

HELIOPHYSICS



EARTH SCIENCE



PLANETARY SCIENCE



ASTROPHYSICS

SCIENCE MISSION DIRECTORATE

**FY 2017 Budget Presentation to the NAC
Craig Tupper, Director, Resource Management
March 10, 2016**

Science Budget Request Summary

	Actual	Enacted	Request	Notional			
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Science	5,243.0	5,589.4	5,600.5	5,408.5	5,516.7	5,627.0	5,739.6
<u>Earth Science</u>	<u>1,784.1</u>		<u>2,032.2</u>	<u>1,989.5</u>	<u>2,001.3</u>	<u>2,020.9</u>	<u>2,047.7</u>
Earth Science Research	453.2		501.7	472.9	461.3	475.9	484.2
Earth Systematic Missions	827.3		933.0	965.5	1,021.3	1,005.0	1,000.1
Earth System Science Pathfinder	223.8		296.0	248.6	216.7	227.8	245.1
Earth Science Multi-Mission Operations	179.7		191.8	194.3	193.6	197.9	202.6
Earth Science Technology	59.7		61.4	60.4	59.7	62.7	63.7
Applied Sciences	40.4		48.2	47.9	48.7	51.5	52.0
<u>Planetary Science</u>	<u>1,446.7</u>		<u>1,518.7</u>	<u>1,439.7</u>	<u>1,520.1</u>	<u>1,575.5</u>	<u>1,625.7</u>
Planetary Science Research	252.8		284.7	271.6	285.7	281.6	287.3
Discovery	259.7		202.5	277.3	337.4	345.0	405.3
New Frontiers	286.0		144.0	81.6	90.7	142.8	234.0
Mars Exploration	305.0		584.8	588.8	565.0	498.4	279.9
Outer Planets and Ocean Worlds	184.0		137.3	56.0	77.8	128.0	247.3
Technology	159.2		165.5	164.4	163.5	179.7	172.0
<u>Astrophysics</u>	<u>730.7</u>		<u>781.5</u>	<u>761.6</u>	<u>992.4</u>	<u>1,118.6</u>	<u>1,192.5</u>
Astrophysics Research	201.7		226.1	236.3	235.7	248.5	252.0
Cosmic Origins	201.0		198.5	198.4	197.3	195.5	209.5
Physics of the Cosmos	104.1		94.1	88.0	94.1	97.7	94.0
Exoplanet Exploration	100.6		133.8	148.0	309.3	373.3	450.8
Astrophysics Explorer	123.3		129.0	91.0	156.0	203.5	186.2
<u>James Webb Space Telescope</u>	<u>645.4</u>	<u>620.0</u>	<u>569.4</u>	<u>533.7</u>	<u>304.6</u>	<u>197.2</u>	<u>149.8</u>
<u>Heliophysics</u>	<u>636.1</u>		<u>698.7</u>	<u>684.0</u>	<u>698.3</u>	<u>714.8</u>	<u>723.9</u>
Heliophysics Research	192.0		180.1	192.0	210.0	215.9	214.2
Living with a Star	263.5		374.2	398.7	244.6	135.8	127.3
Solar Terrestrial Probes	70.6		39.8	38.8	127.3	179.4	198.4
Heliophysics Explorer Program	110.0		104.6	54.5	116.3	183.8	184.0

FY 2017 Program Highlights

- Supports formulation of a Europa mission
 - Multiple flyby mission entered Phase A formulation in June 2015
 - NASA has initiated a study of lander concepts. Preliminary results show that a lander would add significant cost, schedule risk, and complexity to the flyby mission.
- Supports formulation of WFIRST
 - Enters Phase A formulation after APMC review on 2/17/16
 - FY17 and notional outyear budget profile supports launch as early as 2025
- Accelerates Landsat 9 to FY21, within an ongoing Sustainable Land Imaging program
- Fully funds operating Mars missions
- Increases investments in Planetary technology, including power
- Continues efforts to detect and study NEOs, including study of an Asteroid Impact and Deflection Assessment mission with the European Space Agency (ESA)
- Includes \$10M to study a Mars orbiter in the 2020s, in collaboration with STMD and HEOMD
- Increases funding for SMD CubeSats, and initiates a project to advance the use of constellations of small satellites
- Accelerates work in support of the Space Weather Action Plan
- Includes \$298M in mandatory funding

Future SMD Solicitations

FY 2016 Planned

- AO, Heliophysics Explorers, SMEX and Missions of Opportunity, NET Q3
- AO, Astrophysics Explorers, MIDEX and Missions of Opportunity, NET Q4
- AO, Earth Venture Instrument-4, Q4

