Science and Human Exploration and Operations Joint Activities

John M. Grunsfeld, Associate Administrator
Science Mission Directorate

Joint Meeting of the NASA Advisory Council
Science/Human Exploration and Operations Committees
January 12, 2015

Credit: NASA

Humans and Science Transform the World

Credit: NASA

Credit: MIT

Former Massachusetts Institute of Technology (MIT) President Jerome Wiesner (left), who served as President John F. Kennedy's Special Assistant for Science and Technology, is shown here with President Kennedy (center).

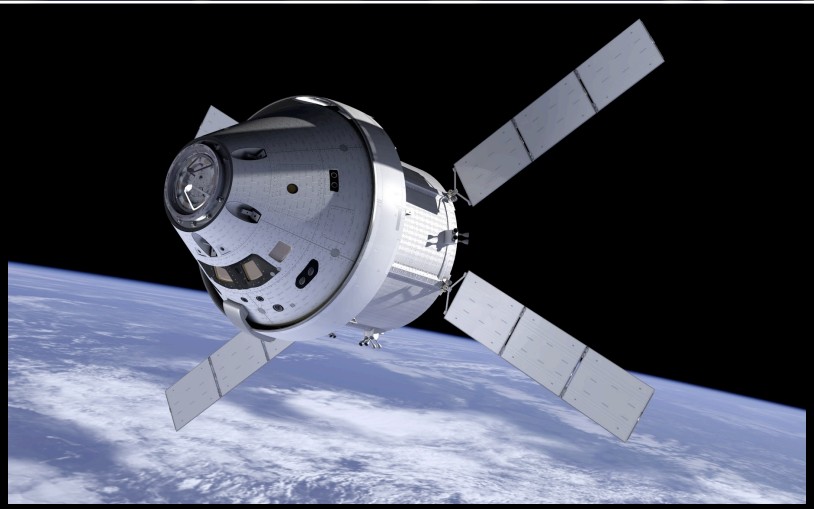
NATIONAL AERONAUTICS AND SPACE ACT OF 1958, Pub. L. No. 85-568,
72 Stat. 426-438 (Jul. 29, 1958)
As Amended

Objectives of Aeronautical and Space Activities.--The aeronautical and space activities of the United States shall be conducted so as to contribute materially to one or more of the following objectives

(1) The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space.

Credit: NASA/ESA

(3) The development and operation of vehicles capable of carrying instruments, equipment, **supplies** and living organisms through space;



NASA: Orion

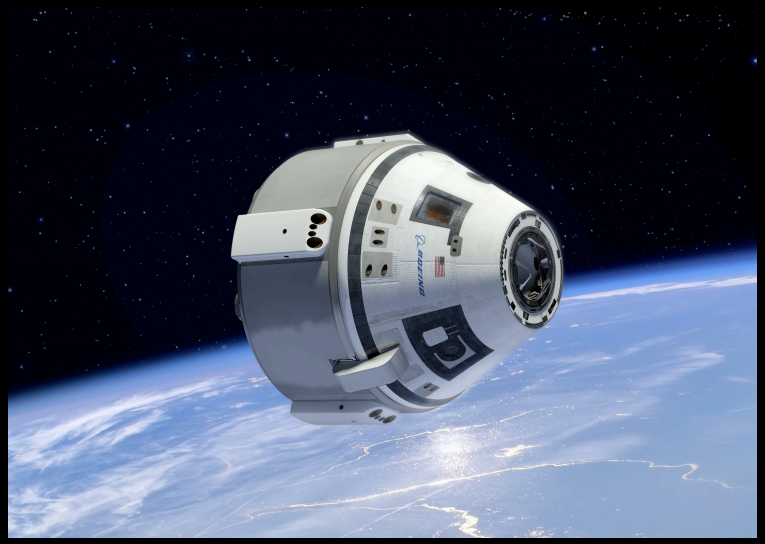
Credit: NASA

Orbital: Cygnus

Credit: NASA

SpaceX: Dragon

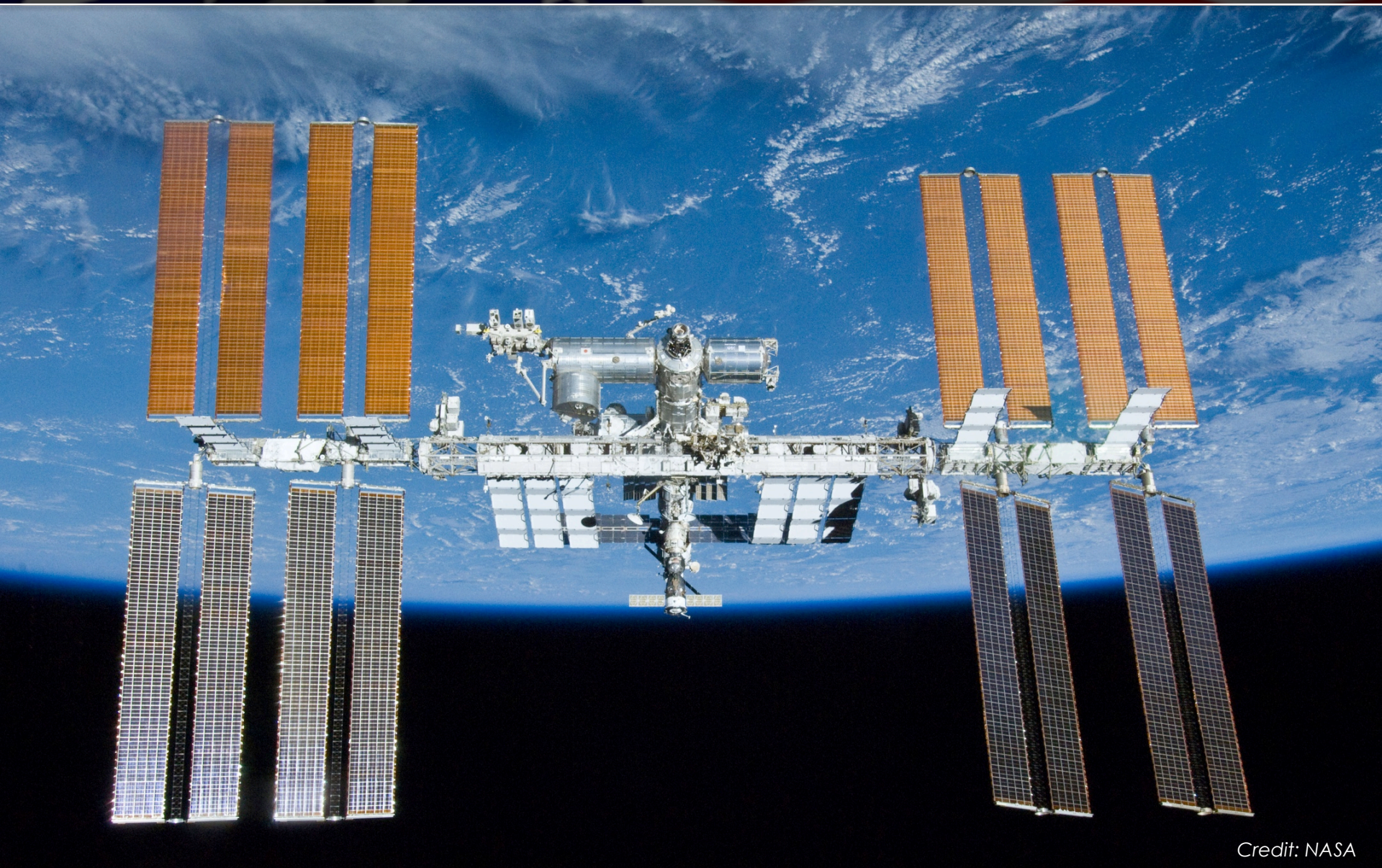
Credit: NASA



Boeing: CST -100

Credit: Boeing

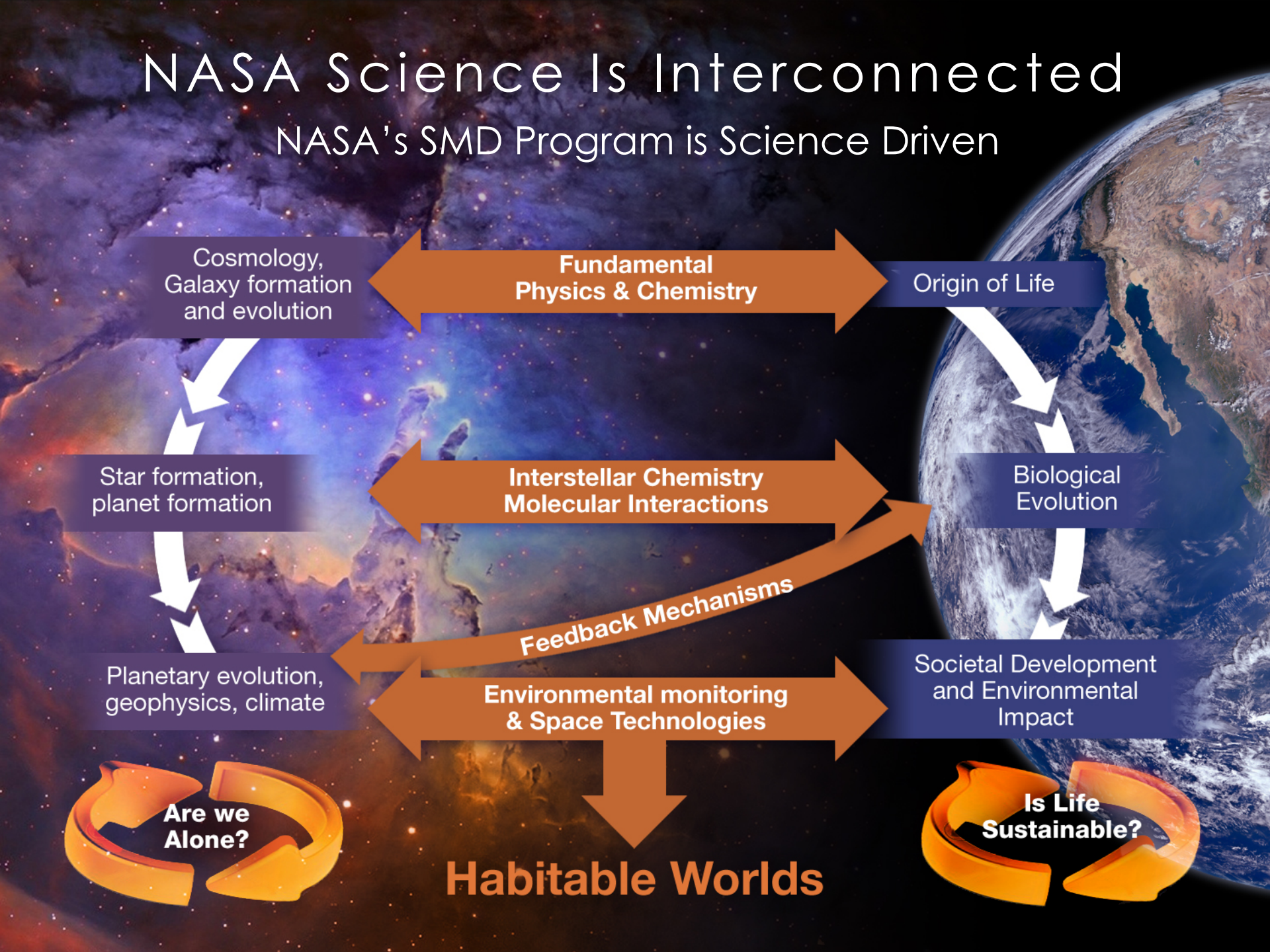
(4) The establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in the utilization of aeronautical and space activities for peaceful and scientific purposes



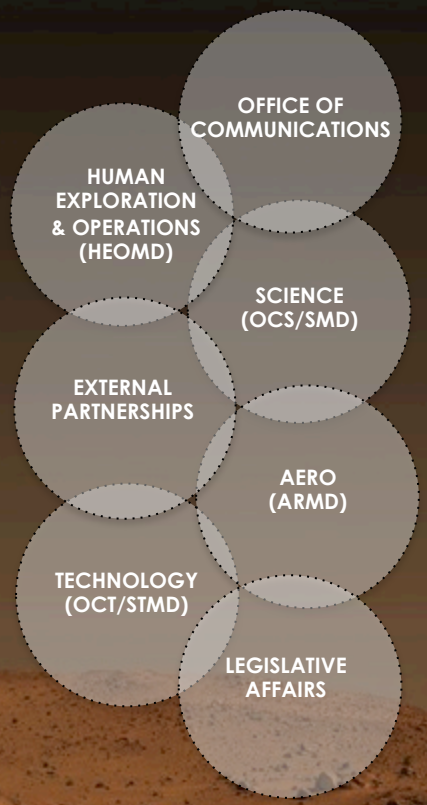
Credit: NASA

NASA Science Is Interconnected

NASA's SMD Program is Science Driven



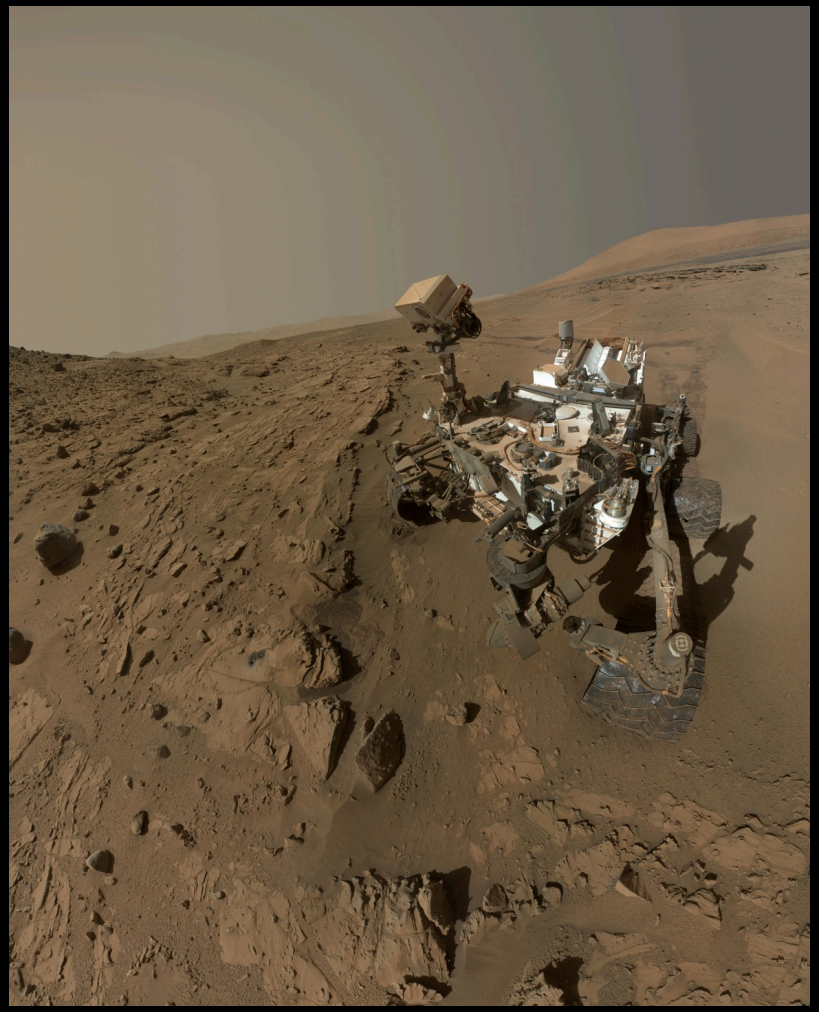
Achieving Alignment for Pioneering Space



Commercial & International Partners • Other Government Agencies • Citizen Innovators

