimated Direct Discretionary Obligations ($ millions)

Code	Object Class	Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Safety, Security, and Mission Services	Construction & Environmental Compliance & Restoration	Office of Inspector General	NASA Total
11.1	Full-time permanent	242	151	87	364	263	7	955	0	22	2,091
11.3	Other than full-time permanent	5	4	1	3	3	1	21	0	0	38
11.5	Other personnel compensation	2	0	0	2	2	0	28	0	0	34
11.8	Special personal service payments	0	0	0	1	0	0	0	0	0	1
11.9	*Subtotal Personnel Compensation*	*249*	*155*	*88*	*370*	*268*	*8*	*1,004*	*0*	*22*	*2,165*
12.1	Civilian personnel benefits	71	40	25	114	77	2	257	0	8	594
13.0	Benefits to former personnel	0	0	0	0	0	0	3	0	0	4
	Total Personnel Compensation & Benefits	**320**	**195**	**113**	**484**	**345**	**10**	**1,264**	**0**	**30**	**2762**
21.0	Travel & transport. of persons	24	5	7	17	11	0	21	0	1	86
22.0	Transportation of things	9	1	2	8	1,212	0	4	0	0	1,236
23.1	Rental payments to GSA	0	0	0	0	0	0	36	0	0	36
23.2	Rental payments to others	3	0	0	0	2	0	3	0	0	8
23.3	Communications, utilities & misc.	3	2	0	3	3	0	64	1	0	76
24.0	Printing & reproduction	1	0	0	0	1	0	4	0	0	6
25.1	Advisory & assistance services	83	9	32	304	73	5	213	21	0	740
25.2	Other services	200	22	39	40	98	7	257	43	5	711
25.3	Other purchases of goods & services from Government accounts	145	6	12	54	26	0	41	18	1	303
25.4	Operation & maintenance. of facilities	61	28	3	115	50	0	241	41	0	539
25.5	Research & development contracts	3,685	196	455	3,167	1,848	6	180	20	0	9,557
25.6	Medical care	0	0	0	0	0	0	6	1	0	7
25.7	Operation & maintenance of equipment	78	29	10	119	278	3	410	2	0	929
26.0	Supplies & materials	28	11	4	23	17	0	18	0	0	101

BUDGET BY OBJECT CLASS

Code	FY 2016 Estimated Direct Discretionary Obligations ($ millions) Object Class	Science	Aeronautics	Space Technology	Exploration	Space Operations	Education	Safety, Security, and Mission Services	Construction & Environmental Compliance & Restoration	Office of Inspector General	NASA Total
31.0	Equipment	48	24	3	63	16	0	32	0	0	186
32.0	Land & structures	0	1	0	33	6	0	31	318	0	389
41.0	Grants, subsidies, & contributions	601	42	45	74	19	58	18	0	0	857
99.5	Below reporting threshold	0	0	0	0	0	0	0	0	0	0
	Other Object Classes	**4,969**	**376**	**612**	**4,020**	**3,660**	**79**	**1,579**	**465**	**7**	**15,767**
	NASA Total, Direct*	**5,289**	**571**	**725**	**4,504**	**4,005**	**89**	**2,843**	**465**	**37**	**18,529**

**Totals may not add due to rounding*

STATUS OF UNOBLIGATED FUNDS

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 2014 or FY 2015 amounts to make them comparable to the budget structure underlying the FY 2016 request.

UNOBLIGATED FUNDS SUMMARY BY APPROPRIATIONS ACCOUNT

Budget Authority ($ millions)	Unobligated Balances Sep. 30, 2014	Estimated Unobligated Balances Sep. 30, 2015	Estimated Unobligated Balances Sep. 30, 2016
Science	277	235	237
Aeronautics	20	19	17
Space Technology	21	16	20
Exploration	104	74	76
Space Operations	132	124	130
Education	25	20	15
Safety, Security, and Mission Services	22	17	18
Construction and Environmental Compliance and Restoration	97	106	117
Science, Exploration, & Aeronautics	0	0	0
Office of Inspector General	0	1	1
NASA Total*	**699**	**612**	**631**

**Totals may not add due to rounding*

REIMBURSABLE ESTIMATES

Reimbursable agreements are agreements where the NASA costs associated with the undertaking are borne by the non-NASA partner. NASA undertakes reimbursable agreements 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 2015 to FY 2016 estimates are based on an annual survey of Centers' anticipated reimbursable agreements. NASA separately budgets for and executed 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 **FY 2014**	Estimate **FY 2015**	Request **FY 2016**
Safety, Security, and Mission Services (non-EUL)	2,108.0	2,587.2	2,259.3
Safety, Security, and Mission Services (EUL)	11.5	18.6	17.3
Office of Inspector General	1.3	1.2	1.2
Total	**2,120.8**	**2,607.0**	**2,277.8**

ENHANCED USE LEASING

In 2003, Congress authorized NASA to demonstrate leasing authority and collections at two Centers. In 2007 and 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 2016 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 2016 EUL ACTIVITY

FY2016 EUL Expenses and Revenues ($ thousands)	ARC	GSFC	JPL (NMO)	KSC	MSFC	SSC	Agency	Total
Base Rent	8,060.9	55.0	93.9	370.2	256.1	120.2	0.0	8,956.3
Institutional Support Income	2,640.1	5.3	0.0	30.8	0.0	7.2	0.0	2,683.4
Additional Reimbursable Demand Services Requested by Lessees (including overhead)	5,548.1	0.0	0.0	132.7	0.0	0.0	0.0	5,680.8
Total Lease Income	**16,249.1**	**60.3**	**93.9**	**533.7**	**256.1**	**127.4**	**0.0**	**17,320.5**
Institutional Support Costs	(2,640.1)	(5.3)	0.0	(30.8)	0.0	(5.7)	0.0	(2,681.9)
Lease Management and Administration	0.0	0.0	0.0	0.0	0.0	(1.5)	0.0	(1.5)
Tenant Building Maintenance and Repair	(1,916.4)	0.0	0.0	0.0	(134.3)	0.0	0.0	(2,050.7)
Cost to Fulfill Reimbursable Demand Services (including overhead)	(5,548.1)	0.0	0.0	(132.7)	0.0	0.0	0.0	(5,680.8)
Total Cost Associated with Leases	**(10,104.6)**	**(5.3)**	**0.0**	**(163.5)**	**(134.3)**	**(7.2)**	**0.0**	**(10,414.9)**
Net Revenue from Lease Activity	**6144.5**	**55.0**	**93.9**	**370.2**	**121.8**	**120.2**	**0.0**	**6905.6**
Beginning Balance, Capital Asset Account	**527.0**	**0.0**	**0.0**	**34.9**	**0.0**	**120.4**	**1882.4**	**2564.7**
Net Revenue from Lease Activity Retained at Center	**3993.9**	**35.8**	**61.0**	**240.6**	**79.2**	**78.1**	**2,417.0**	**6,905.6**
Total Available, Capital Assets Account	**4520.9**	**35.8**	**61.0**	**275.5**	**79.2**	**198.5**	**4299.4**	**9,470.3**
Planned Maintenance, Various Buildings	1,836.1	0.0	61.0	0.0	79.2	75.0	0.0	2,051.3
Replace Roofs on Various Buildings	899.9	0.0	0.0	0.0	0.0	0.0	0.0	899.9
GEWA Activities	0.0	19.8	0.0	0.0	0.0	0.0	0.0	19.8
Replace Batteries, Sunwise Solar Battery Bank L7-0071	0.0	0.0	0.0	56.9	0.0	0.0	0.0	56.9

Purchase/Install SafeTraxx Fall Protection K6-1996D	0.0	0.0	0.0	120.0	0.0	0.0	0.0	120.0
Repair Deteriorated Culverts, 10th St.	0.0	0.0	0.0	51.6	0.0	0.0	0.0	51.6
Replace worn and damaged exit doors 1200, framework, OSB1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lead remediation building 9101	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Repair 1000' of sewage pipe building 9752	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Repair potable water leak building 9760	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refurbish switchgear, secure all power feeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy and Sustainability Upgrades, Various Buildings (Various Centers)	0.0	0.0	0.0	0.0	0.0	0.0	1692.0	1692.0
HQ Share of Net Revenue at 35 percent	0.0	0.0	0.0	0.0	0.0	0.0	682.3	682.3
Capital Asset Account Expenditures	**2,736.0**	**19.8**	**61.0**	**228.5**	**79.2**	**75.0**	**2,374.3**	**5573.8**
Capital Asset Account Ending Balance	**1,784.9**	**16.0**	**0.0**	**47.0**	**0.0**	**123.5**	**1,925.1**	**3,896.5**
In Kind Activity	**0.0**	**0.0**	**0.0**	**40.0**	**0.0**	**0.0**	**0.0**	**40.0**

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 (e.g., 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).