FY 2017 Planned

- AO, New Frontiers, Q2
- AO and MOO, Heliophysics STP-5, NET Q3
- AO, Earth Venture Suborbital-3, Q4
- ROSES NRA, February 2017

Recent Cost Performance

NASA Science is providing reliable cost estimates for its missions, contributing to program stability

	<u>Original</u> <u>Baseline</u>	<u>Current/</u> <u>Actual</u>	Actual vs. <u>Original</u>
Juno	742.0	708.8	-4%
GRAIL	427.0	398.0	-7%
Suomi NPP	593.0	765.2	29%
NuSTAR	110.0	116.0	5%
Van Allen	534.0	504.0	-6%
Landsat 8	583.4	502.8	-14%
IRIS	141.0	143.0	1%
LADEE	168.0	191.4	14%
MAVEN	567.0	472.0	-17%
GPM	555.0	484.3	-13%
OCO-2	249.0	320.3	29%
SMAP	485.7	454.3	-6%
<u>MMS</u>	<u>857.3</u>	<u>875.3</u>	2%
Total	6012.4	5935.5	-1%

The total cost to develop 13 Science missions launched since August 2011 (excluding MSL/Curiosity) reflects a net underrun of our original estimates by 1%.

Astrophysics Budget Features

What's changed since FY 2016 budget

- Science Education increased to \$25M/year; addressed later
- WFIRST increased to \$90M in FY17 to advance formulation
- Hubble planning budget set flat at ~ \$98M/year
- SOFIA planning budget set flat at ~ \$84M/year
- Spitzer budget set to minimum for closeout; continuation in FY17 will be determined by 2016 Senior Review
- Euclid cost growth covered
- SR&T lines increased in FY17 to enable next Decadal studies
- Directed R&T funds/FTE moved to other Themes, as per demand
- Minor changes in other projects
- Senior Review funding may be inadequate to continue all currently operating missions

What's the same

- Most other operating missions other than Hubble and SOFIA, most other missions in development other than Euclid, and most R&A programs

Preparing for the 2020 Astrophysics Decadal Survey

- This FY17 budget request includes \$5M to conduct mission concept studies in FY17 as input to the 2020 Decadal Survey
 - A well informed Decadal Survey makes better recommendations
 - Mission concept study includes: Science case, Technology assessment, Design reference mission with strawman payload, Cost assessment
- NASA is initiating four large mission concept studies:
 - Far Infrared Surveyor
 - Habitable Exoplanet Imaging Mission
 - Large Ultraviolet/Optical/Infrared Surveyor
 - X-ray Surveyor
- NASA is also planning to charter medium-size mission concept studies

Astrophysics Program Content

	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
Astrophysics	730.7		781.5	761.6	992.4	1,118.6	1,192.5
<u>Astrophysics Research</u>	<u>201.7</u>		<u>226.1</u>	<u>236.3</u>	<u>235.7</u>	<u>248.5</u>	<u>252.0</u>
Science Education	42.0		25.0	25.0	25.0	25.0	25.0
Astrophysics Research and Analysis	71.1		72.7	73.0	73.0	73.0	73.0
Balloon Project	38.0		37.0	37.3	37.4	38.9	40.4
<u>Other Missions and Data Analysis</u>	<u>50.6</u>		<u>91.4</u>	<u>101.0</u>	<u>100.3</u>	<u>111.6</u>	<u>113.6</u>
Astrophysics Data Curation and Archival	18.6		17.8	18.8	18.9	18.9	18.9
Astrophysics Data Program	17.0		17.6	17.6	17.6	17.6	17.6
Astrophysics Senior Review	-		37.4	49.3	40.5	33.6	34.0
Contract Administration, Audit & QA Svcs	15.0		14.9	15.0	15.0	15.1	15.1
Astrophysics Directed R&T	-		3.7	0.2	8.4	26.4	28.1
<u>Cosmic Origins</u>	<u>201.0</u>		<u>198.5</u>	<u>198.4</u>	<u>197.3</u>	<u>195.5</u>	<u>209.5</u>
Hubble Space Telescope (HST)	98.6		97.3	98.3	98.3	98.3	98.3
Stratospheric Observatory for Infrared Astronom	70.0		83.8	84.8	84.8	84.8	84.8
<u>Other Missions and Data Analysis</u>	<u>32.4</u>		<u>17.4</u>	<u>15.3</u>	<u>14.2</u>	<u>12.4</u>	<u>26.4</u>
Cosmic Origins Future Missions Spitzer	1.2		1.1	1.5	1.5	1.5	1.5
Herschel	14.6		3.5	-	-	-	-
Cosmic Origins SR&T	5.1		1.0	-	-	-	-
Cosmic Origins Program Management	8.8		9.3	10.9	9.8	8.0	22.0
Management	2.6		2.5	2.9	2.9	2.9	2.9