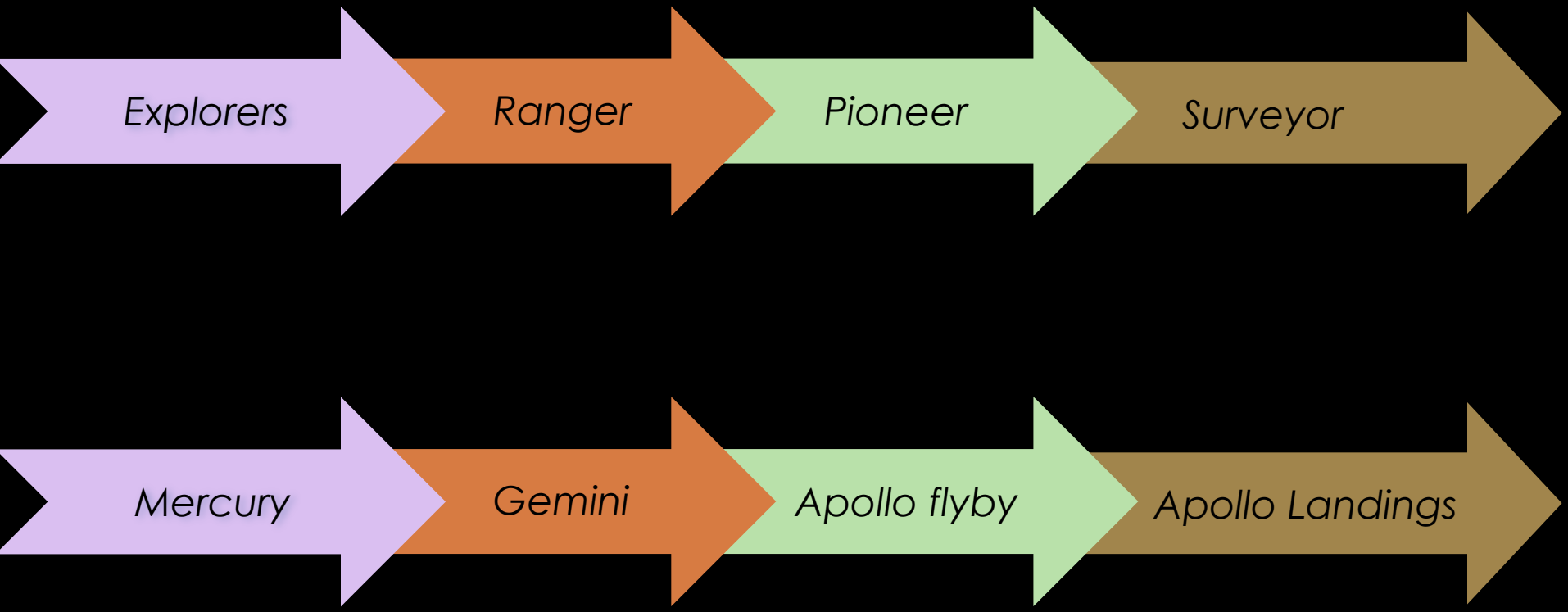
Where Human Exploration and Operations Directorate (HEOMD) and Science Mission Directorate (SMD) Meet

- How does science fit into and drive space exploration plans?
- What questions can scientists sent into space uniquely answer?
- How does combining science and human exploration inform design?



Credit: NASA/JPL-Caltech/MSSS

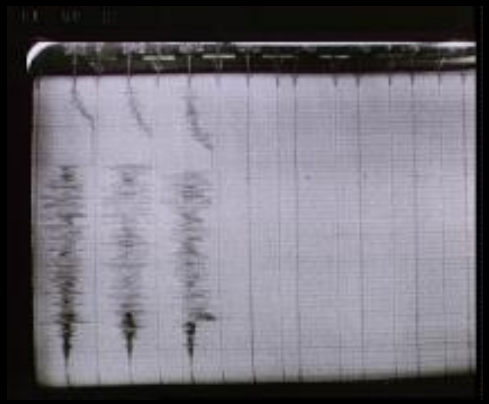
Lunar & planetary program

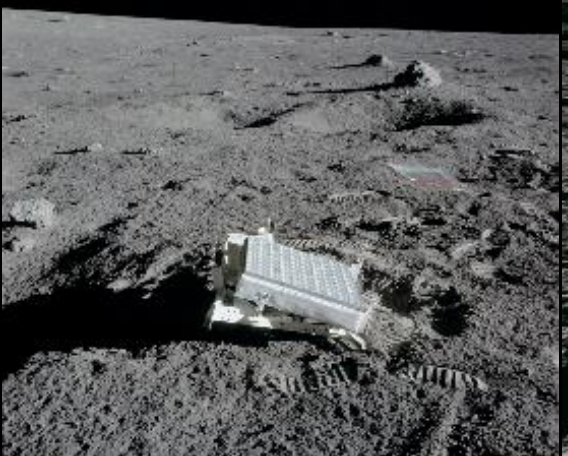


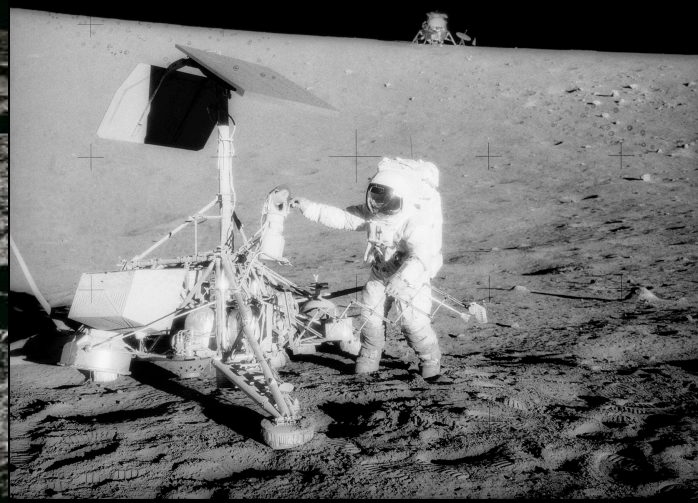
Mercury → Gemini → Lunar flyby → Lunar Landings

Apollo Lunar Surface Experiments Package (ALSEP)

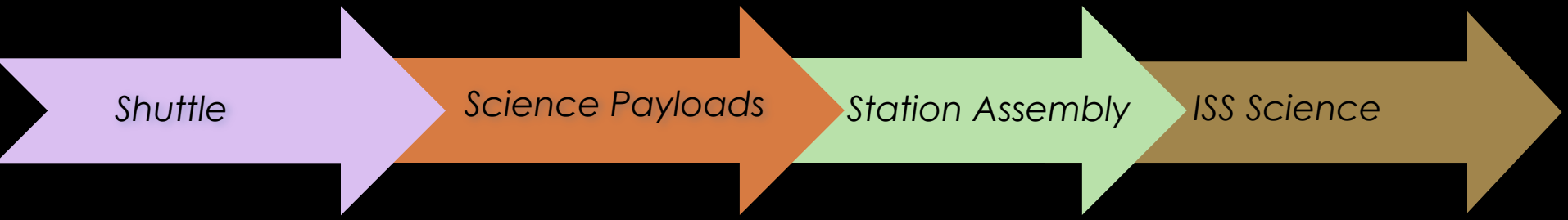
Geology (moon rocks)
Seismograph
Reflectors
Lunar Magnetometer
Solar wind experiments
Lunar atmosphere







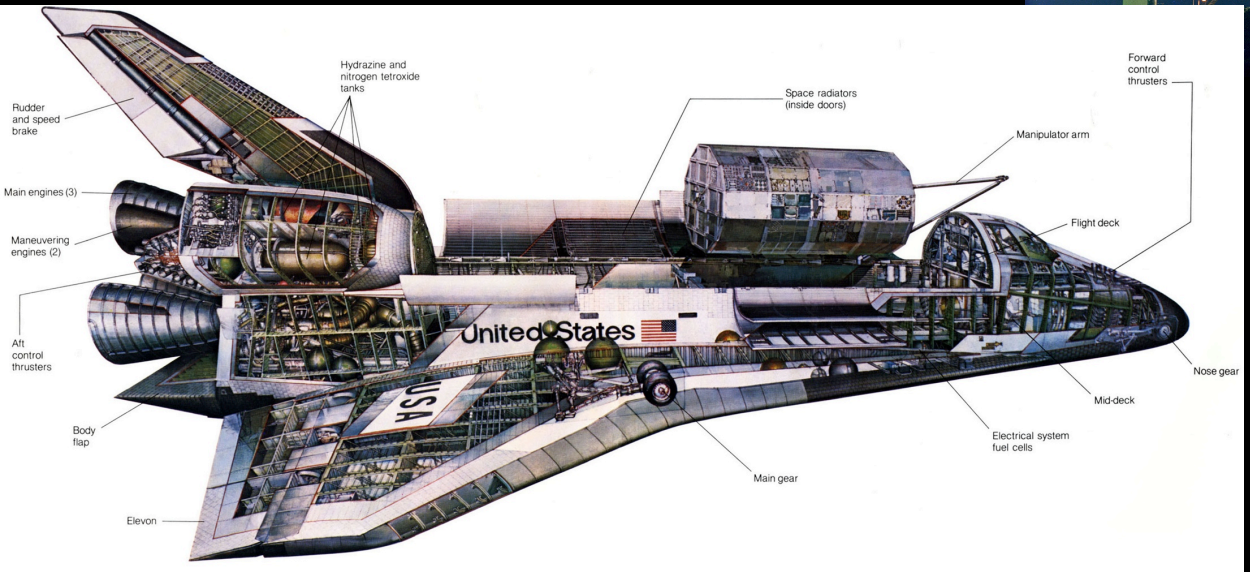
Shuttle, Station and Science



Shuttle → Science Payloads → Station Assembly → ISS Science

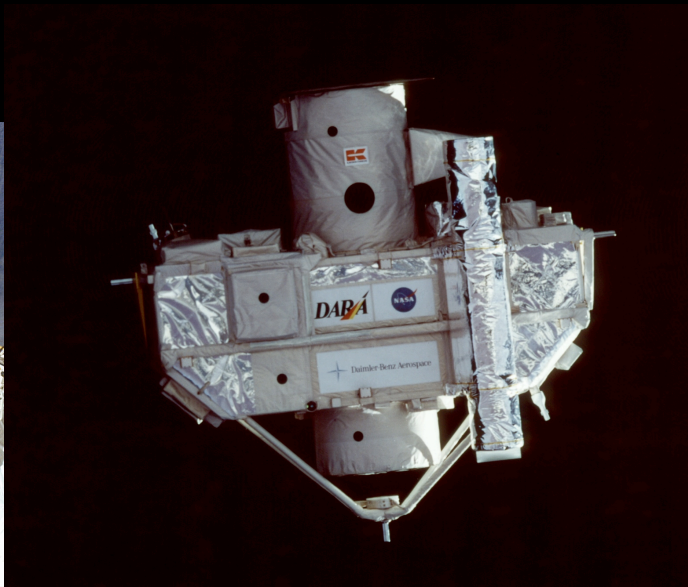
From the start Shuttle was envisioned as a transport system for deployment of space experiments and ISS materials

Credit: KSC/NASA

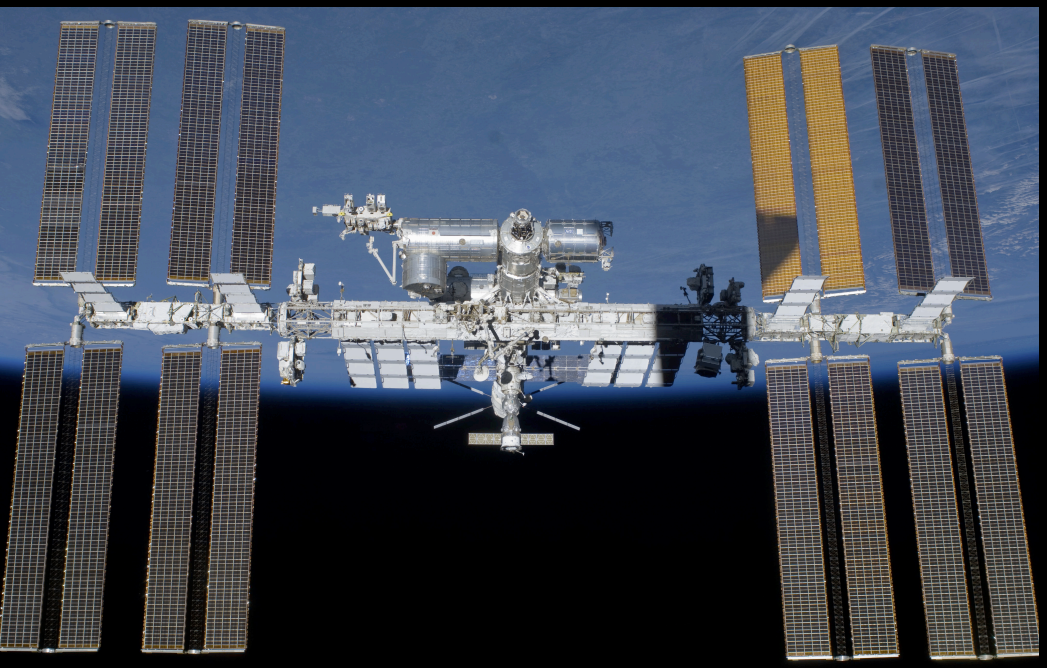


Shuttle → Science Payloads → Station Assembly → ISS Science

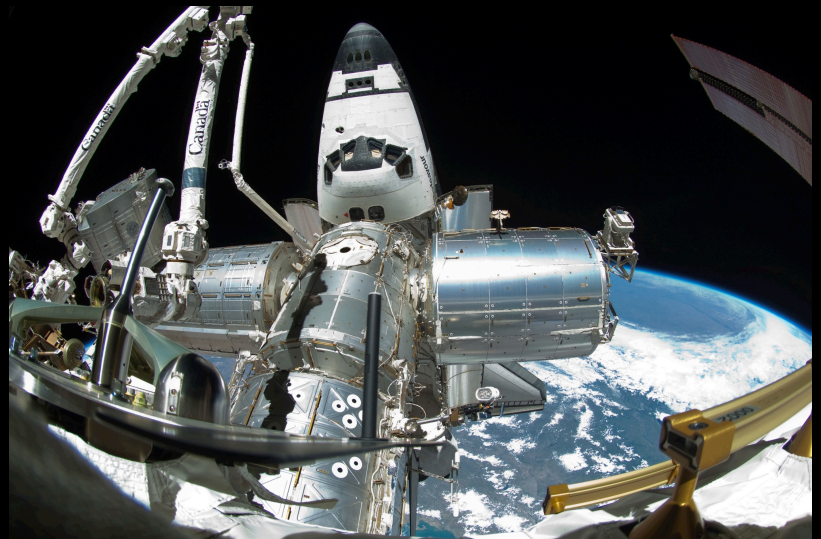
Hubble
ORFEUS-2
Spacelab
Astro-1
CGRO



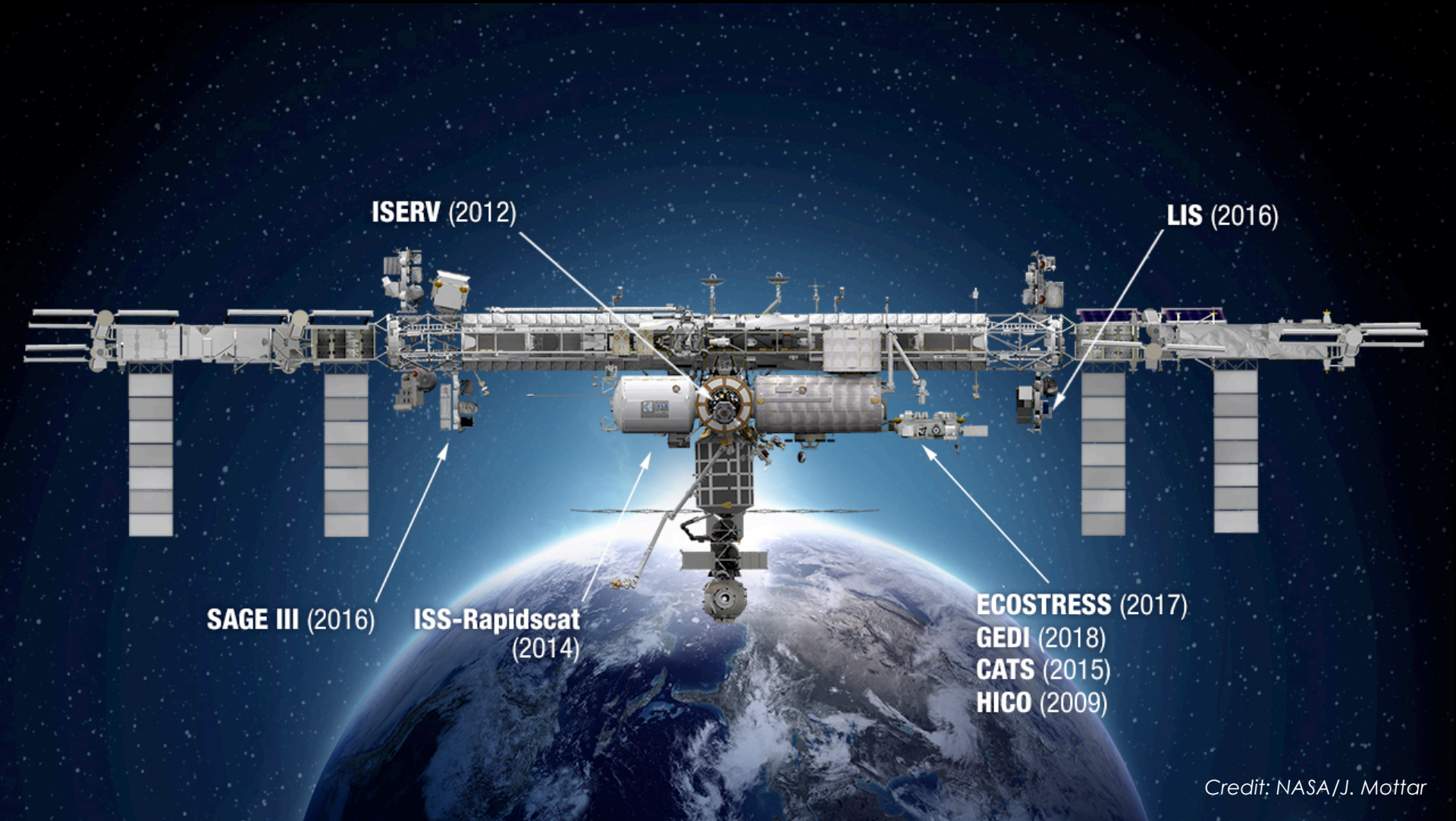
Shuttle → Science Payloads → Station Assembly → ISS Science