ENHANCED USE LEASING

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.

NATIONAL HISTORIC PRESERVATION ACT

In FY 2014, NASA established a new fund based upon the National Historic Preservation Act of 1966. The Act provides the authority to administer, operate, manage, lease and maintain property, and demolish or remove buildings or space in buildings owned by NASA. It also allows any funds received from leasing the properties, buildings, or space in buildings to be deposited to the credit of a special receipt account and expended for purposes of operating, maintaining, and managing the properties and demolishing or removing the buildings. Agreements or contracts with public or private agencies, corporations, or persons, upon such terms and conditions is allowed. There are no civil servants funded from the National Historic Preservation Act Fund (NHPA). The NHPA activities will be maintained under the National Historic Preservation Act authority under Section 111. These funds are in addition to annual appropriations.

The table below depicts the estimated amounts of anticipated NHPA expenses and revenues for FY 2016. NASA currently expects total rental income of $10.3 million. Of the total rental income of $10.3M, $4.2 million represents net revenue from lease activities. The net revenue amount of $4.2 million will be used for historic building maintenance and repairs for historic properties at ARC as well as other properties throughout the Agency.

FY2016 EUL Expenses and Revenues ($ thousands)	ARC
Base Rent	4,150.0
Institutional Support Income	6,100.0
Total Rental Income	**10,250.0**
Institutional Support Costs	(6,100.0)
Total Cost Associated with Leases	**(6,100.0)**
Net Revenue from Lease Activity	***4,150.0***
Beginning Balance, Capital Asset Account	**0.0**
Net Revenue from Lease Activity	***4,150.0***
Historic Buildings Maintenance and Repair (ARC)	(2,075.0)
Historic Buildings Maintenance and Repair (Agency)	(2,075.0)
Capital Asset Account Expenditures	***(4,150.0)***
Capital Asset Account Ending Balance	**0.0**
Additional Reimbursable Demand Services Requested by Leasees	10,832.0
Cost to Fulfill Reimbursable Demand Services	(10,832.0)
Net activity due to Reimbursable Demand Services	**0.0**
In Kind Activity	**0.0**

NATIONAL HISTORIC PRESERVATION ACT

DEFINITIONS

Base Rent

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Reimbursable Demand Services

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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 the International Space Station (ISS). Human Explorations and Operations ISS Research is conducted in two broad categories: Exploration ISS Research and Non-Exploration ISS Research.

	Actual	Estimate	Request	Notional			
Budget Authority ($ millions)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
Exploration ISS Research	133	141	175	156	157	162	164
Non-Exploration ISS Research	155	148	185	169	170	171	171
Total	**289**	**290**	**360**	**325**	**327**	**333**	**335**
Percent of Non-Exploration to Total	54	51	51	52	52	51	51

The amounts included for FY 2014 reflect actual, FY 2015 thru FY 2020 are reflective of the NASA outyear planning.

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 the 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 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, 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. The Center continues to build momentum in the private sector, and is actively working with leading companies that include Merck, Eli Lilly, COBRA PUMA Golf, Proctor & Gamble, and Novartis. CASIS awarded 36 research and technology projects that include a wide diversity in discipline and application.

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 request. This includes the agency-wide safety oversight functions as well as the 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 amounts are embedded in program, project, and mission support budgets.

BUDGET SUMMARY FOR SAFETY OVERSIGHT

	Actual	Estimate	Request	Notional			
Budget Authority ($ millions)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
Safety and Mission Assurance (AMO)	48.7	48.7	50.1	50.8	51.6	52.4	53.2
Institutional Operational Safety (CMO)	33.2	33.3	32.6	37.3	37.8	38.4	39.2
SMA Technical Authority (CMO)	52.1	52.4	48.2	49.7	50.7	51.6	52.9
Agency-wide Safety Oversight	**134.0**	**134.4**	**130.9**	**137.8**	**140.1**	**142.4**	**145.3**
Program Specific	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**	**300.0**
NASA Total, Safety	**434.0**	**434.4**	**430.9**	**437.8**	**440.1**	**442.4**	**445.3**

Agency-Wide Safety Oversight - Agency level programs and activities that support the overarching NASA Safety and Mission Success program.

Safety and Mission Assurance - The Safety and Mission Assurance program administers and refines the pertinent policies, procedural requirements, and technical safety standards. The program participate 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 responsibility 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 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.

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 FY 2014	Estimate FY 2015	Request FY 2016*
1) Number of Physicians Receiving PCAs		22	24	24
2) Number of Physicians with One-Year PCA Agreements		22	24	24
3) Number of Physicians with Multi-Year PCA Agreements		0	0	0
4) Average Annual PCA Physician Pay (without PCA payment)		$156,691	$158,258**	$159,841**
5) Average Annual PCA Payment		$19,229	$18,433	$18,308
6) Number of Physicians Receiving PCAs by Category (non-add)	Category I Clinical Position	19	21	21
	Category II Research Position	0	0	0
	Category III Occupational Health	0	0	0
	Category IV-A Disability Evaluation	0	0	0
	Category IV-B Health and Medical Admin.	3	3	3

**FY 2016 data will be approved during the FY 2017 Budget cycle.*

***Based on estimated 1 percent pay increases in 2015 and 2016*

MAXIMUM ANNUAL PCA AMOUNT PAID TO EACH CATEGORY OF PHYSICIAN

The allowance amount authorized will be the minimum amount necessary to address the recruitment and retention problems, noted below, 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

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.
- The time to train a new physician to fully support a mission is approximately two years.
- JSC's needs for clinical resources continue to be re-evaluated in the post-Space Shuttle era but include the need to support the health and wellbeing (operating 24/7) of the ISS crew, support of the active astronaut corps and the operation of the ever-increasing Lifetime Surveillance of Astronaut Health program (which includes all retired astronauts).
- Flight surgeons are required to have both clinical and aerospace medicine backgrounds, and must maintain current board certification.
- There is a shortage of qualified flight surgeons nationwide, with other institutions, including the military, actively recruiting already trained physicians.
- Unique responsibilities for flight surgeons include: worldwide deployment for mission support and contingency operations; expertise in integration of spaceflight medicine and physiology with engineering challenges in extreme environments.

JSC filled two clinical positions in FY 2014 and the ability to offer PCA was an important factor in the candidates' acceptance of employment offers. JSC is planning to hire two to three physicians in the next two years in order to fully serve the needs of the Agency. However, with limited hiring capability, JSC cannot backfill for all losses. JSC's focus must continue to concentrate on retaining the current physician population and having the capability to fill positions that may become vacant due to resignations and/or retirements. Being able to offer PCA has become an increasingly crucial tool in competing with the private sector for the most qualified physicians.

Category IV-B Health and Medical Administration

NASA currently has three physicians in this category receiving PCA: two at KSC and one at Headquarters. KSC in not currently experiencing retention issues and has been gradually reducing the PCA amounts with the intent to phase out PCA for the two physicians.

Recruiting and retaining physicians in the Washington, DC area requires that NASA must compete with several major medical schools in the Washington, DC area, as well as other Federal agencies such as the National Institutes of Health, Department of Defense, Veterans Administration, Department of Homeland Security, and the Federal Aviation Administration. Physician compensation is commensurately high in this location and competition for qualified physicians is intense. Additionally, attracting physicians from outside the area is difficult due to commuting challenges and the high cost of living.

The Headquarters position is a medical leadership and oversight position that is largely administrative with little opportunity for clinical practice. Many aerospace medicine physicians prefer clinical practice to a medical leadership position. Licensure and renewal of professional certification, which is requires knowledge of current clinical practices, is difficult to maintain while serving in this position. This position is responsible for the success of the medical care system supporting human space flight in the

United States and internationally, with significant travel obligations and other pressures associated with this position. These factors also present additional recruitment and retention challenges.

HOW PCA ALLEVIATES RECRUITMENT AND RETENTION PROBLEMS

PCA has been very effective at NASA. It has been used effectively at JSC to retain highly qualified physicians over several years. The attrition rate for physicians at JSC for FY 2013 was 14 percent (three losses including one resignation and two retirements); the FY 2014 attrition rate was 11 percent (two losses including one resignation and one retirement).While the attrition rate remains high, an increasing number of JSC's losses are due to retirements of physicians with at least 20 years of experience. This demonstrates that PCA is instrumental in retaining physicians for a significant period of time. JSC anticipates two more retirements in FY 2015 and several others will be eligible within the next five years. JSC was able to fill two critical physician positions in FY 2014 by using PCA to compete with higher compensation in the private sector.

KSC in not currently experiencing retention issues. KSC plans to decrease the current PCA amounts in FY 2015 and continue decreasing the amount of PCA in FY 2016 to prevent a negative impact on the net income of the two physicians.

Offering PCA to the physician at Headquarters was instrumental in retaining this physician.

ADDITIONAL INFORMATION

In the future, retaining essential civil service physicians will become increasingly critical to maintaining core competencies and fulfilling mission objectives. The multi-year Federal pay freeze and 2013 furlough cause physicians to question the stability of Federal service, which affects the ability to attract and 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 Safety, Security, and Mission Services 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

	Actual	Estimate	Request	Notional			
Budget Authority ($ millions)	**FY 2014**	**FY 2015**	**FY 2016**	**FY 2017**	**FY 2018**	**FY 2019**	**FY 2020**
ARC	2.3	2.5	2.5	2.5	2.5	2.5	2.5
AFRC	1.3	1.3	1.4	1.4	1.5	1.5	1.5
GRC	2.7	2.8	3.0	3.0	3.0	3.0	3.0
GSFC	5.1	5.3	5.4	5.6	5.7	5.9	6.1
HQ	14.4	12.9	14.1	14.5	15.1	15.0	15.3
JSC	7.3	7.4	7.6	7.6	7.6	7.6	7.6
KSC	5.2	7.4	7.6	7.8	8.0	8.2	8.5
LaRC	2.4	2.4	2.7	2.8	2.8	2.8	2.9
MSFC	4.7	4.8	4.8	4.9	4.9	4.9	5.0
SSC	1.9	1.9	1.8	1.7	1.8	1.8	1.9
NASA Total	**47.3**	**48.7**	**50.9**	**51.8**	**52.9**	**53.2**	**54.3**

Public Affairs per baseline service level definition as part of the Safety, Security, and Mission Services 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 2014	**FY 2015**	**FY 2016**
Number of Paid Experts and Consultants	31.0	31.0	31.0
Annual FTE Usage	8.9	8.9	8.9
Salaries	$1.0M	$1.0M	$1.0M
Total Salary and Benefits Costs	$1.2M	$1.2M	$1.2M
Travel Costs	$0.2M	$0.2M	$0.2M
Total Costs	**$1.4M**	**$1.4M**	**$1.4M**

FY 2014 are actual obligations. FY 2015 and FY 2016 are estimated Budget Authority

A broader definition of consulting services could include the total object class "Advisory and Assistance Services" as shown in the Supporting Data Budget by Object Class section of this volume.

	Actual	Estimate	Request
(Cost in $ millions)	**FY 2014**	**FY 2015**	**FY 2016**
Advisory and Assistance Services	706.0	739.0	740.0

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 to Office of Personnel Management (OPM) annually.

E-GOV INITIATIVES AND BENEFITS

E-GOVERNMENT FUNDING CONTRIBUTIONS AND SERVICE FEES BY INITIATIVE

NASA is providing funding contributions in FY 2016 for each of the following E-Government initiatives:

Initiative	2016 Contributions (Includes In-Kind)	2016 Service Fees*
E-Rulemaking	0	13,473
Grants.gov	167,049	0
E-Training	0	1,350,000
Recruitment One-Stop	0	107,319
Enterprise HR Integration	0	293,615
E-Payroll	0	3,950,075
E-Travel	0	1,932,319
Integrated Acquisition Environment (IAE)	0	1,907,628
Financial Management LoB	124,236	0
Human Resources Management LoB	58,695	350,000
Geospatial LoB	225,000	0
Budget Formulation and Execution LoB**	105,000	0
NASA Total	**679,980**	**9,904,429**

**Service fees are estimates as provided by the E-Government initiative managing partners*

***Final FY 2016 commitments have yet to be finalized by Managing Partners (OMB MAX)*

After submission of the budget, NASA will post FY 2016 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 2016 are described in the following.

eRulemaking (Managing Partner EPA) FY 2016 Benefits

NASA's benefits from the eRulemaking initiative are largely focused on providing the public benefits by providing one-stop access to the Agency's information on rulemakings and non-rulemaking activities via the Regulations.gov Web siteWeb site.

NASA uses the Federal Docket Management System (FDMS) to post its rulemakings in order for the public to gain access to review and comment on these rulemakings. NASA relies on Regulations.gov to retrieve public comments on its rulemakings. NASA's use of the FDMS and Regulations.gov substantially improves the transparency of its rulemaking actions as this use increases public participation in the regulatory process. Direct budget cost savings and cost avoidance result from NASA's transition to FDMS 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.

E-GOV INITIATIVES AND BENEFITS

Grants.gov (Managing Partner HHS) FY 2016 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 2016 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. The System for Administration, Training, and Educational Resources at NASA (SATERN) is a web-based talent management tool that 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. Currently SATERN offers learners access to more than 2,500 online courses and 18,000 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 2016 Benefits

USAJOBS simplifies the Federal Job Search Process for Job Seekers and Agencies. The USAJOBS.gov Web site 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.

E-GOV INITIATIVES AND BENEFITS

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.

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 2016 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 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-Payroll FY 2016 Benefits

The E-Payroll Initiative standardizes and consolidates government-wide federal civilian payroll services and processes by simplifying and standardizing human resources (HR)/payroll policies and procedures and better integrating payroll, HR, and finance functions. Prior to beginning the initiative, 26 federal agencies provided payroll services. Four providers were selected to furnish payroll services for the Executive branch. Since 2004, the Department of Interior (DOI) has served as NASA's payroll provider, using their system, the Federal Personnel and Payroll System (FPPS), to process NASA's HR and Payroll transactions and supply all key delivery aspects of its payroll operation functions. The E-Payroll initiative benefits NASA by permitting the Agency to focus on its mission related activities, rather than on administrative payroll functions. Payroll processing costs are reduced through economies of scale and avoiding the cost of duplicative capital system modernization activities. The initiative also promotes standardization of business processes and practices and unified service delivery.

E-Travel (Managing Partner GSA) FY 2016 Benefits

The E-Gov Travel Service 2 (ETS2), planned to be implemented in summer 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 includes:

- 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 and cohesive travel policies and processes;
- Enhanced security and privacy controls for the protection of government and personal data; and
- Improved agency process improvements, 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 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 2016 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
- Report subcontracting accomplishments

Citizens can:

- Retrieve data on contract awards
- Track federal spending
- Search to find registered businesses
- Monitor business opportunities

E-GOV INITIATIVES AND BENEFITS

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 2016 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 Web site. FFATA requires OMB to lead the development of a single, searchable Web site through which the public can readily access information about grants and contracts provided by Federal government agencies[1].

Based on the recommendations of the Transparency Act Taskforce, the Web site 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 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 Web sites 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;
- The amount of the award;
- Information on the award including transaction type, funding agency, etc.;
- The location of the entity receiving the award; and
- 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 Web site. Cross-government cooperation with OMB's Integrated Acquisition Environment initiative allows agencies and contributing

[1] More information on the development of this Web site can be found at: http://www.federalspending.gov.

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 2014 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 2016 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 2016 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 (SSCs). 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.

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. NASA participates in the ongoing 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 2016 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 scientist 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 2016 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 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 Web site, 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).

COST AND SCHEDULE PERFORMANCE SUMMARY

2015 MAJOR PROGRAM ANNUAL REPORT SUMMARY

The 2015 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 2015 MPAR consists of this summary and FY 2016 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 ICESat-2 can be found in the respective project page in the FY 2016 Congressional Justification.