Credit: NASA



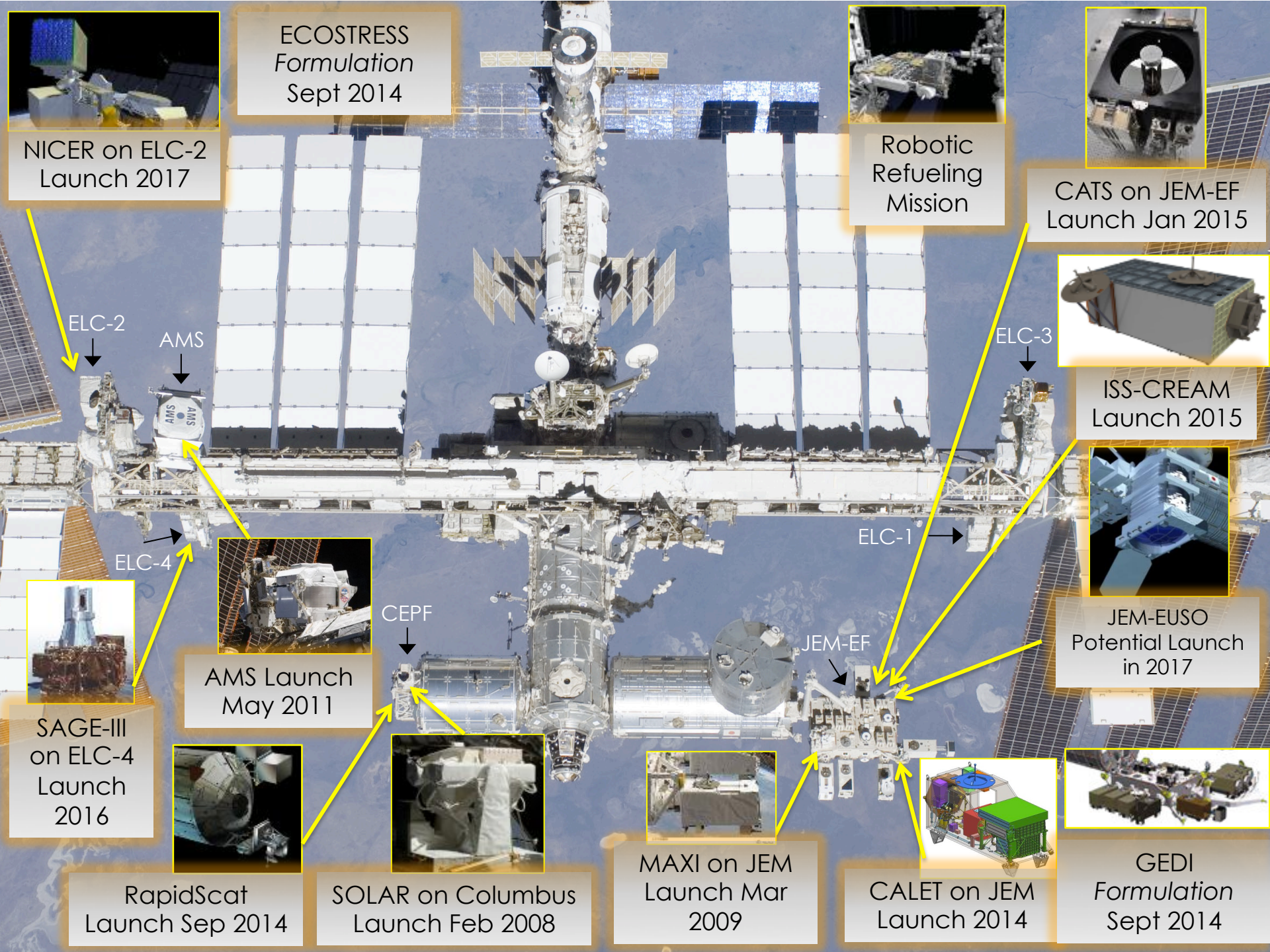
Shuttle → Science Payloads → Station Assembly → ISS Science



Credit: NASA/J. Mottar

Present Day HEOMD and SMD Joint Activity Areas

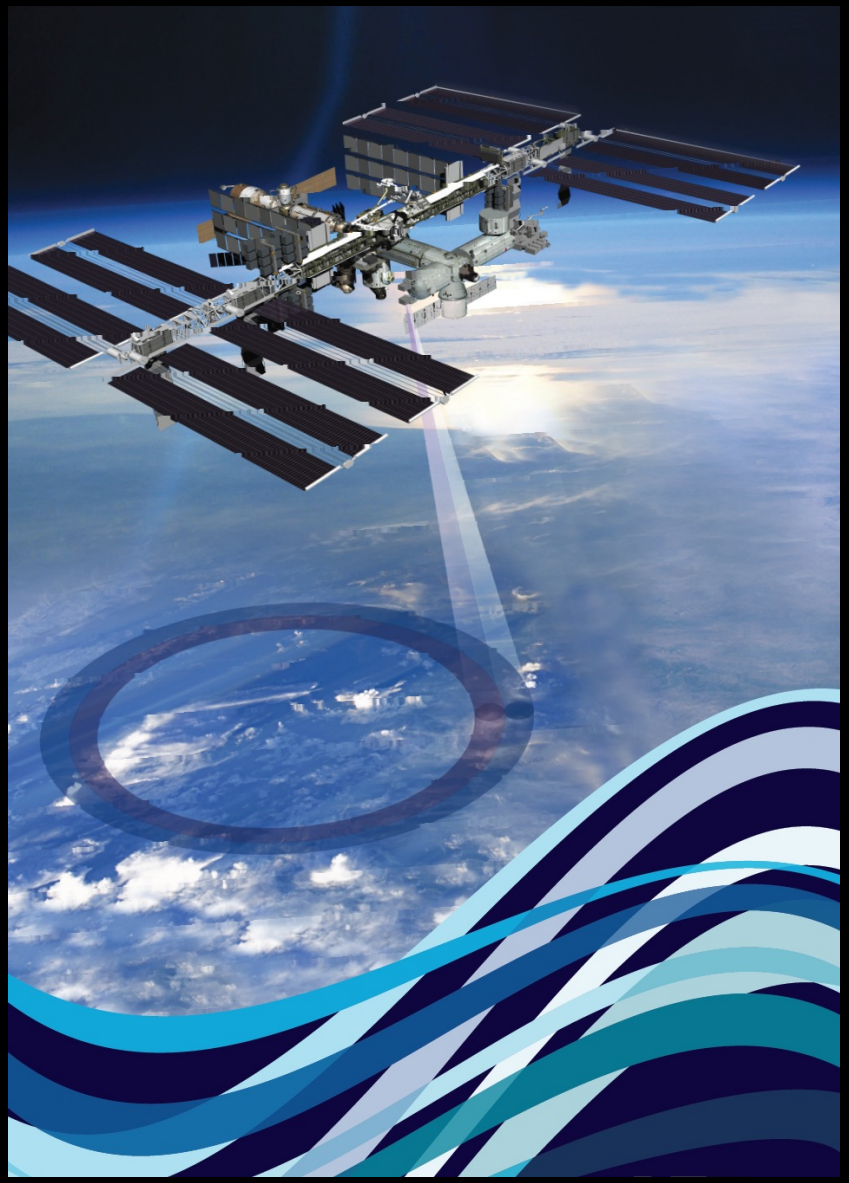
- **Science Instruments on the International Space Station (ISS)**
- **Mars Exploration Program**
  - Mars 2020 Partnership – borne out of current Mars strategy discussions
  - Mars Science Laboratory (Curiosity)
  - Partnership on HEO/Space Technology Mission Directorate (STMD) instrumentation - Mars EDL Instrumentation (MEDLI-2), Mars Oxygen ISRU Experiment (MOXIE), and Mars Environmental Dynamics Analyzer (MEDA)
- **Planetary Protection**
- **Space Communications and Navigation (SCaN)**
- **Asteroid Redirect Mission**
  - improve detection/characterization of Near Earth Objects (NEOs)
  - interplanetary radar capabilities
- **Space Radiation**
  - Space Radiation Working Group
- **Launch Services**
- **Joint Robotic Precursor**
- **In discussions regarding potential collaboration on satellite servicing**


ECOSTRESS
Formulation
Sept 2014
NICER on ELC-2
Launch 2017
Robotic
Refueling
Mission
CATS on JEM-EF
Launch Jan 2015
ISS-CREAM
Launch 2015
ELC-2
AMS
ELC-3
ELC-4
ELC-1
CEPF
JEM-EF
JEM-EUSO
Potential Launch
in 2017
AMS Launch
May 2011
SAGE-III
on ELC-4
Launch
2016
RapidScat
Launch Sep 2014
SOLAR on Columbus
Launch Feb 2008
MAXI on JEM
Launch Mar
2009
CALET on JEM
Launch 2014
GEDI
Formulation
Sept 2014

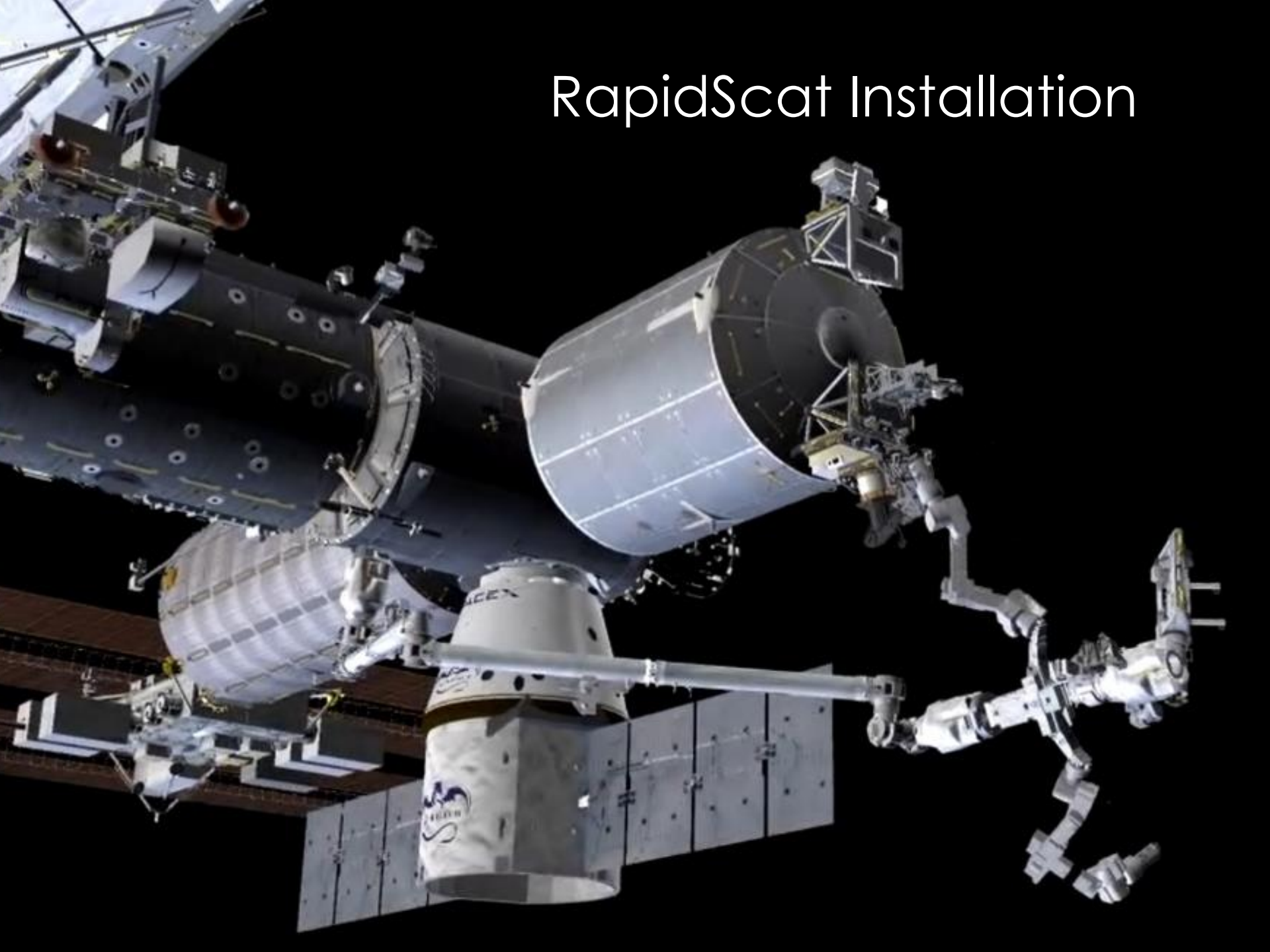
RapidScat: A Joint ISS/ESD Mission

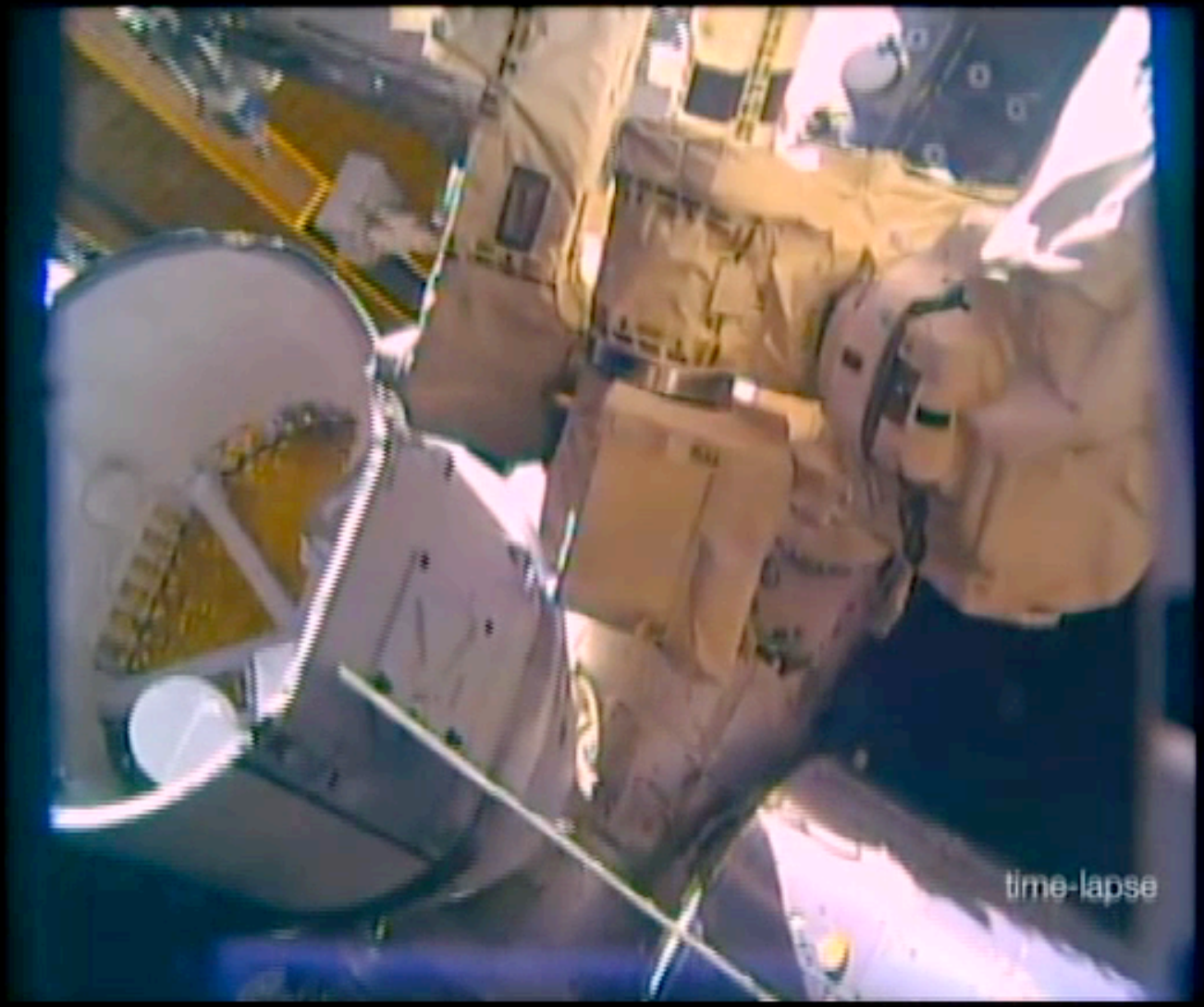
RapidScat: Measurement of ocean winds in support of climate studies and weather forecasting

Follow-on to QuikSCAT



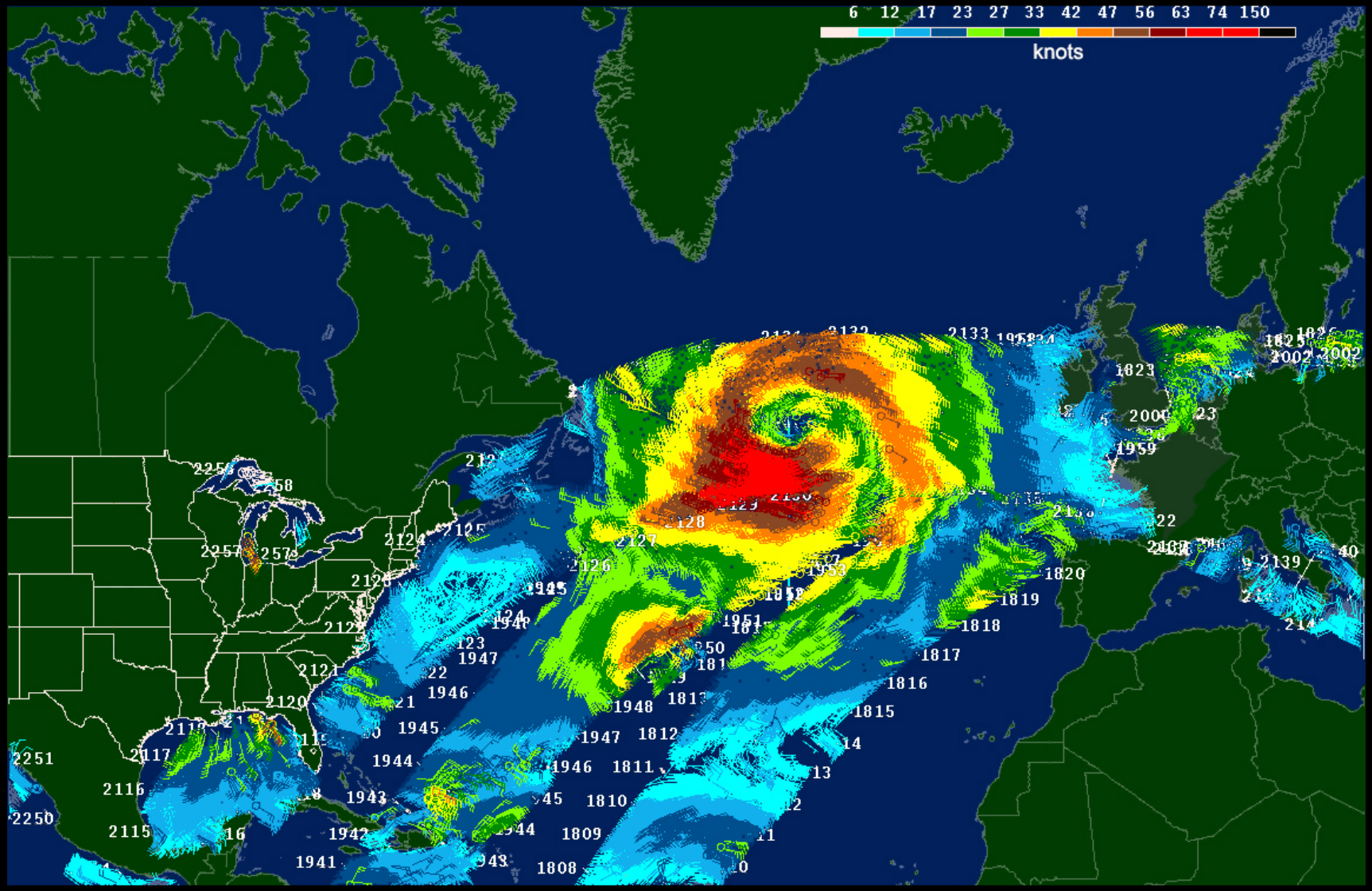
RapidScat Installation





Credit: NASA

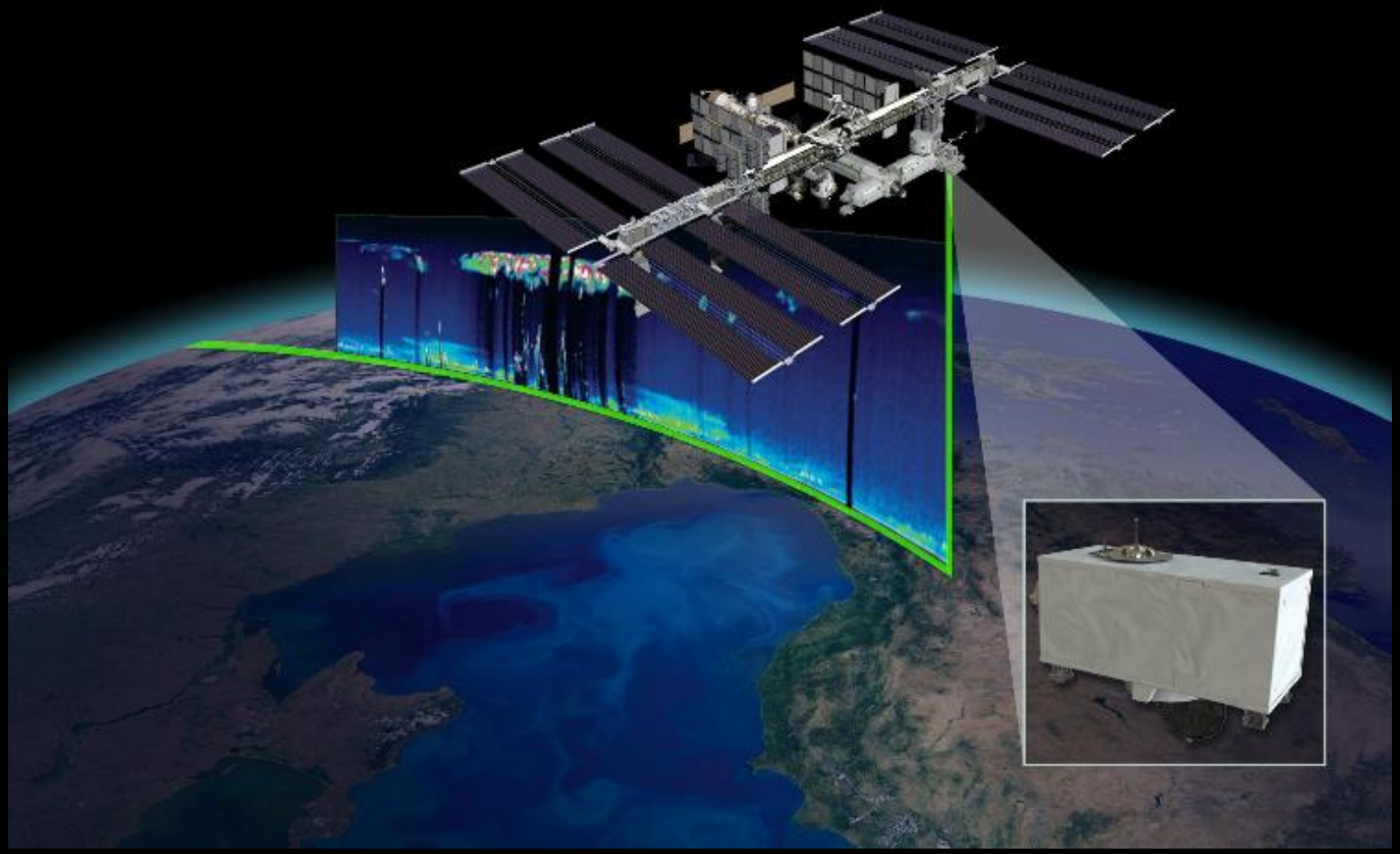
ISS RapidScat Operational



Credit: NASA/JPL-Caltech/NOAA

ISS-RapidScat data on a North Atlantic extratropical cyclone at 2300 UTC, Oct. 13, 2014.

Cloud-Aerosol Transport System (CATS)



Credit: NASA

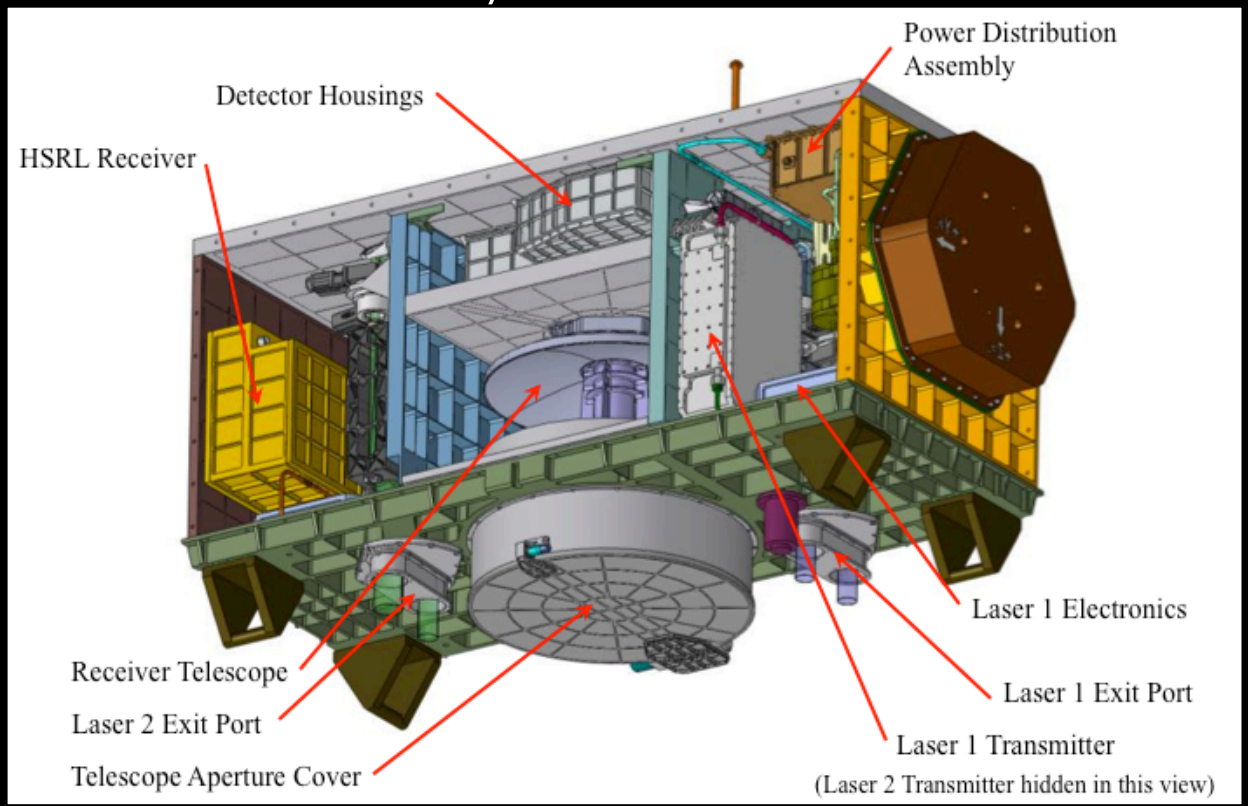
Lidar remote sensing from the ISS
Provide profile measurements of atmospheric aerosols and clouds for hazard warning and climate prediction
CATS Launch to ISS – January 2015

cats.gsfc.nasa.gov

CATS

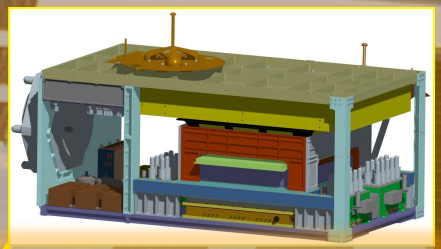
- Utilizes ISS as an affordable Earth Science observing platform
- Provides in-space demonstration of technologies for future satellite missions
- Demonstrates build-to-cost project development with streamlined management structure