CHANGES IN MPAR COMPOSITION SINCE THE FY 2015 NASA BUDGET ESTIMATES

Six new projects with estimated lifecycle costs greater than $250 million received authority to proceed into the development phase since NASA submitted its 2014 MPAR in the FY 2015 NASA Congressional Justification:

- Exploration System Development – Ground Systems Development and Operations (EGS-GSDO) with a baseline development cost of $1,843.5 million at a joint confidence level of 70 percent;
- Gravity Recovery and Climate Experiment Follow-On (GRACE-FO), with a baseline development cost of $264.0 million at a joint confidence level of 70 percent;
- Ionospheric Connection Explorer (ICON), with a baseline development cost of $196.0 million at a joint confidence level of 70 percent;
- Space Launch System (SLS), with a baseline development cost of $7,021.4 million at a joint confidence level of 70 percent (this covers phases C and D to launch readiness for EM-1);
- Solar Probe Plus (SPP), with a baseline development cost of $1,055.7 million at a joint confidence level of 70 percent;
- Transiting Exoplanet Survey Satellite (TESS), with a baseline development cost of $323.2 million at a joint confidence level of 70 percent. The TESS project experienced a development cost decrease of 8% since its baseline. This is due to the launch vehicle cost being lower than planned.

The 2014 MPAR in the FY 2015 NASA Congressional Justification included three projects (OCO-2, GPM and SOFIA) that are no longer in MPAR reporting. NASA successfully launched the GPM spacecraft on February 27, 2014, and the OCO-2 spacecraft on July 2, 2014. NASA launched the GPM and OCO-2 spacecraft approximately -13% and -14% respectively below the baseline development cost due to the excellent project management of risk, cost, and schedule. SOFIA achieved full operational capability on February 21, 2014.

CHANGES IN COST AND SCHEDULE ESTIMATES FROM THE 2014 MPAR

Five projects had no or minor changes in their cost or schedule estimates over the last year.

Three projects OSIRIS-REx and SOC experienced development cost decreases of -9% and -15% respectively.

COST AND SCHEDULE PERFORMANCE SUMMARY

- The OSIRIS-REx development cost decrease is attributable to underruns in several different development activities.
- The SOC development cost decrease is primarily due to launch vehicle cost being lower than planned.

The ICESat-2 project is establishing a new baseline pursuant to sec. 103(e) of PL 109-155, with this budget request. Details concerning ICESat-2 purpose, cost estimate, schedule, and risks are provided in the ICESat-2 project pages of this budget.

MPAR SUMMARY TABLE

Figure 1 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);
- Initial operating capability (IOC); or
- Launch Readiness for EM-1

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:

- The SGSS project is experiencing contractor performance issues and has prepared the notification required under the NASA Authorization Act.
- Webb: 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.

COST AND SCHEDULE PERFORMANCE SUMMARY

- 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).
- EGS-GSDO: The 80% JCL is inferred from analysis based on FY14 President's Budget Request (PBR) including FY14 Appropriation changes. JCL analysis was completed prior to the release of the FY15 PBR. The ABC is informed by the 80% JCL and adjusted to reflect the FY15 PBR budget reduction.

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 1: MPAR Summary and Confidence Levels

Project	Base Year	JCL (%)	Development Cost Estimate ($M)		Cost Change (%)	Key Milestone	Key Milestone		Schedule Change (months)
			Base	2015			Base	2015	
EGS-GSDO*	2015	80	1,843.5	1,843.5	0	Launch Readiness for EM-1	Nov 2018	2018	0
GRACE FO	2015	70	264.0	262.8	0	LRD	Feb 2018	Feb 2018	0
ICESat-2**	2015	70	763.7	763.7	0	LRD	Jun 2018	Jun 2018	0
ICON	2015	70	196.0	196.0	0	LRD	Oct 2017	Oct 2017	0
InSight	201	70	541.8	541.8	0	LRD	Mar 2016	Mar 2016	0
Webb	2012	66	6,197.9	6,190.4	0	LRD	Oct 2018	Oct 2018	0
MMS	2010	70	857.3	884.5	3	LRD	Mar 2015	Apr 2015	1
OSIRIS-REx	2014	70	778.6	709.7	-9	LRD	Oct 2016	Oct 2016	0
SGSS	2013	70	368.1	Under Review	N/A	FAR	Jun 2017	Under Review	N/A
SLS	2015	70	7,021.4	7,021.4	0	Launch Readiness for EM-1	Nov 2018	Nov 2018	0
SMAP	2013	>70	485.7	479.0	-1	LRD	Mar 2015	Mar 2015	0
SOC	2014	N/A	376.9	320.0	-15	LRD	Oct 2018	Oct 2018	0
SPP	2015	70	1,055.7	1,055.7	0	LRD	Aug 2018	Aug 2018	0
TESS	2015	70	323.2	296.4	-8	LRD	Jun 2018	Jun 2018	0

**The 80% JCL is inferred from analysis based on FY14 President's Budget Request (PBR) including FY14 Appropriation changes. JCL analysis was completed prior to the release of the FY15 PBR. The ABC is informed by the 80% JCL and adjusted to reflect the FY15 PBR budget reduction.*

***Pursuant to sec. 103(e) of PL 109-155, this budget request establishes a new baseline for ICESat-2. The original ICESat-2 baseline in 2013 had a 37% cost increase.*

National Aeronautics and Space Administration

Report Regarding

Basic Research for Fiscal Year 2016

Pursuant to

Section 1008(c) of the America Competes Act (P.L. 110-69)

BASIC RESEARCH

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) 2016 NASA budget request is $18.5 billion. The NASA Research and Development (R&D) budget consists of 18% basic research, 13% applied research, and 35% 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 four accounts: (1) Science investments, (2) the International Space Station, and (3) Exploration research.

Based on the FY 2016 budget request, NASA expects that 38% of its basic research in FY 2016 will be for *high-risk, high-reward* fundamental technical and scientific challenges that are novel and multidisciplinary. NASA is budgeting $1,250M 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

(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 is an example of a *high-risk, high-reward* science project:

Orbiting Carbon Observatory 2 (OCO-2) (http://oco.jpl.nasa.gov) is NASA's first dedicated satellite to study atmospheric carbon dioxide (CO2). CO2 is one of several gases, known as greenhouse gases, which trap heat near the surface of the Earth. Substantial increases in the abundance of CO2 will generate an increase in the Earth's surface temperature.

Understanding where atmospheric CO2 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 measurements of atmospheric CO2 with the precision, resolution, and coverage needed to characterize sources and sinks on regional scales. OCO-2 will also be able to quantify CO2 variability over the seasonal cycles, year after year.

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 drove our second attempt in July 2014, which succeeded. The first global maps of atmospheric carbon dioxide from OCO-2 demonstrate its performance and promise, showing elevated carbon dioxide concentrations across the Southern Hemisphere from springtime biomass burning. The agreement between OCO-2 and models based on existing carbon dioxide data is remarkably good, but there are some interesting differences. Some of the differences are likely due to gaps in our current knowledge of carbon sources in certain regions -- gaps that OCO-2 will help fill in.

Soil Moisture Active Passive (SMAP, http://www.nasa.gov/smap): the SMAP mission, scheduled to launch in 2015, will produce global maps of soil moisture, which will help improve our understanding of Earth's water and carbon cycles and our ability to manage water resources. Everywhere on Earth not covered with water or not frozen, SMAP will measure how much water is in the top layer of soil. It also distinguishes between ground that is frozen or thawed. SMAP will measure soil moisture every 2-3 days, permitting changes around the world to be observed over time scales ranging from major storms to seasons. SMAP will help monitor droughts, predict floods, support crop production, and aid weather forecasting, while improving our understanding of global climate change.

To enable SMAP to meet its accuracy requirements while covering the globe every three days or less, it has the largest rotating mesh antenna ever deployed in space. Once deployed, the antenna will be 19.7 feet (6 meters) in diameter, but during launch it must be stowed into a space of only one foot by four feet (30 by 120 centimeters) – about the size of a tall kitchen trash can. During deployment it must unfold without snagging, so precisely that the surface shape of the mesh is accurate within about an eighth of an inch (a few millimeters). Performing science research within such tight parameters and accuracy requirements is just one of the examples of risky endeavors that NASA undertakes to advance the state of the science.

(2) International Space Station (http://www.nasa.gov/mission_pages/station/research/index.html): NASA's research goals for the space station are driven by the NASA Authorization Act of 2010 and are focused on the following areas: human health and exploration, technology development and demonstration, physical sciences research, biology and biotechnology research, earth and space science research, education, and enabling the development of market driven commercial research and applications in low Earth orbit. NASA will conduct a new rodent research habitat validation flight with a small amount of science in 2015, and then in 2016 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.

(3) Exploration (http://www.nasa.gov/exploration/humanresearch/): NASA's Human Research Program (HRP) 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, biomedical technology, and space radiation effects. One example of this *high-risk, high-reward* research is in the area of biomedical ultrasound technology.