Payload Overview

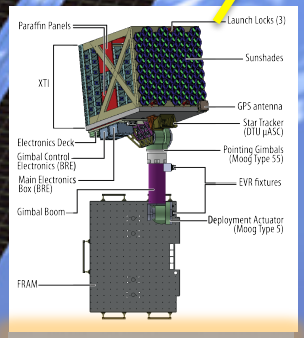


Astrophysics on the ISS

AMS
(DOE-sponsored)
Launch
May 16, 2011

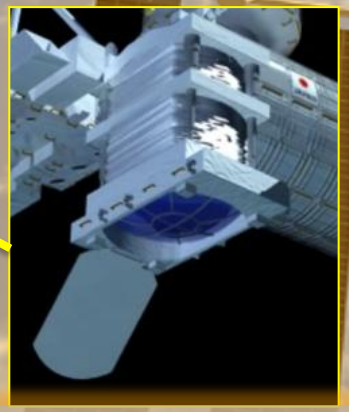


ISS-CREAM
Sp-X Launch 2015



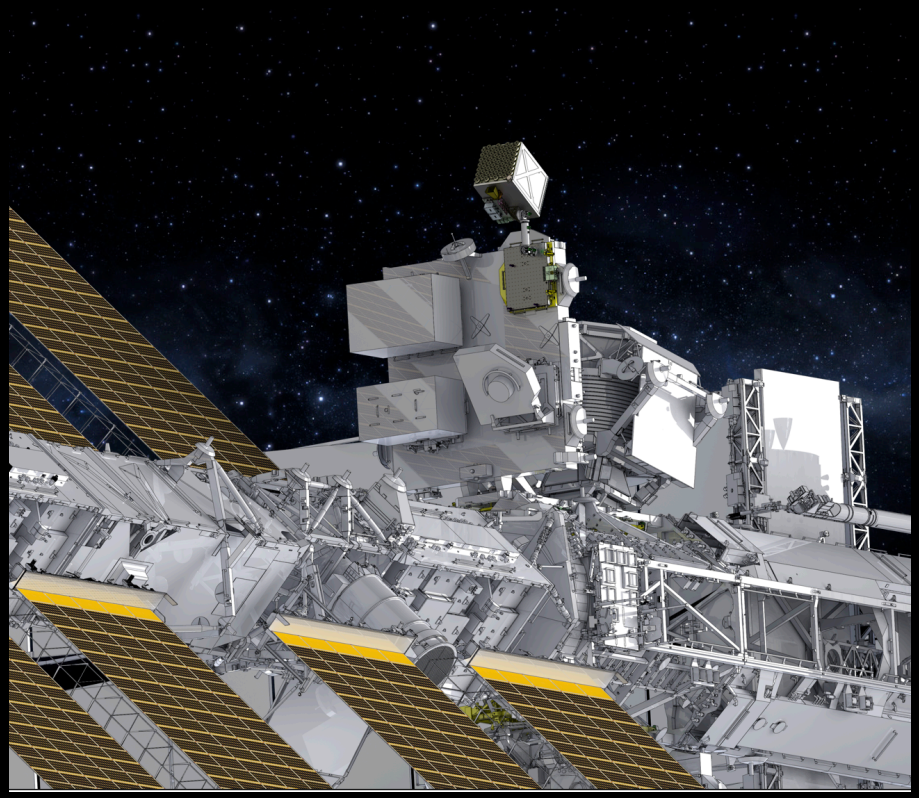
NICER
Sp-X Launch
2016

CALET on JEM
HTV Launch 2015

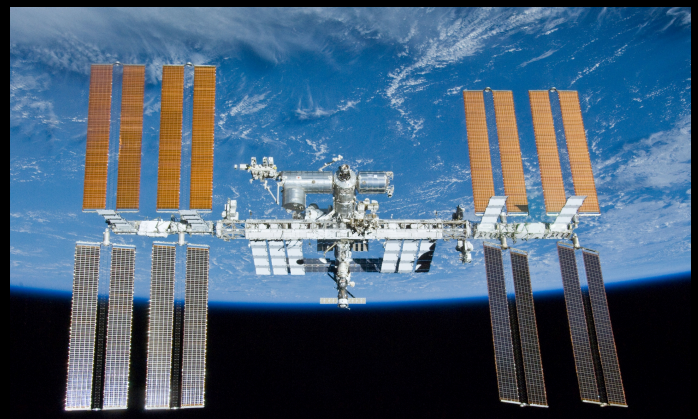


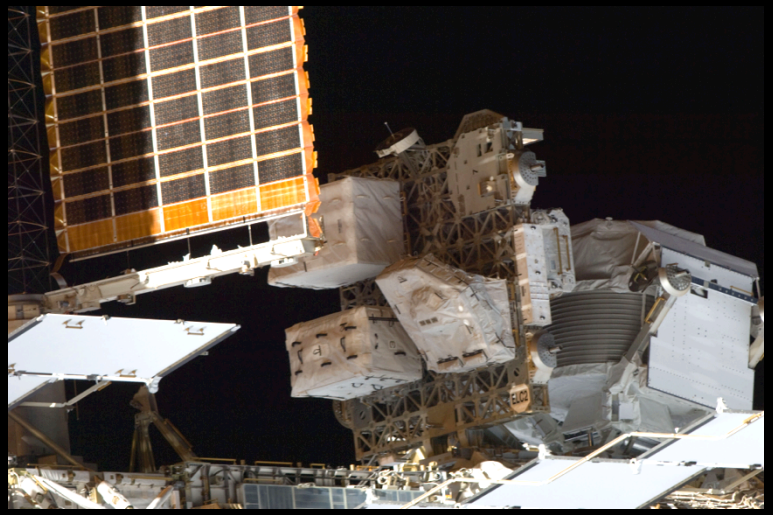
JEM-EUSO
Launch Date TBR

Neutron-star Interior Composition ExploreR (NICER)



NICER's future home





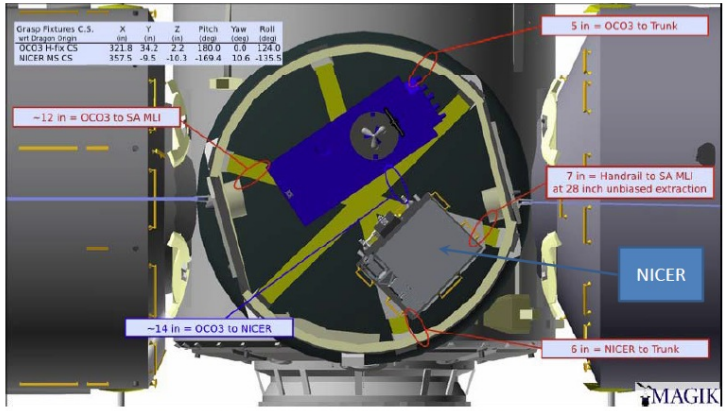
Science: Understanding ultra-dense matter through observations of neutron stars in the soft X-ray band

Launch: October 2016, SpaceX-12 resupply

Platform: ISS ExPRESS Logistics Carrier (ELC), with active pointing over nearly a full hemisphere

NICER: Transport on SpaceX Dragon

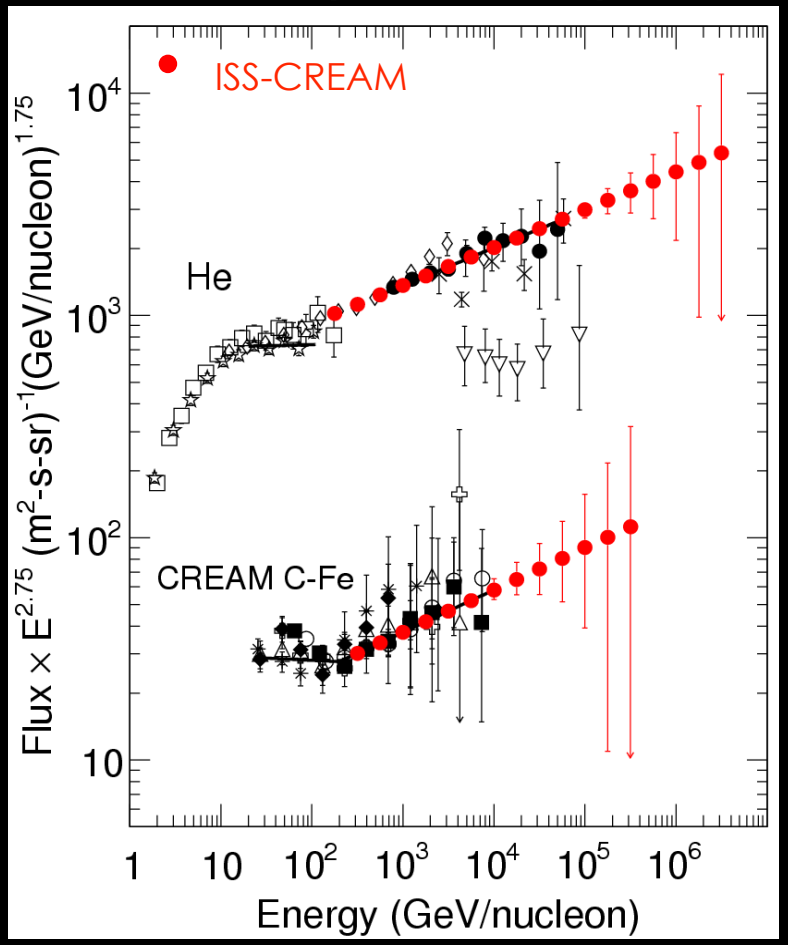
- Manifested with one other payload on SpaceX-12 ISS re-supply mission
- Located in the unpressurized "trunk"
- *Dragon* provides survival power during transport.



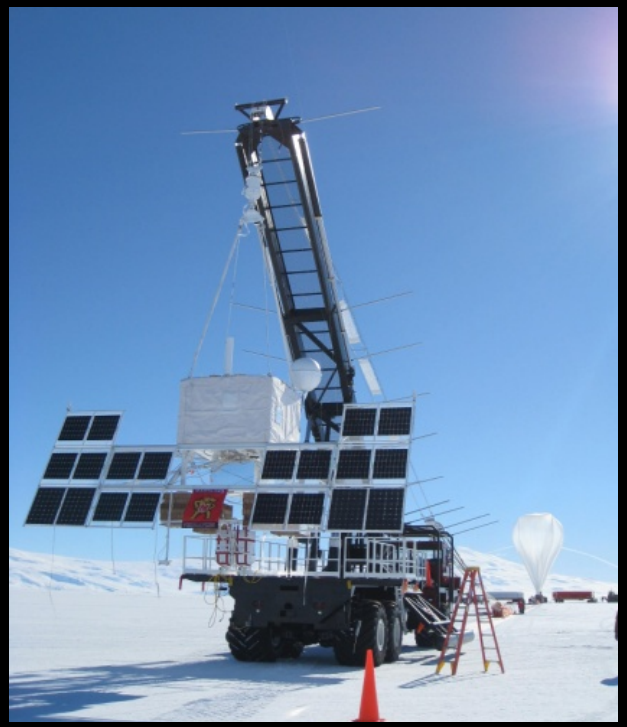
Orthographic View Looking ISS Zenith

Cosmic Ray Energetics And Mass (CREAM) on the ISS

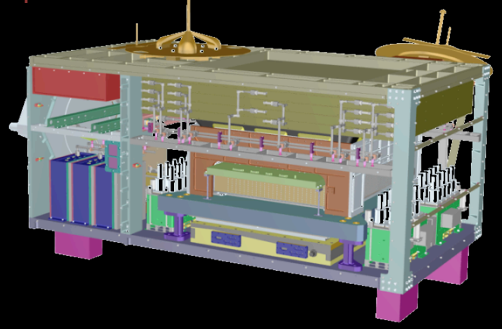
- Balloon-borne CREAM flown 6 times over Antarctica with ~161 days total flight time, longest exposure to date for a single balloon project.
- SMD and HEOMD/ISS working to transfer a balloon payload to a station payload.



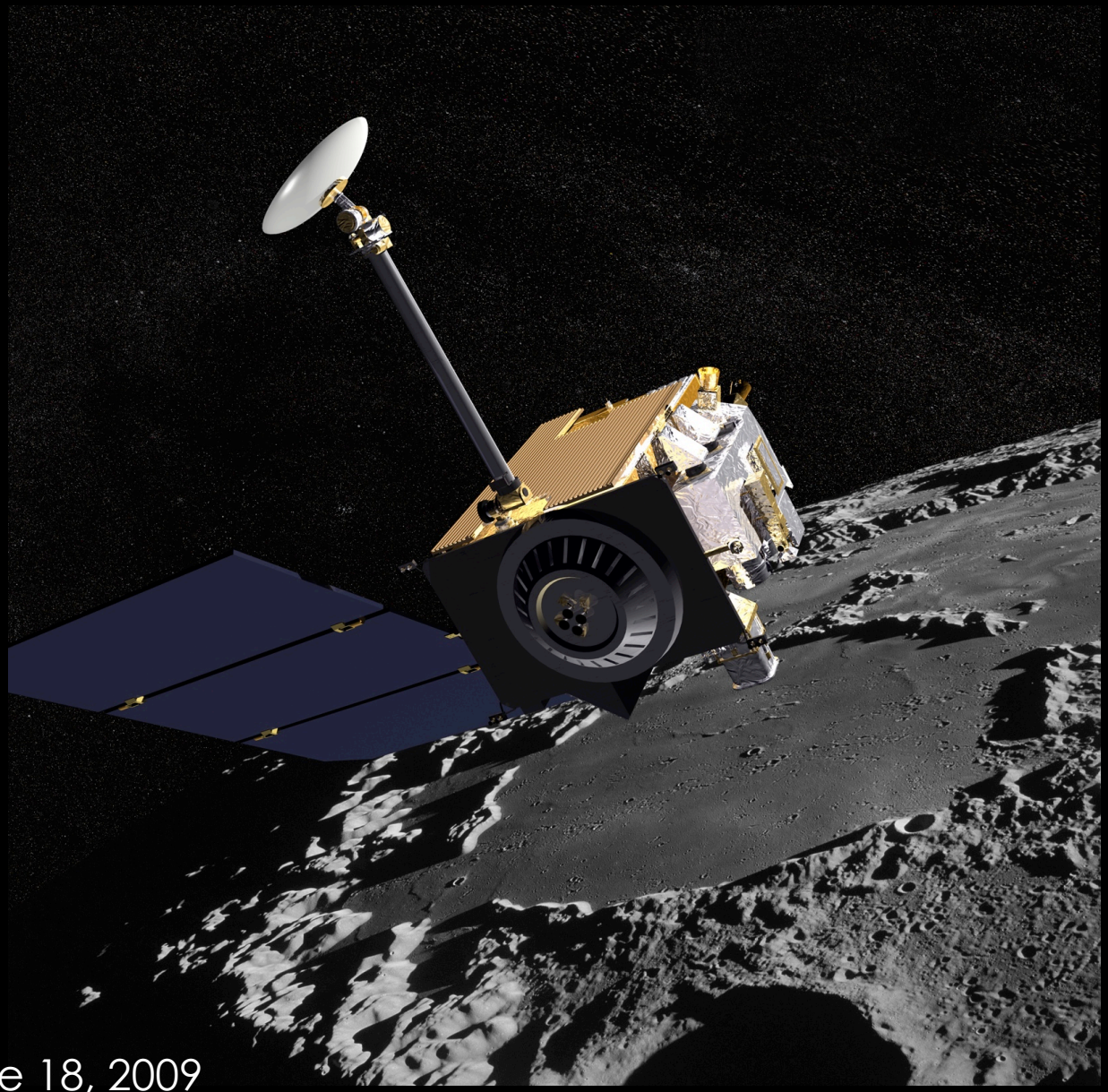
Ahn et al. ApJ **714**, *L89*, 2010



Increase exposure by at least an order of magnitude



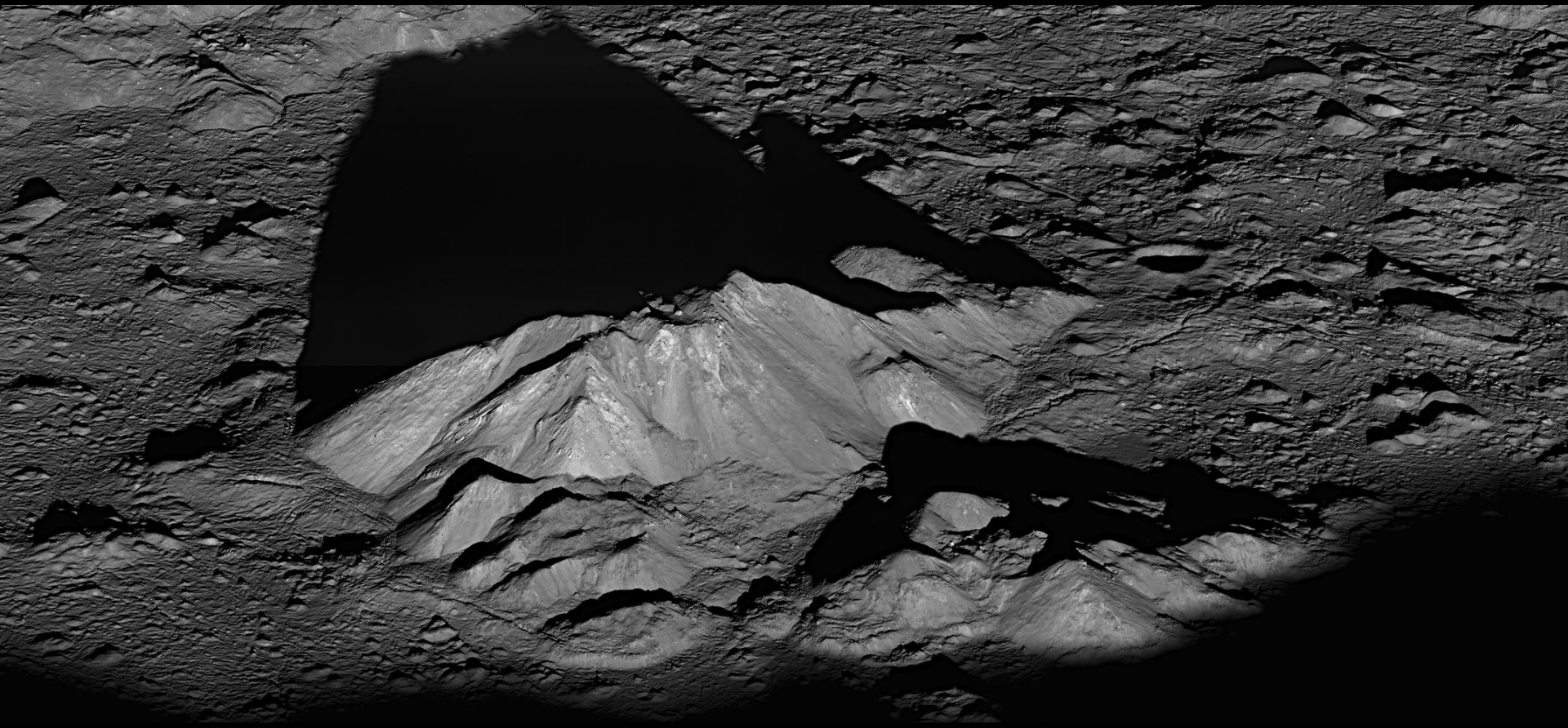
Lunar Reconnaissance Orbiter (LRO)



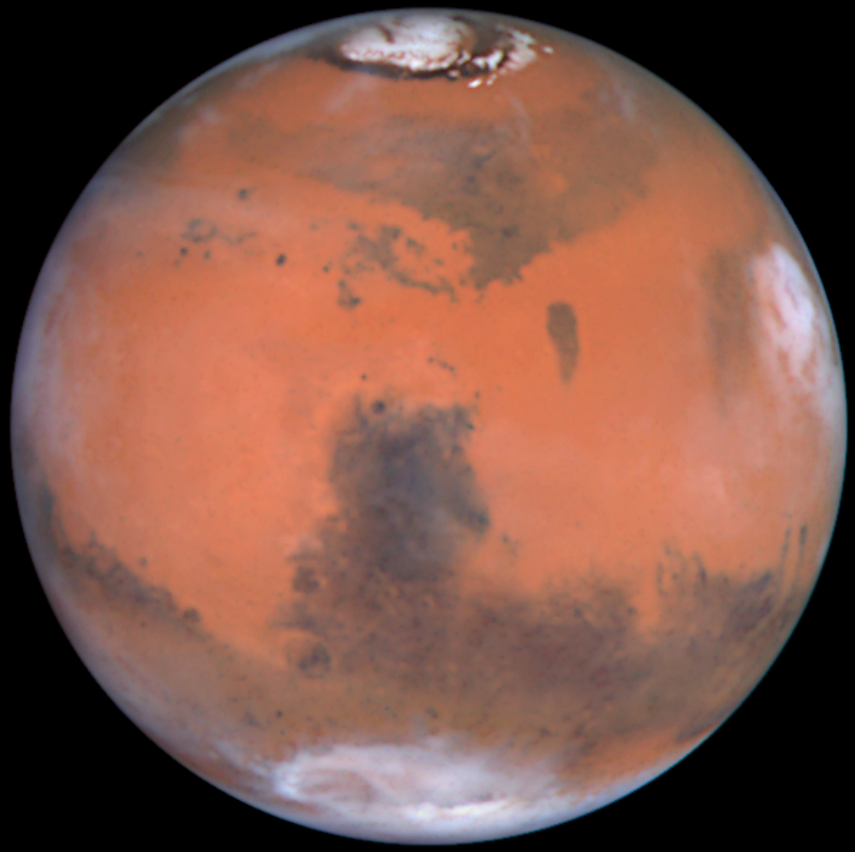
Launch: June 18, 2009

Credit: Chris Meaney/MASA

Tycho Crater's Peak

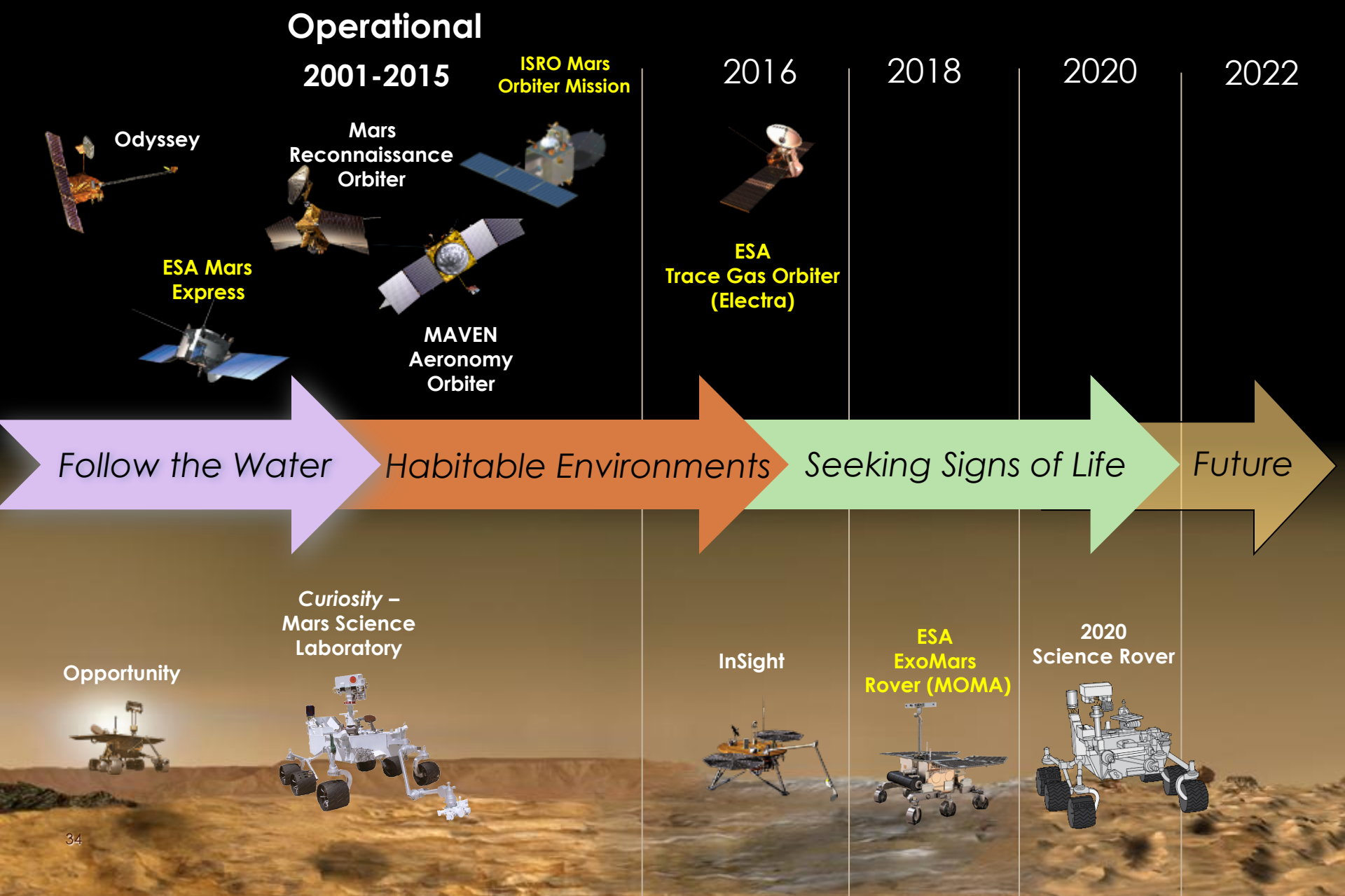


Credit: NASA Goddard/Arizona State University

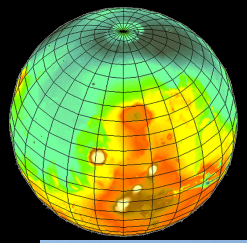


Credit: NASA

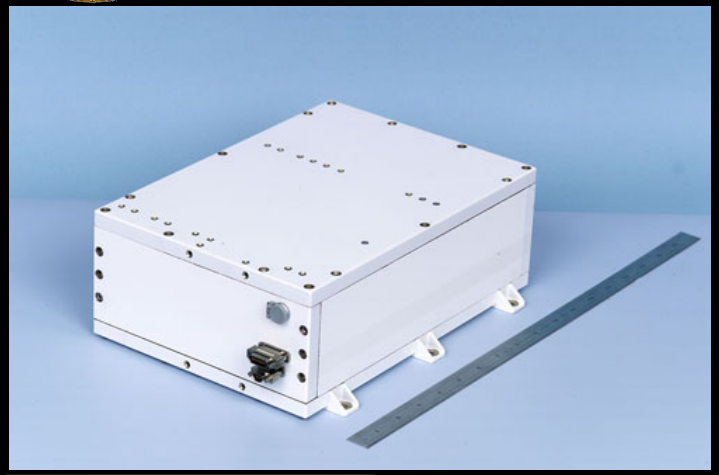
Current & Future Mars Missions



HEOMD and SMD Activities for Future Human Explorers to Mars



Mars Odyssey's Mars Radiation Environment Experiment (MARIE)

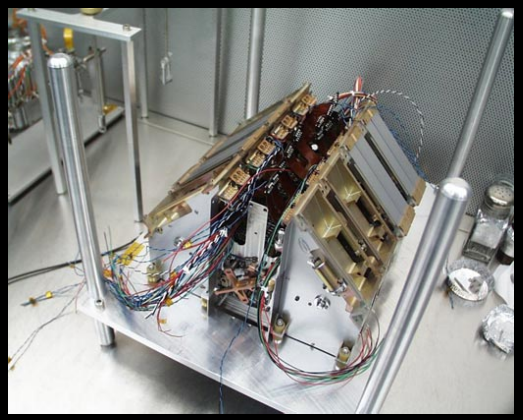


Mars Science Laboratory's Radiation Assessment Detector (RAD), Mars Descent Imager (MARDI) and Mars EDL Instrument (MEDLI)

RAD

Phoenix's Mars Instruments

Thermal and Evolved Gas Analyzer (TEGA)



Robotic Arm and Camera

Mars Descent Imager

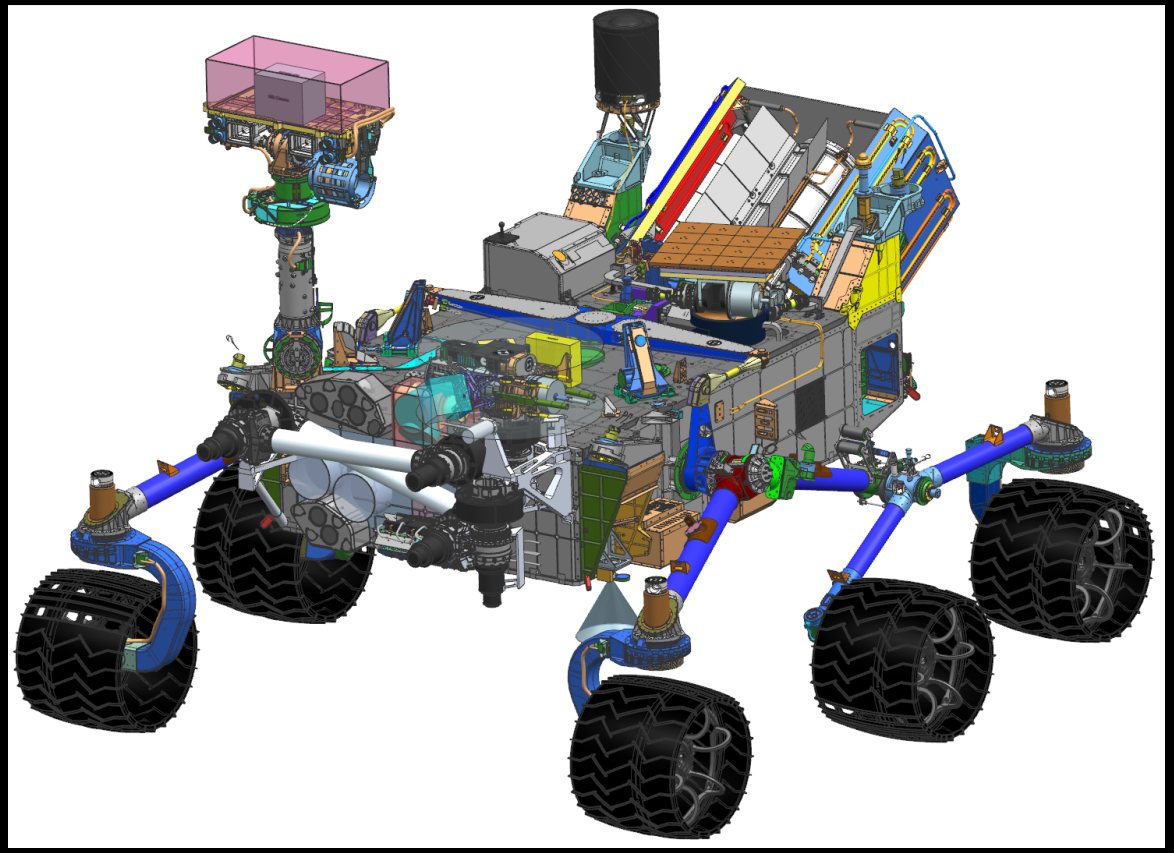
Seeking Signs of Life: Mars 2020 Rover

Conduct rigorous *in situ* science

- Characterize the geology and habitability of the landing site
- Seek signs of ancient life with an integrated set of context and fine-scale measurements