Evaluating and treating an injury or illness in space poses serious challenges. These challenges are similar to those faced by patients in underserved parts of the world, at remote military installations, or in emergency care situations where medical resources and infrastructure are limited. NASA has developed ultrasounds techniques for use on orbit and telemedicine evaluations to allow rapid diagnostic solutions. Developing ultrasounds for space flight has enabled the improvement of protocols for focused assessment, and diagnostic technique advancements that have influenced medical practice on Earth.

NASA research will continue to make contributions to the terrestrial practice of medicine by enabling the development and validation of specific diagnostic techniques including: diagnosing bone fractures in emergency settings, diagnosing collapsed lung and other pulmonary conditions, and increasing diagnostic accuracy in the management of renal stones.

SUMMARY

The NASA 2016 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 38% of its basic research to be *high-risk, high-reward*.

FY 2016 PROPOSED APPROPRIATIONS LANGUAGE

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, **[**$5,244,700,000**]** *$5,288,600,000*, to remain available until September 30, **[**2016: *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 $100,000,000 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**]** *2017. (Science Appropriations Act, 2015.)*

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, **[**$651,000,000**]** *$571,400,000*, to remain available until September 30, **[**2016**]** *2017. (Science Appropriations Act, 2015.)*

SPACE TECHNOLOGY

For necessary expenses, not otherwise provided for, in the conduct and support of space *technology* 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, **[**$596,000,000**]** *$724,800,000*, to remain available until September 30, **[**2016**]** *2017. (Science Appropriations Act, 2015.)*

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, **[**$4,356,700,000**]** *$4,504,400,000*, to remain available until September 30, **[**2016: *Provided*, That not less than $1,194,000,000 shall be for the Orion Multi-Purpose Crew Vehicle: *Provided further*, That not less than $2,051,300,000 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, $1,700,000,000 shall be for launch vehicle development and $351,300,000 shall be for exploration ground systems: *Provided further*, That the National Aeronautics and Space Administration (NASA) shall provide to the Committees on Appropriations of the House of Representatives and the Senate, concurrent with the annual budget submission, a 5 year budget profile and funding projection that adheres to a 70 percent Joint Confidence Level (JCL) and is consistent with the Key Decision Point C (KDPC) for the Space Launch System and with the future KDP-C for the Orion Multi- Purpose Crew Vehicle: *Provided further*, That in complying with the preceding proviso NASA shall include budget profiles and funding projections that conform to the KDP-C management agreement for development completion of the Space Launch System by December 2017, and the management agreement for the Orion Multi-Purpose Crew Vehicle upon completing KDP-C: *Provided further*, That in no case shall the JCL of the Space Launch System or the Orion Multi-Purpose Crew Vehicle be less than the guidance outlined in NASA Procedural Requirements 7120.5E: *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 $805,000,000 shall be for commercial spaceflight activities: *Provided further*, That $306,400,000 shall be for exploration research and development**]** *2017. (Science Appropriations Act, 2015.)*

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, **[**$3,827,800,000**]** *$4,005,200,000*, to remain available until September 30, **[**2016**]** *2017. (Science Appropriations Act, 2015.)*

EDUCATION

For necessary expenses, not otherwise provided for, in the conduct and support of 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, **[**$119,000,000**]** *$88,900,000*, to remain available until

September 30, **[**2016, 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**]** *2017*. *(Science Appropriations Act, 2015.)*

SAFETY, SECURITY, AND MISSION SERVICES

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, **[**$2,758,900,000**]** *$2,843,100,000*, to remain available until September 30, **[**2016**]** *2017: Provided, That $12,700,000 will be used to support the National Aeronautics and Space Administration's (NASA's) activities related to implementation of the Digital Accountability and Transparency Act (DATA Act; Public Law 113–101; 31 U.S.C. 6101 note), to include changes in business processes, workforce, or information technology to support high quality, transparent Federal spending information, of which $9,700,000 shall be available to support NASA's implementation of a uniform procurement instrument identifier as described in 48 C.F.R. subpart 4.16: Provided further, That the amounts in the first proviso are available only to supplement and not supplant existing DATA Act activities*. *(Science Appropriations Act, 2015.)*

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, **[**$419,100,000**]** *$465,300,000*, to remain available until September 30, **[**2020**]** *2021*: *Provided*, **[**That of the $429,100,000 provided for in direct obligations under this heading, $419,100,000 is appropriated from the general fund and $10,000,000 is provided from recoveries of prior year obligations: *Provided further*,**]** 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 2015 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 20145 of title 51, United States Code. *(Science Appropriations Act, 2015.)*

INSPECTOR GENERAL

For necessary expenses of the Office of Inspector General in carrying out the Inspector General Act of 1978, **[**$37,000,000**]** *$37,400,000*, of which $500,000 shall remain available until September 30, **[**2016**]** *2017*. *(Science Appropriations Act, 2015.)*

FY 2016 PROPOSED APPROPRIATIONS LANGUAGE

ADMINISTRATIVE PROVISIONS

Funds for any announced prize otherwise authorized shall remain available, without fiscal year limitation, until the 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 of this Act, shall be treated as a reprogramming under section 505 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, 2015.)*

ACRONYMS AND ABBREVIATIONS

$K	Dollars in thousands
$M	Dollars in millions
21CSLC	21st Century Space Launch Complex
3U	3-unit
45SW	US Air Force 45th Space Wing
AANAPISI	Asian American and Native American Pacific Islander-Serving Institutions
AAV	Advanced Air Vehicles
ABC	Agency Baseline Commitment
ACC	Advanced Composites Consortium
ACCESS	Advancing Collaborative Connections for Earth System Science
ACCESS-II	Alternative Fuel Effects on Contrails and Cruise Emissions II
ACE	Advanced Composition Explorer (Heliophysics)
ACE	Aerosol, Cloud, and Ecosystems (Earth Science)
ACME	Advanced Combustion via Microgravity Experiments
ACTE	adaptive compliant trailing-edge technology
ADAP	Astrophysics Data Analysis Program
ADCAR	Astrophysics Data Curation and Archival Research
ADS-B	Automatic Dependent Surveillance-Broadcast
AEDL	Advanced Entry Descent and Landing
AES	Advanced Exploration Systems
AFO	Altimetry Follow-On
AFRC	Armstrong Flight Research Center
AFRL	Air Force Research Laboratory
AFTA	Astrophysics Focused Telescope Assets
AIM	Aeronomy of Ice in the Mesosphere
AirMOSS	Airborne Microwave Observatory of Subcanopy and Subsurface
AIRS	Atmospheric Infrared Sounder
AIST	Advanced Information Systems Technology
AITS	Agency Information Technology Services
AMMOS	Advanced Multi-Mission Operations System
AMO	Agency Management and Operations
AMR	Advanced Microwave Radiometer
AO	Announcements of Opportunity
AOSP	Airspace Operations and Safety Program
APL	Applied Physics Laboratory
APMC	Agency Project Management Council
AR	Advanced Radiometer
ARC	Ames Research Center
ARCD	Aerospace Research and Career Development
ARM	Asteroid Redirect Mission

ACRONYMS AND ABBREVIATIONS

ARMD	Aeronautics Research Mission Directorate
ARRA	American Recovery and Reinvestment Act
ARSET	Applied Remote SEnsing Training
ARTEMIS	Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun
ASCENDS	Active Sensing of CO2 Emissions over Nights, Days, and Seasons
ASDM	Astrophysics Decadal Strategic Mission
ASI	Agenzia Spaziale Italiana
ASPERA	Analyzer of Space Plasmas and Energetic Atoms
ATCC	A-Complex Test Control Center
ATD	Air Traffic Management Technology Demonstration-1
ATLAS	Advanced Topographic Laser Altimeter System
ATM	Air Traffic Management
ATTREX	Airborne Tropical TRopopause EXperiment
AU	astronomical units
AURA	Association of Universities for Research in Astronomy
BAA	Broad Agency Announcement
BARREL	Balloon Array for Radiation-belt Relativistic Electron Losses
BEAM	Bigelow Expandable Activity Module
BEDI	Big Earth Data Initiative
BFELoB	Budget Formulation & Execution Lines of Business
BTC	budget to complete
BWG	Beam Wave Guide
CAL	Cold Atom Laboratory
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation
CAMMEE	Committee on Aerospace Medicine and the Medicine of Extreme Environments
CAP	Cross-Agency Priority
CARVE	Carbon in Arctic Reservoirs Vulnerability Experiment
CAS	Convergent Aeronautics Solutions
CASIS	Center for the Advancement of Science in Space
CAST	Commercial Aviation Safety Team
CATALYST	Cargo Transportation and Landing by Soft Touchdown
CATS	Cloud Aerosol Transport System
CBT	Computer-Based Training
CCAFS	Cape Canaveral Air Force Station
CCD	charge-coupled device
CCDev2	Commercial Crew Development Round 2
CCM	Camera Control Module
CCMC	Community Coordinated Modeling Center
CCP	Commercial Crew Program