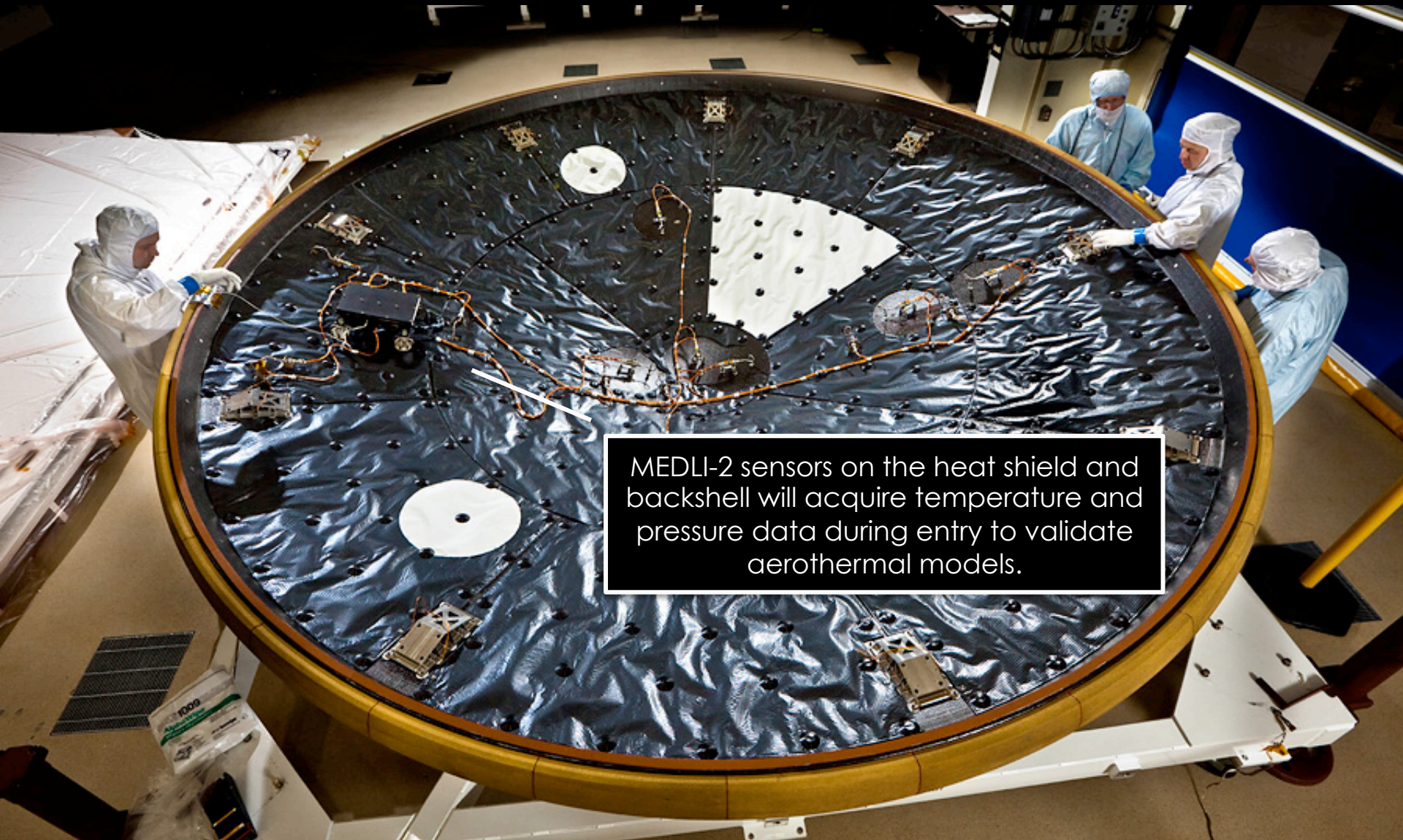
Enable the future

- Critical ISRU and technology demonstrations for future Mars exploration

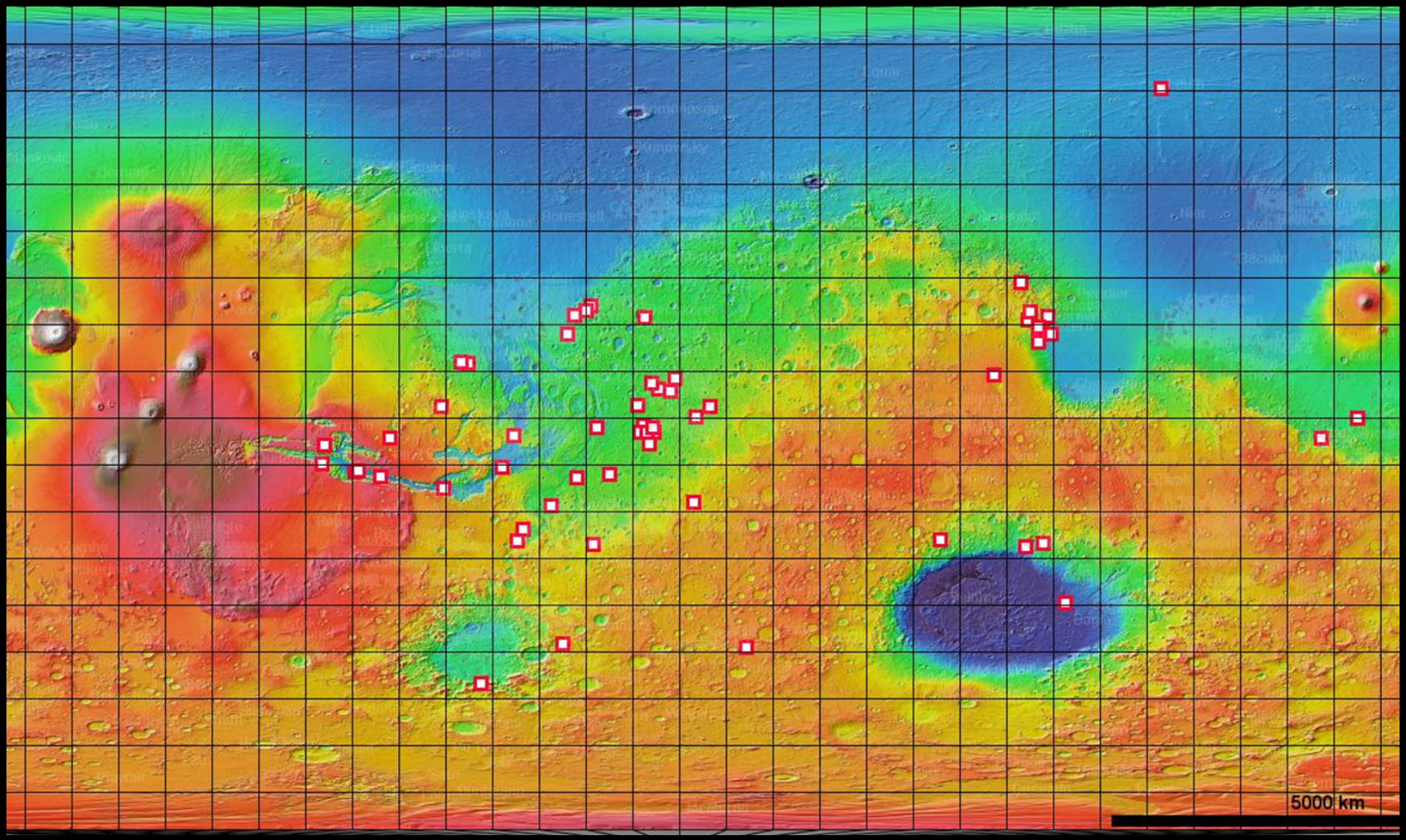


Returnable cache of samples

Three Payloads On The Mars 2020 Mission Will Address Strategic Knowledge Gaps For Human Exploration



Mars Site Selection: Early Stages of SMD/HEOMD Development



Solar System Exploration Research Virtual Institute (SSERVI) Science/Exploration Balance in Teams

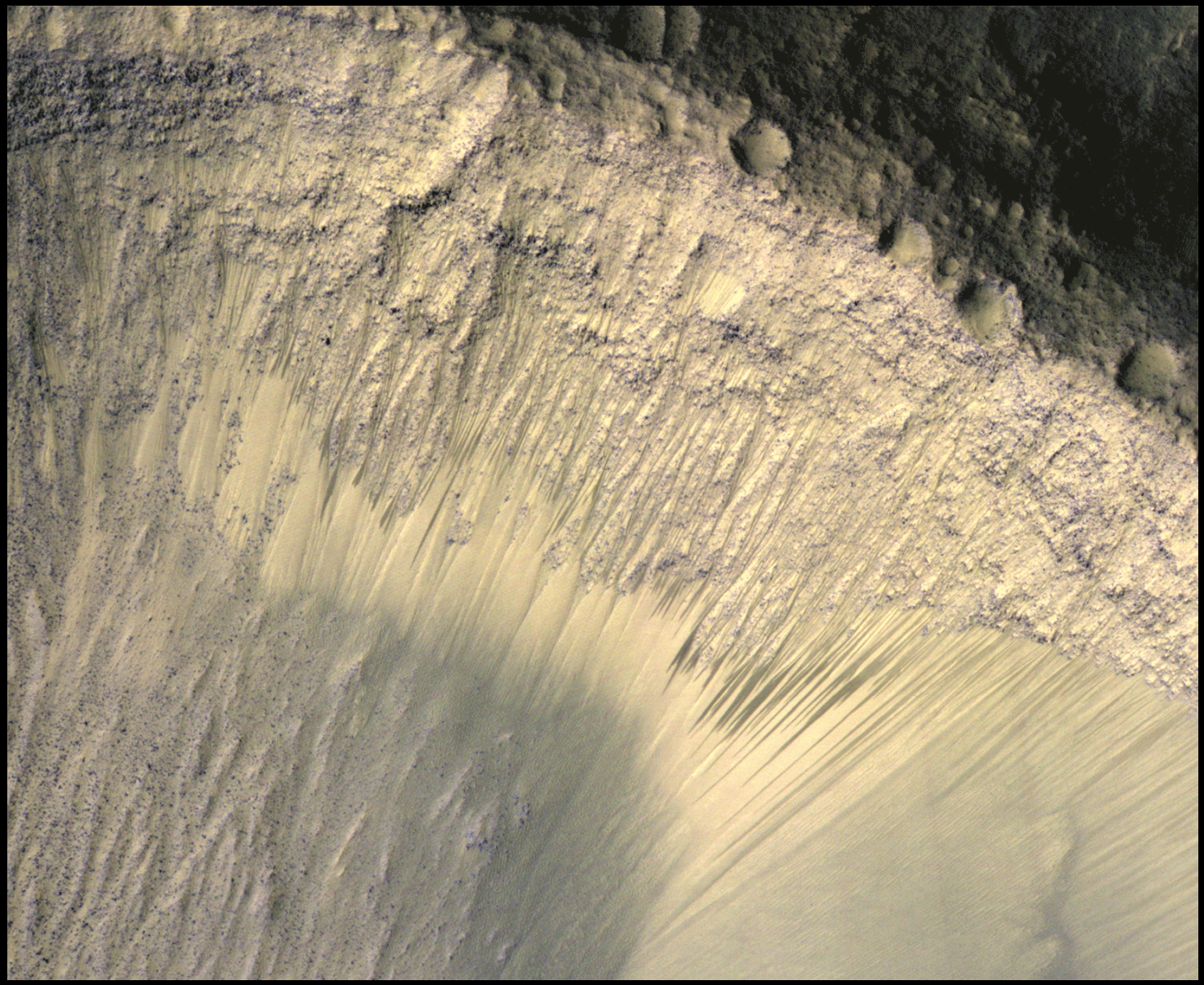
		Horanyi	Kring	Batkke	Pieters	Bussey	Britt	Hellerman	Farrell	Glotch
SCIENCE EMPHASIS	Role of Target Body(s) in revealing the origin and evolution of the inner Solar System	●	●	●	●					
	Target Body structure and composition		●	●	●	●	●	●		●
	Innovating observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe	●							●	
	Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes		●	●	●	●				●
EXPLORATION EMPHASIS	Dust and plasma interactions on Target Body(s)	●					●		●	
	Near-Earth asteroid characterization (incl. NEAs that are potential human destinations)	●	●	●	●	●	●		●	●
	Geotechnical properties (Moon, NEAs, Mars)	●	●		●	●	●	●		●
	Regolith of Target Bodies	●	●		●	●	●	●	●	●
	Radiation	●							●	●
	Volatiles (in its broad sense) and other potential resources on Target Body(s)				●	●		●	●	●
	In-Situ Resource Utilization (ISRU)/Prospecting (Moon, NEAs, Mars)	●				●		●		●
	Propulsion-induced ejecta (Moon, NEAs, Mars)						●			
	Operations/Operability (all destinations, incl. transit)		●					●		●
	Human health and performance (all destinations, incl. transit)									●

Solar System Exploration Research Virtual Institute (SSERVI) Science/Exploration Balance in Teams

SCIENCE EMPHASIS	Role of Target Body(s) in revealing the origin and evolution of the inner Solar System	Horanyi, Kring, Boltke, Pieters
	Target Body structure and composition	Glotch, Kring, Boltke, Bussey, Pieters, Britt, Hellermann
	Innovating observations that will advance our understanding of the fundamental physical laws, composition, and origins of the Universe	Horanyi, Farrell
	Moon, NEA, and Martian moon investigations as windows into planetary differentiation processes	Glotch, Kring, Boltke, Bussey, Pieters, Hellermann
EXPLORATION EMPHASIS	Dust and plasma interactions on Target Body(s)	Horanyi, Farrell, Britt
	Near-Earth asteroid characterization (incl. NEAs that are potential human destinations)	Glotch, Horanyi, Kring, Boltke, Bussey, Pieters, Farrell, Britt
	Geotechnical properties (Moon, NEAs, Mars)	Glotch, Horanyi, Kring, Bussey, Pieters, Britt, Hellermann
	Regolith of Target Bodies	Glotch, Horanyi, Kring, Bussey, Pieters, Farrell, Britt, Hellermann
	Radiation	Glotch, Horanyi, Farrell
	Volatiles (in its broad sense) and other potential resources on Target Body(s)	Glotch, Bussey, Pieters, Farrell, Hellermann
	In-Situ Resource Utilization (ISRU)/Prospecting (Moon, NEAs, Mars)	Glotch, Horanyi, Bussey, Hellermann
	Propulsion-induced ejecta (Moon, NEAs, Mars)	Britt
	Operations/Operability (all destinations, incl. transit)	Glotch, Kring, Hellermann
	Human health and performance (all destinations, incl. transit)	Glotch

Planetary Protection

Protect the Earth, Avoid Harmful Contamination



WORKSHOP

Planetary Protection Knowledge Gaps for

Human Extraterrestrial Missions

Website: www.nasa.gov/ames/ppw2015workshop/

Registration: www.hou.usra.edu/meetings/ppw2015/

MARCH 24–26, 2015

NASA AMES RESEARCH CENTER, CA

Space Communications and Navigation (SCaN)

- Network services
- Architecture development
- Technology development
- Interoperable space data communication
- Spectrum policy management
- Positioning, Navigation and Timing policy
- Public outreach and communication

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- Network services
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- Spectrum policy management
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- Live status:
  https://eyes.nasa.gov/dsn/dsn.html

SCaN

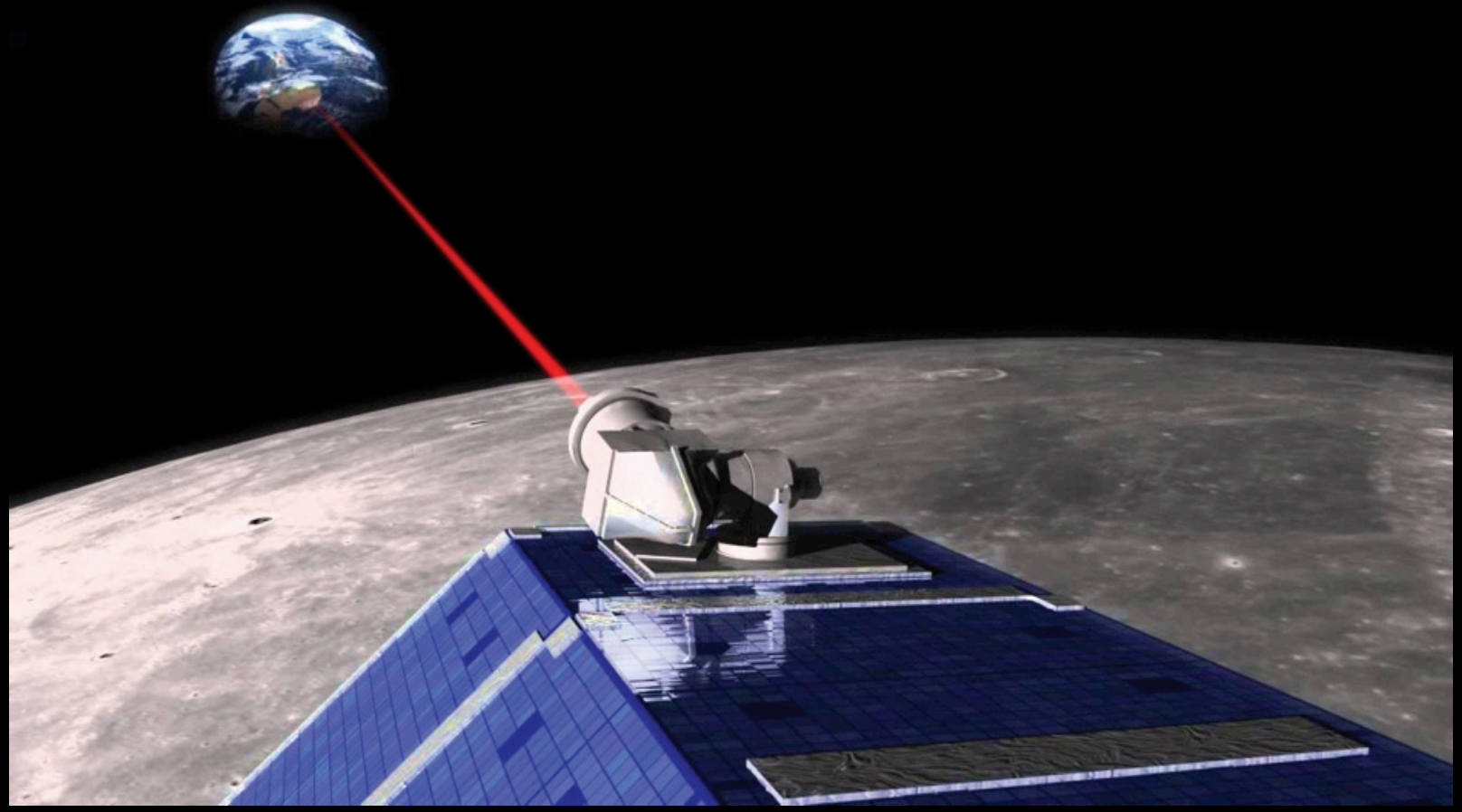
Network Services: SCaN provides most space communication services for SMD missions

- 70 active spacecraft
- + 20 more planned within 5 years
- 3 networks
  - Deep Space Network (DSN)
  - Near Earth Network (NEN)
  - Space Network (SN)

- Scan-Users Plans and Requirements Working Group (SUPRWG) Charter approved by SCaN Board of Directors

Credit: NASA/JPL-Caltech

SCaN Technology Development



Credit: NASA

Lunar Lasar Communication Demonstration (LLCD) was part of the Lunar Atmosphere and Dust Environment Explorer (LADEE) mission

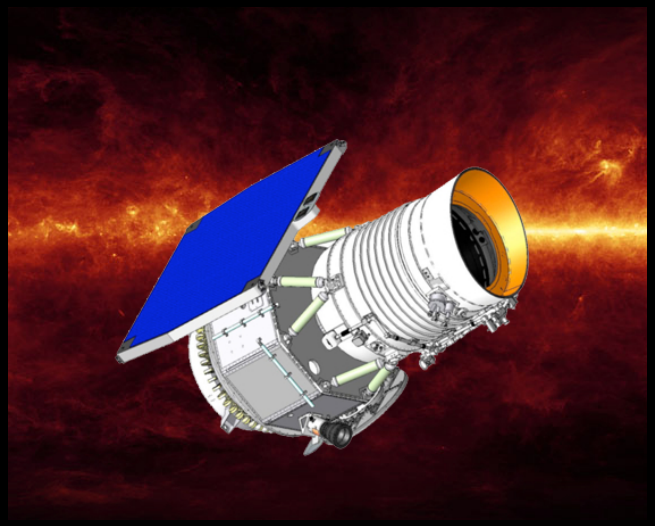
Astromaterials Curation

Mission:

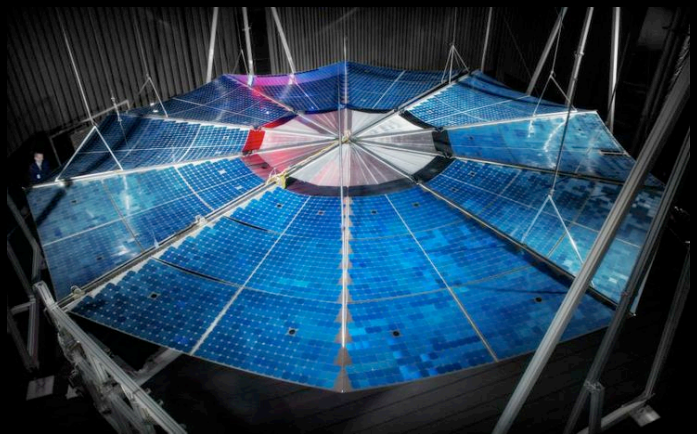
To protect, preserve and distribute samples for study from the Moon, Mars and interplanetary space in support of solar system exploration.

Asteroid Redirect Mission Cross-Agency Leveraging Examples

SMD Asteroid Observations



STMD Solar Electric Propulsion Technology Development



HEOMD and STMD Capture Risk Reduction

LaRC full-scale CRS flat floor testing

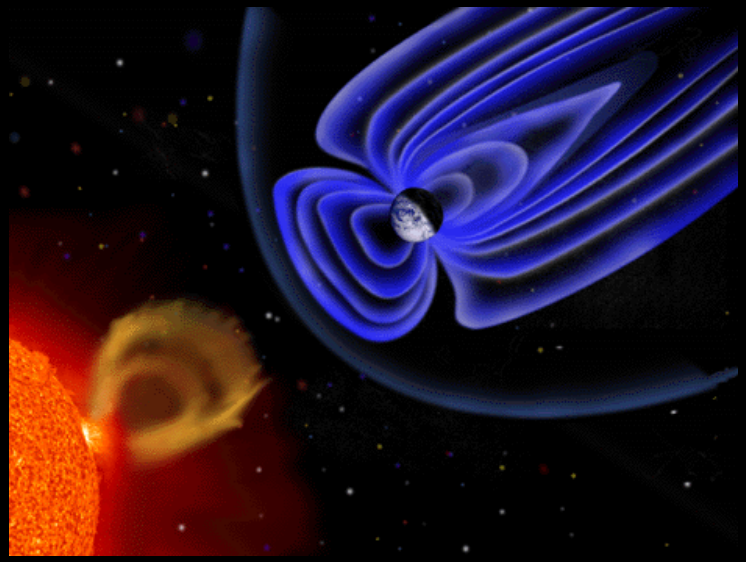
KSC Swamp Works full-scale testing of boulder extraction

Space Radiation

- Solar Variability Affects Human Technology, Humans in Space, and Terrestrial Climate.
- The Sphere of the Human Environment Continues to Expand Above and Beyond Our Planet.

  - Increasing dependence on space-based systems

  - Permanent presence of humans in Earth orbit and beyond



Space Radiation

Space Radiation Working Group (SWRG)

- HQ-chartered group

Space Radiation Community of Practice

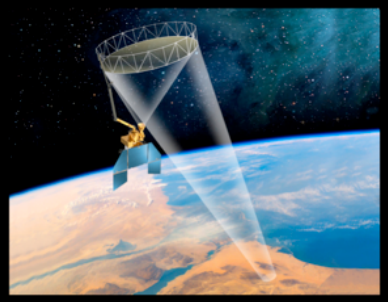
- Cross-Directorate, cross-Center, group of subject matter experts

Community Coordinated Modeling Center

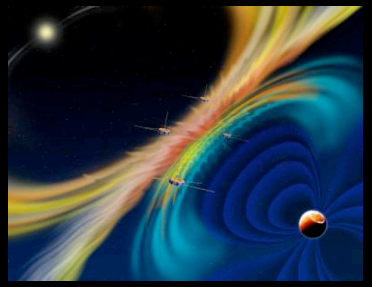
- Collaborative multi-Agency effort based at Goddard Space Flight Center

Launch Services
2015-2016 Launch Schedule

2015



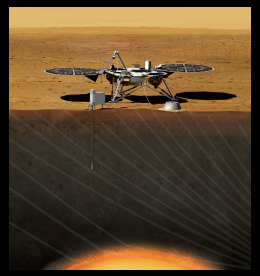
SMAP
Soil Moisture
Active Passive
(Delta II 7320)



MMS
Magnetospheric
MultiScale
(Atlas V 421)

Jason-3
(Falcon 9 v1.1)

2016



INSIGHT
Interior Exploration
using Seismic
Investigations, Geodesy
and Heat Transport
(Atlas V 401)

GOES-R
Geostationary Operational
Environmental Satellite
(Atlas V 541)

OSIRIS-Rex
Origins Spectral
Interpretation Resource
Identification Security
Regolith Explorer
(Atlas V 411)

CYGNSS
Cyclone Global
Navigation
Satellite System
(Pegasus XL)

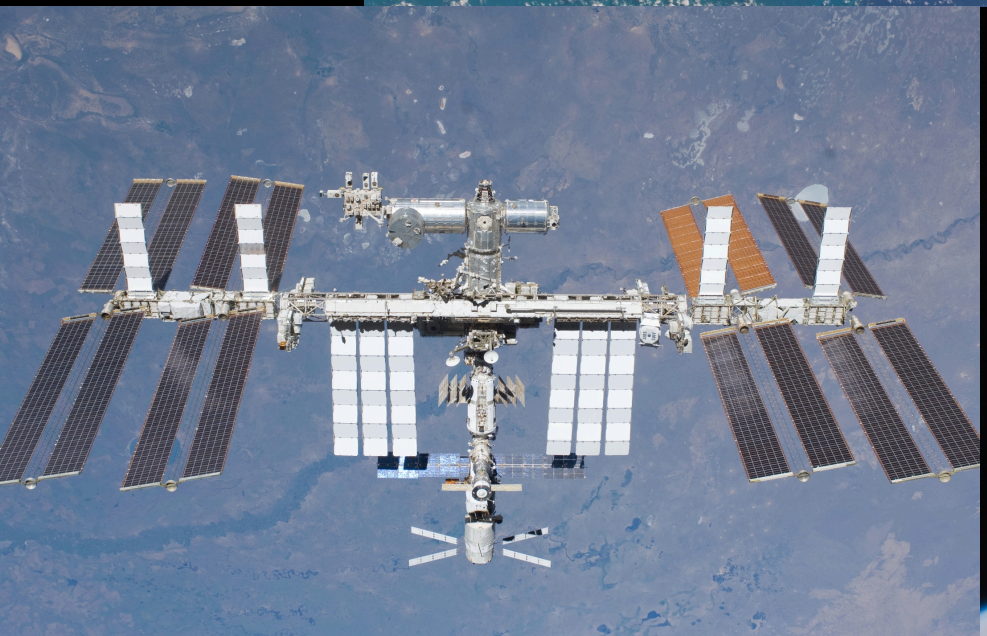
JPSS-1
Joint Polar Satellite
System
(Delta II 7920)

HEOMD / SMD Cooperative Activities: SMD-funded figures consistent with FY2015 Budget Request)

	FY13	FY14	FY15	FY16	FY17	FY18	FY19	
SMD ISS payloads:								
Astrophysics								
NICER	6.4	25.6	11.1	11.6	3.6	1.4		
CREAM	4.8	3.3	1.9	1.3	1.3	1.3		
CALET	0.9	0.8	0.6					
JEM-EUSO	0.5	0.9	1.2	1.1	1.0			potential future payload
Earth Science								
SAGE-III	24.4	22.6	22.1	14.1	4.8	3.9		
OCO-3	7.4	16.8						
HIREP-HICO, RAIDS		0.1	0.1	0.1	0.1	0.1	0.1	
CATS-ISS	1.0	0.9	1.1	1.0	1.1	1.1	1.1	
RapidScat	0.2	0.2	1.9	1.2	0.6			
ISERV		0.4	0.2					
GEDI			42.2	33.8	27.7	8.9	2.8	selected September 2014
ECOSTRESS		7.8	6.3	16.4	14.5	9.2	4.1	selected September 2014
Direct SMD support of human spaceflight planning								
Joint Robotics Precursor Activity	10.0	10.0	10.0	10.0	10.0	10.0	10.0	Including SSERVI
NEO Observations	20.5	40.5	40.0	40.0	40.0	40.0	40.0	
Other SMD missions contributing to human spaceflight planning								
OSIRIS-Rex	125.5	218.7	224.8	193.7	44.0	26.1	43.1	
Mars Program	369.5	288.0	279.3	381.7	547.8	573.1	518.8	
LRO science mission	10.5	11.5	2.2	2.2				
Astromaterial curation	5.7	6.3	6.4	6.1	6.3	6.4	6.6	

HEOMD / SMD Cooperative Activities: HEO-funded figures consistent with FY2015 Budget Request)

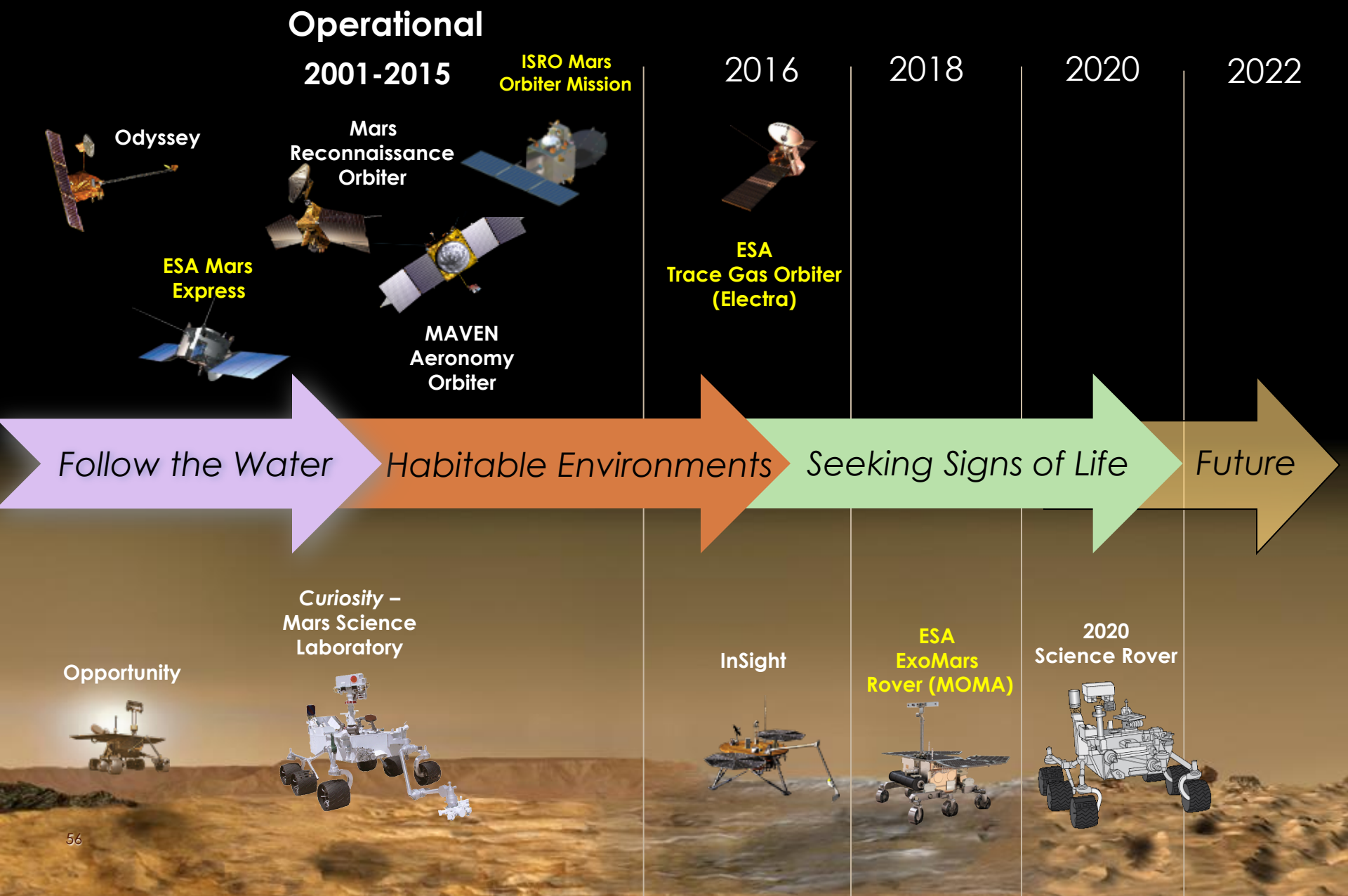
	FY13	FY14	FY15	FY16	FY17	FY18	FY19	
Ongoing HEO support of SMD missions								
SCAN	440.4	358.5	388.2	507.1	566.6	516.8	498.1	supports more than SMD
LSP	80.3	79.7	80.1	80.0	80.0	80.0	80.0	supports more than SMD
ISS MUSS	205.4	200.4	184.8	182.2	182.5	182.5	182.5	supports more than SMD
AMS Ops Support	0.9	1.1	0.7	0.8	0.8	0.8	0.8	
HEO/STMD instrumentation on SMD Mars missions								
RAD on MSL	0.2	1.5						
Mars 2020: MEDLI-2			1.1	tbd	tbd	tbd	tbd	
Mars 2020: MEDA			0.6	tbd	tbd	tbd	tbd	
Mars 2020: MOXIE (ISRU)			tbd	tbd	tbd	tbd	tbd	
Potential future HEO support of SMD missions								
In-Space Robotic Servicing	50.0	64.0	65.0	65.0	65.0	65.0	65.0	
SLS			tbd	tbd	tbd	tbd	tbd	
Evolvable Mars?			tbd	tbd	tbd	tbd	tbd	
Hayabusa 2 (Japan)			tbd	tbd	tbd	tbd	tbd	
HEO JRPA / SSERVI	2.9	3.7	17.6	13.8	10.7			
Goldstone NEO imaging	1.6	1.0						
ARM	40.0	40.0	40.0	40.0	40.0	40.0	40.0	



Credit: NASA/JPL-Caltech

Credit: J. Grunsfeld

Current & Future Mars Missions



backup

NICER: Neutron star Interior Composition ExploreR
CREAM: Cosmic Ray Energetics and Mass
CALET: CALorimetric Electron Telescope
JEM-EUSO: Japanese Experiment Module - Extreme Universe Space Observatory
SAGE-III: Stratospheric Aerosol and Gas Experiment
OCO-3: Orbiting Carbon Observatory
HREP: HICO and RAIDS Experiment Payload
HICO: Hyperspectral Imager for the Coastal Ocean
RAIDS: Remote Atmospheric and Ionospheric Detection System
CATS-ISS: Cloud-Aerosol Transport System
ISERV: ISS SERVIR Environmental Research and Visualization System
GEDI: Global Ecosystem Dynamics Investigation Lidar
ECOSTRESS: ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
OSIRIS-Rex: Origins Spectral Interpretation Resource Identification Security -- Regolith Explorer
LRO: Lunar Reconnaissance Orbiter
MSL: Mars Science Laboratory
MEDLI: Mars Science Laboratory Entry Descent and Landing Instrument
RAD: Radiation Assessment Detector
AMS: The Alpha Magnetic Spectrometer
MEDA: Mars Environmental Dynamics Analyzer
ISRU: In-Situ Resource Utilization
MOXIE: Mars Oxygen ISRU Experiment
SCAN: Space Communications and Navigation
JRPA: Joint Robotic Precursor Activity
SSERVI: Solar System Exploration Research Virtual Institute