ACRONYMS AND ABBREVIATIONS

CCtCap	Commercial Crew transportation Capabilities
CDC	Centers for Disease Control
CDI	Climate Data Initiative
CDM	Continuous Diagnostic Mitigation
CDR	Critical Design Reviews
CDTI	Center for the Development of Industrial Technology
CECR	Construction and Environmental Compliance and Restoration
CERES	Clouds and the Earth's Radiant Energy
CFD	Computational Fluid Dynamics
CFOC	Chief Financial Officer's Council
CGE	Concur Government Edition
CHAMPS™	CubeSat High-Impulse Adaptable Modular Propulsion System™
CHS	Crew Health and Safety
CIBER	Cosmic Infrared Background Experiment Rocket
CINDI	Coupled Ion Neutral Dynamic Investigation
CIRs	co-rotating interaction regions
CL	confidence level
CLARREO	Climate Absolute Radiance and Refractivity Observatory
CMEs	coronal mass ejections
CMO	Center Management and Operations
CMS	Carbon Monitoring System
CNES	Centre National d'Etudes' Spatiales
CoF	Construction of Facilities
COFAR	Council on Financial Assistance Reform
Comet C-S	Comet Churyumov-Gerasimenko
COR	Cosmic Origins
CoSTEM	committee on science, technology, engineering, and mathematics
COTS	commercial off-the-shelf
CPC	Certification Products Contracts
CPOD	CubeSat Proximity Operations Demonstration
CREAM	Cosmic Ray Energetics and Mass
CRP	Commercialization Readiness Program
CRS	Commercial Resupply Services
CRT	Climate Resilience Toolkit
CRV	current replacement value
CSA	Canadian Space Agency
CSC	Computer Sciences Corporation
CSL	Belgian Centre Spatial de Liège
CSO	Communications Services Office
CSTD	Crosscutting Space Technology Development

ACRONYMS AND ABBREVIATIONS

CYGNSS	Cyclone Global Navigation Satellite System
D&B	Dun and Bradstreet
DAAC	Distributed Active Archive Center
DATA	Digital Accountability and Transparency Act
DCT	Development to Certification Timeline
DESDynI	Deformation, Ecosystem Structure and Dynamics of Ice
DISCOVER-AQ	Deriving Information on Surface Conditions from COlumn and VERtically Resolved Observations Relevant to Air Quality
DLP	Data Loss Prevention
DLR	German Aerospace Center
DLS	deployable launch system
DNA	Deoxyribonucleic acid
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of Interior
DOJ	Department of Justice
DOL	Department of Labor
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
DPMC	Directorate Program Management Council
DPR	Dual-frequency Precipitation Radar
DRE	discrete roughness elements
DRIVE	Diversify, Realize, Integrate, Venture, Educate
DSAC	Deep Space Atomic Clock
DSCC	Deep Space Communications Complex
DSCOVR	Deep Space Observatory
DSI	Deutsches SOFIA Institut
DSN	Deep Space Network
DSOC	Deep Space Optical Communication
DSS	Deep Space Station
DUNS	Data Universal Numbering System
ECAST	Expert and Citizen Assessment of Science and Technology
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
ECR	Environmental Compliance and Restoration
eCryo	Evolvable Cryogenics
EFT	Exploration Flight Test
EGS	Exploration Ground Systems
EHRI	Enterprise HR Integration
EHRS	Electronic Health Records System
EICC	EPSCoR Interagency Coordinating Committee
ELV	Expendable Launch Vehicle

ACRONYMS AND ABBREVIATIONS

EM	Exploration Mission
EO-1	Earth Observing-1
EONS	Education Opportunities in NASA STEM
eOPF	electronic Official Personnel Folder
EOS	Earth Observation Systems
EPA	Environmental Protection Agency
EPIC	Earth Poly-Chromatic Imaging Camera
EPSCoR	Experimental Project To Stimulate Competitive Research
EQM	Engineering Qualification Model
ERA	Environmentally Responsible Aviation
ERBS	Earth Radiation Budget Science
ESA	European Space Agency
ESDN	Edison Demonstration of Smallsat Networks
ESM	Earth Systematic Missions
ESSP	Earth System Science Pathfinder
ESTEEM	Earth Systems, Technology and Energy Education for MUREP
ESTO	Earth Science Technology Office
ESTP	Earth Science Technology Program
ETD	Exploration Technology Development
ETS2	E-Gov Travel Service 2
EUL	Enhanced Use Leasing
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUS	Exploration Upper Stage
EVI	Earth Venture Instruments
EVM	Earth Venture small Missions
EX	Explorers
FAA	Federal Aviation Administration
FDC	Flight Demonstrations and Capabilities
FDMS	Federal Docket Management System
FFATA	Federal Funding Accountability and Transparency Act
FFI	Forsvarets Forskning Institute
FGS	Fine Guidance Sensor
FIRST	For Inspiration and Recognition of Science and Technology
FIT	Financial Innovation and Transformation
FMLoB	Financial Management Lines of Business
FO	Follow-On
FOC	Full operational capability
FPB	Flight Planning Board
FPI	Fast Plasma Investigation
FPPS	Federal Personnel and Payroll System

ACRONYMS AND ABBREVIATIONS

FRR	Flight Readiness Review
FY	Fiscal Year
G-3	Gulfstream 3
GALEX	Galaxy Evolution Explorer
GCIS	Global Change Information System
GEDI	Global Ecosystem Dynamics Investigation Lidar
GEMS	Gravity and Extreme Magnetism
GEO-CAPE	GEOstationary Coastal and Air Pollution Events
GFZ	German Research Centre for Geosciences
GIS	Geographic Information System
GLOBE	Global Learning and Observations to Benefit the Environment
GMAO	Global Modeling and Assimilation Office
GNC	Guidance, Navigation, and Control
GOLD	Global-scale Observations of the Limb and Disk
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GPSP	Global Positioning System-Payload
GRACE	Gravity Recovery and Climate Experiment
GRAIL	Gravity Recovery and Interior Laboratory
GRC	Glenn Research Center
GRC-PBS	Glenn Research Center Plum Brook Station
GRIFEX	GEO-CAPE Readout Integrated Circuit Experiment
GSA	General Services Administration
GSDO	Ground Systems Development and Operations Program Office
GSFC	Goddard Space Flight Center
GSRT	GSFC System Review Team
HAWC+	High-resolution Airborne Wideband Camera
HBCU	Historically Black Colleges and Universities
HECC	High End Computing Capability
HEEET	Heat shield for Extreme Entry Environment Technology
HEO	Human Exploration and Operations
HEOMD	Human Exploration and Operations Mission Directorate
HF	High Frequency
HHS	Department of Health and Human Services
HIAD	Hypersonic Inflatable Aeroshell Decelerator
HICO	Hyperspectral Imager for the Coastal Ocean
HIS	Heavy Ion Sensor
HITL	human-in-the-loop
HMI	Helioseismic and Magnetic Imager
HMTA	Health and Medical Technical Authority

ACRONYMS AND ABBREVIATIONS

HMV	Heavy Maintenance Visit
HP3	Heat Flow and Physical Properties Package
HQ	Headquarters
HR	Human resources
HRP	Human Research Program
HS-3	Hurricane and Severe Storm Sentinel
HSFO	Human Space Flight Operations
HSI	Hispanic-Serving Institutions
HVAC	Heating, Ventilating, and Air Conditioning
HyspIRI	Hyperspectral and Infrared Imager
I&T	Integration & Test
I3P	Infrastructure Integration Program
IAA	Interagency Agreement
IADS	Integrated Arrival/Departure/Surface
IAE	Integrated Acquisition Environment
IASP	Integrated Aviation Systems Program
IBEX	Interstellar Boundary Explorer
ICESat-2	Ice, Cloud, and land Elevation Satellite-2
ICON	Ionospheric Connection Explorer
IDIQ	indefinite-delivery-indefinite-quantity
IDS	Intrusion Detection Systems
ILT	Instructor-Led Training
IMC	International Mission Contributions
InSight	Investigations, Geodesy and Heat Transport
INTA	National Institute of Aerospace Technology
InVEST	In-space Validation of Earth Science Technology
IOC	Initial operating capability
IPAO	Independent Program Assessment Office
IPCC	Intergovernmental Panel on Climate Change
IR	Infrared
IRIS	Interface Region Imaging Spectrograph
IRS	Internal Revenue Service
ISARA	Integrated Solar Array and Reflectarray Antenna
ISCM	Information Security Continuous Monitoring
ISERV	ISS SERVIR Environmental Research and Visualization System
ISIM	Integrated Science Instrument Module
ISRO	Indian Space Research Organisation
ISRS	In-Space Robotic Servicing
ISRU	in-situ resource utilization
ISS	International Space Station

ACRONYMS AND ABBREVIATIONS

IT	information technology
I-trek	I turn research into empowerment and knowledge
ITSEC-EDW	IT Security Enterprise Data Warehouse
IV&V	Independent Verification and Validation
JAXA	Japanese Aerospace Exploration Agency
JCL	Joint Confidence Level
JEL	jacking, equalizing, and leveling
JEM-EF	Japanese Experiment Module – Exposed Facility
JHU	Johns Hopkins University
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center
JUICE	Jupiter Icy Moons Explorer
KaBOOM	Ka-Band Objects Observation and Monitoring
KaRIn	Ka-band Radar Interferometer
KBOs	Kuiper Belt objects
KDP	Key Decision Point
KOA	Keck Observatory Archive
KSC	Kennedy Space Center
LADEE	Lunar Atmosphere and Dust Environment Explorer
LaRC	Langley Research Center
LBTI	Large Binocular Telescope Interferometer
LC	Launch Complex
LCC	Life Cycle Cost
LCPSO	Land Cover Project Science Office
LDCM	Landsat Data Continuity Mission
LDSD	Low Density Supersonic Decelerator
LEARN	Leading Edge Aeronautics Research for NASA
LED	Light-Emitting Diode
LEED	Leadership in Energy and Environmental Design
LH2	Liquid Hydrogen
LIDAR	Light Detection and Ranging
LIS	Lightning Imaging Sensor
LISA	Laser Interferometer Space Antenna
LLCD	Lunar Laser Communication Demonstration
LMSSC	Lockheed Martin Space Systems Company
LoB	Lines of Business
LOX	liquid oxygen
LRA	Laser Retro-reflector Assembly
LRD	Launch Readiness Date

ACRONYMS AND ABBREVIATIONS

LRO	Lunar Reconnaissance Orbiter
LRR	Launch Readiness Review
LVC-DE	Live Virtual Constructive-Distributed Environment
LWS	Living With a Star
MAA	MUREP Aerospace Academy
MAF	Michoud Assembly Facility
MAIANSE	MUREP for American Indian and Alaskan Native STEM Engagement
MARSIS	Mars Advanced Radar for Subsurface and Ionospheric Sounding
MAVEN	Mars Atmosphere and Volatile EvolutioN
MCI	Minority University Research and Education Program Community College Curriculum Improvement
MCR	Mission Concept Review
MDR	Mission Design Review
MEaSUREs	Making Earth System data records for Use in Research Environments
MEDLI	Mars Entry, Descent, and Landing Instrumentation
MEI	Minority University Research and Education Program Educator Institute
MER	Mars Exploration Rover
MERLIN	Mesoscale Eastern Range Lightning Information Network
MERRA	Modern Era Retrospective-analysis for Research and Applications
MESSENGER	MErcury Surface, Space ENvironment, GEochemistry, and Ranging
MIDEX	Medium-Class Explorers
MIRI	Mid Infrared Instrument
MIRO	MUREP Institutional Research Opportunity
MIs	minority institutions
MIT	Massachusetts Institute of Technology
MLCC	multi-layer ceramic capacitor
MLTI	mesosphere-lower thermosphere-ionosphere
MMOD	MicroMeteoroid and Orbital Debris
MMS	Magnetospheric Multiscale
MO	Missions of Opportunity
MO&I	Mission Operations and Integration
MODIS	Moderate Resolution Imaging Spectroradiometer
MOM	Mars Orbiter Mission
MOMA-MS	Mars Organic Molecule Analyzer Mass Spectrometer
MOO	Multi-Mission Operations
MOXIE	Mars Oxygen ISRU Experiment
MPAR	Major Program Annual Report
MPCV	Multi-Purpose Crew Vehicle
MPRAT	Mission Profile Risk Assessment Test
MRO	Mars Reconnaissance Orbiter

ACRONYMS AND ABBREVIATIONS

MSE	MUREP STEM Engagement
MSFC	Marshall Space Flight Center
MSI	Minority-Serving Institutions
MSL	Measurement Systems Laboratory
mths	months
MUREP	Minority University Research and Education Program
MUSES	Multi-User System for Earth Sensing
MUSS	Multi User Systems and Support
N/A	not applicable
NAC	National Agency Check
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NCCS	NASA Center for Climate Simulations
NCRP	National Council on Radiation Protection
NEACC	NASA Enterprise Applications Competency Center
NEN	Near Earth Network
NEO	near-Earth objects
NEOO	Near-Earth Object Observations
NESC	NASA Engineering and Safety Center
NextGen	Next Generation Air Transportation System
NHPA	National Historic Preservation Act
NIAC	NASA Innovative Advanced Concepts
NICER	Neutron star Interior Composition ExploreR
NIFS	NASA Internship, Fellowship, and Scholarship
NIH	National Institutes of Health
NIRCam	Near Infrared Camera
NIRISS	Near Infrared Imager and Slitless Spectrograph
NISAR	NASA-ISRO Synthetic Aperture Radar
NISN	NASA Integrated Services Network
NIST	National Institute of Standards and Technology
NLCs	noctilucent clouds
NLS	United Launch Services
NMO	NASA Management Office
NOAA	National Oceanographic and Atmospheric Administration
NOx	mono nitrogen oxide
NPP	National Polar-orbiting Partnership
NRA	NASA Research Announcement
NRC	National Research Council
NREP	NanoRacks Exposure Platform
NRPTA	National Rocket Propulsion Test Alliance

ACRONYMS AND ABBREVIATIONS

NSBRI	National Space Biomedical Research Institute
NSF	National Science Foundation
NSSC	NASA Shared Services Center
NSSDC	National Space Science Data Center
NSTP PPD	National Space Policy Launch Infrastructure and Modernization Plan
NuSTAR	Nuclear Spectroscopic Telescope Array
O&M	operations and maintenance
OA	Office of Audits
OCAMS	OSIRIS-REx Camera Suite
OCHMO	Office of Chief Health Medical Officer
OCO	Orbiting Carbon Observatory
OCSD	Optical Communications and Sensor Demonstration
OCT	Office of the Chief Technologist
OE	Office of Education
OI	Office of Investigations
OIG	Office of Inspector General
OLA	OSIRIS-REx Laser Altimeter
OLI	Operational Land Imager
OMB	Office of Management and Budget
OMDA	Other Missions and Data Analysis
OMI	Ozone Monitoring Instrument
OMPS	Ozone Mapping and Profiler Suite
ONERA	French Office National d'Etudes et Recherches Aérospatiales
OPM	Office of Personnel Management
Orb-#	Orbital Sciences Commercial Resupply Services #
ORR	Operational Readiness Review
OSC	Orbital Sciences Corporation
OSHA	Occupational Safety and Health Administration
OSIRIS-REx	Origins Spectral Interpretation Resource Identification and Security-Regolith Explorer
OSMA	Office of Safety and Mission Assurance
OSTM	Ocean Surface Topography Mission
OSTST	Ocean Surface Topography Science Team
OTE	Optical Telescope Element
OTES	OSIRIS-REx Thermal Emission Spectrometer
OVIRS	OSIRIS-REx Visible and Infrared Spectrometer
OVWST	Ocean Vector Winds Science Team
PACE	Pre-Aerosol, Clouds, and ocean Ecosystem
PAMSS	Planetary Atmosphere Minor Species Sensor
Pan-STARRS	Panoramic Survey Telescope and Rapid Reporting System

ACRONYMS AND ABBREVIATIONS

PB	President's Budget
PCA	Physicians' comparability allowance
PCOS	Physics of the Cosmos
PDA	progressive damage analysis
PDR	preliminary design review
PDS	Planetary Data System
PEP	Particle Environment Package
PI	Principal Investigator
PIR	Program Implementation Review
PIV	Personal Identity Verification
P.L.	Public Law
POWER	Protecting Our Workers and Ensuring Reemployment
PSL	Propulsion Systems Laboratory
Pu	plutonium
PV	Planetary Ventures, LLC
QM-1	qualification motor 1
QuikSCAT	Quick Scatterometer
R&D	Research and Development
R&T	Research and Technology
RAD	Radiation Assessment Detector
RAIF	Research Aircraft Integration Facility
RAO	Right Anterior Oblique
RAP	Robotics Alliance Project
RBA	Reflector Boom Assembly
RBI	Radiation Budget Instrument
REDD	Reducing Emissions from Deforestation and forest Degradation
RESOLVE	Regolith and Environment Science and Oxygen and Lunar Volatiles Extraction
REXIS	Regolith X-ray Imaging Spectrometer
RF	radio frequency
RFU	Radio Frequency Unit
RHESSI	Ramaty High Energy Solar Spectroscopic Imager
RID	Research Infrastructure Development
RIME	Radar for Icy Moons Exploration
RISE	Rotation and Interior Structure Experiment
ROD	Record of Decision
ROSES	Research Opportunities in Space and Earth Sciences
RPO	rendezvous and proximity operations
RPS	Radioisotope Power Systems
RPT	Rocket Propulsion Testing
RRM	Robotic Refueling Mission

ACRONYMS AND ABBREVIATIONS

RRS	Research Range Services
RS	Reflected Solar
RTCA	Radio Technical Commission for Aeronautics
RTG	Radioisotope Thermoelectric Generator
RVLT	Revolutionary Vertical Lift Technology
SAC-D	Satellite for Scientific Applications-D
SAFFIRE	Spacecraft Fire Experiment
SAGE	Stratospheric Aerosol and Gas Experiment
SAM	Sample Analysis at Mars (Planetary Science)
SAM I	Stratospheric Aerosol Measurement (Earth Science)
SAO	Smithsonian Astrophysical Observatory
SAR	Synthetic Aperture Radar
SARDA	Spot and Runway Departure Advisor
SASO	Safe Autonomous Systems Operations
SBA	Small Business Administration
SBIR	Small Business Innovation Research
SCaN	Space Communications and Navigation
SCAP	Strategic Capabilities Asset Program
SDO	Solar Dynamics Observatory
SDR	System Design Review
SEA	STEM Education and Accountability
SEAP	STEM Education and Accountability Projects
SEIS	Seismic Experiment for Interior Structure
SEP	solar electric propulsion
SERENA	Search for Exospheric Refilling and Emitted Natural Abundances
SET	Space Environment Testbeds
SETAG	Space Environmental Testing Assets Group
SEWP	Solutions for Enterprise-Wide Procurement
SEXTANT	Station Explorer X-ray Timing and Navigation Technology
SFCO	Space Flight Crew Operations
SFS	Space and Flight Support
SGP	Space Geodesy project
SGSS	Space Network Ground Segment Sustainment
SIM	Spectral Irradiance Monitor
SIPS	Science Investigator-led Processing Systems
SIR	System Integration Review
SL-8	SpaceLoft-8
SLI	Sustainable Land Imaging
SLPSRA	Space Life and Physical Sciences Research and Applications
SLPSRAD	Space Life and Physical Sciences Research and Applications Division

ACRONYMS AND ABBREVIATIONS

SLS	Space Launch System
SMA	Safety and Mission Assurance
SMAP	Soil Moisture Active/Passive
SMART NAS	Shadow Mode Assessments Using Realistic Technologies for the National Airspace System
SMD	Science Mission Directorate
SMEX	Small Explorers
SMS	Safety and Mission Success
SNC	Sierra Nevada Corporation
SOC	Solar Orbiter Collaboration
SOFIA	Stratospheric Observatory for Infrared Astronomy
SOHO	Solar and Heliospheric Observatory
SoloHI	Solar Orbiter Heliospheric Imager
SORCE	Solar Radiation and Climate Experiment
SOST	Subcommittee on Ocean Science and Technology
SOT	Solar Optical Telescope
Space Grant	National Space Grant College and Fellowship Program
SpaceX	Space Exploration Technologies Company
SPB	Solar Pressure Balloon
SPDF	Space Physics Data Facility
SPHERES	Synchronized Position Hold, Engage, Reorient, and Experimental Satellites
SPOC	Science Processing and Operations Center
SPP	Solar Probe Plus
SpX-#	Space Exploration Technologies Company Commercial Resupply Services #
SR&T	Strategic Research and Technology
SRB	Strategic Review Board
SRC	Sample Return Capsule
SRP	supersonic retrorocket propulsion
SRR	Systems Requirement Review
SSC	Stennis Space Center
SSERVI	Solar System Exploration Research Virtual Institute
SSFL	Santa Susana Field Laboratory
SSL	Space Systems Loral
SSMS	Safety, Security, and Mission Services
ST	Space Technology
STEM	science, technology, education, and mathematics
STEREO	Solar TErrestrial RElations Observatory
STIP	Strategic Technology Investment Plan
STMD	Space Technology Mission Directorate
STP	Solar Terrestrial Probes

ACRONYMS AND ABBREVIATIONS

STPH-5 LIS	Space Test Program Houston-5 Lightning Imaging System
STScI	Space Telescope Science Institute
STTR	Small Business Technology Transfer
SWEAP	Solar Wind Electrons Alphas and Protons
SWOT	Surface Water Ocean Topography
SwRI	Southwest Research Institute
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
TBW	truss-braced wing
TCTE	Total Solar Irradiance Calibration Transfer Experiment
TCU	Tribal Colleges and Universities
TDM	Technology Demonstration Missions
TDRS	Tracking and Data Relay Satellite
TDT	Transonic Dynamics Tunnel
TEMPO	Tropospheric Emissions: Monitoring of Pollution
TESS	Transiting Exoplanet Survey Satellite
TFM	Traffic Flow Management
TGO	Trace Gas Orbiter
THEMIS	Time History of Events and Macroscale Interactions during Substorms
THOR	Terrestrial HIAD Orbital Reentry
TIM	Total Irradiance Monitor
TIMED	Thermosphere Ionosphere Mesosphere Energetics and Dynamics
TIR-FFD	Thermal-Infrared Free-Flyer
TIRS	Thermal Infrared Sensor
TMC	Technical and Management and Cost
TPS	Thermal Protection System
TR&T	Targeted Research & Testing
TRACT	Transport Rotorcraft Airframe Crash Testbed
TRL	Technology Readiness Level
TRMM	Tropical Rainfall Measurement Mission
TSI	total solar irradiance
TSIS	Total and Spectral Solar Irradiance Sensor
TSS	Terminal Sequencing and Spacing
TTT	Transformational Tools and Technologies
TWINS	Two Wide-angle Imaging Neutral-atom Spectrometers
UAS	Unmanned Aircraft Systems
UAV	unmanned aerial vehicle

ACRONYMS AND ABBREVIATIONS

UAVSAR	Uninhabited Aerial Vehicle Synthetic Aperture Radar
UHB	ultra-high bypass
UHF	ultra high frequency
UKSA	United Kingdom Space Agency
ULA	United Launch Alliance
ULS	United Launch Services
UNEX	University-Class Explorers
UPSS	universal propellant servicing system
UPTWT	Unitary Plan Wind Tunnel
USAF	United States Air Force
USAID	U.S. Agency for International Development
U.S.C.	United States Code
USGCRP	US Global Change Research Program
USGS	US Geological Survey
USRA	Universities Space Research Association
UTM	UAS Traffic Management
UVS	Ultraviolet Spectrograph
VAB	Vehicle Assembly Building
VAC	Vertical Assembly Center
VAFB	Vandenberg Air Force Base
VIIP	visual impairment/intra-cranial pressure
VIIRS	Visible Infrared Imaging Radiometer
VIL	Vehicle Integration and Launch
VSPT	Variable-Speed Power Turbine
WANs	Wide Area Networks
WASP	Web Application Security Program
WBS	work breakdown structure
WCF	Working Capital Fund
Webb	James Webb Space Telescope
WFA	Work from Anywhere
WFF	Wallops Flight Facility
WFIRST	Wide-Field Infrared Survey Telescope
WISE	Wide-field Infrared Survey Explorer
WISPR	Wide-field Imager for Solar PRobe
WSTF	White Sands Test Facility
XMM-Newton	X-ray Multi-Mirror Mission
ZBOT	Zero Boil-Off Tank