Astrophysics Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<u>Physics of the Cosmos</u>	<u>104.1</u>		<u>94.1</u>	<u>88.0</u>	<u>94.1</u>	<u>97.7</u>	<u>94.0</u>
Physics of the Cosmos Future Missions	0.1		0.5	2.1	2.1	2.5	2.5
Euclid	7.5		12.9	7.5	7.7	9.9	6.1
Chandra X-Ray Observatory	55.6		52.4	56.7	57.4	58.4	58.4
Fermi Gamma-ray Space Telescope	16.9		-	-	-	-	-
XMM	2.9		-	-	-	-	-
Planck	6.0		-	-	-	-	-
Physics of the Cosmos SR&T	12.0		25.4	18.5	23.7	23.8	23.9
Physics of the Cosmos Program Management	3.0		2.9	3.2	3.2	3.2	3.2
<u>Exoplanet Exploration</u>	<u>100.6</u>		<u>133.8</u>	<u>148.0</u>	<u>309.3</u>	<u>373.3</u>	<u>450.8</u>
Decadal Strategic Mission (WFIRST)	50.0		90.0	108.2	267.7	331.8	409.9
Exoplanet Exploration Future Missions	0.9		0.5	1.1	8.2	8.3	8.3
Kepler	17.2		2.8	-	-	-	-
Keck Operations	6.0		6.1	6.2	-	-	-
Large Binocular Telescope Interferometer	2.0		1.3	-	-	-	-
Exoplanet Exploration SR&T	19.4		28.0	26.5	27.6	26.9	26.2
Exoplanet Exploration Program Management	5.1		5.1	6.0	5.9	6.3	6.4

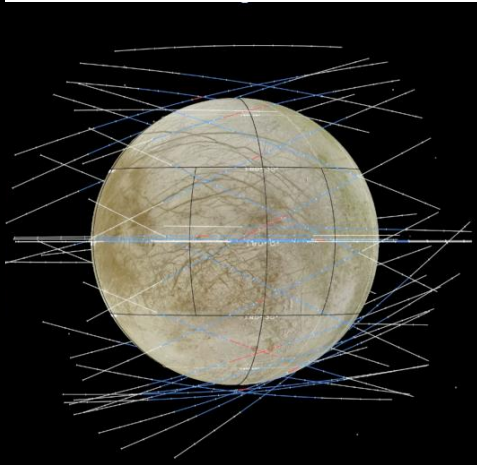
Astrophysics Program Content (cont'd)

	<u>Actual</u> <u>FY 201</u>	<u>Enacted</u> <u>FY 201</u>	<u>Request</u> <u>FY 201</u>	<u>Notional</u>			
				<u>FY 201</u>	<u>FY 201</u>	<u>FY 202</u>	<u>FY 202</u>
<u>Astrophysics Explorer</u>	<u>123.</u>		<u>129.</u>	<u>91.</u>	<u>156.</u>	<u>203.</u>	<u>186.</u>
Transiting Exoplanet Survey Satellite (TESS)	80.1	73.5	87.0	27.9	9.1	2.5	0.0
<u>Other Missions and Data Analy</u>	<u>43.</u>		<u>42.</u>	<u>63.</u>	<u>146.</u>	<u>201.</u>	<u>186.</u>
Astrophysics Explorer Future Missions	1.1		16.8	42.7	132.2	192.6	178.5
ASTRO-H (SXS)	11.3		12.0	11.4	9.5	-	-
NICER	11.7		3.5	1.3	-	-	-
Nuclear Spectroscopic Telescope Array	7.4		-	-	-	-	-
Swift	4.9		-	-	-	-	-
Suzaku (ASTRO-E II)	0.6		-	-	-	-	-
Astrophysics Explorer Program Management	6.2		9.8	7.7	5.1	8.5	7.7
James Webb Space Telescop	645.4	620.0	569.4	533.7	304.6	197.2	149.8
Astrophysics + Webb Total	1,376.1		1,350.9	1,295.3	1,297.0	1,315.8	1,342.3

Planetary Budget Features: What's Changed

- **InSight** future launch options are under review
- Releases the next **New Frontiers** AO in January 2017
- Established Outer Planets and Ocean Worlds program
- Funds all extended missions through FY 2017, pending results from the 2016 Senior Review
- New multi-directorate Aeroscience Ground Test Capabilities project established to sustain Mars entry, descent, and landing test capabilities
- Increases investments in Planetary technology, including power
- Includes funding to study a Mars orbiter to fly in the 2020s, in collaboration with STMD and HEOMD

Ocean Worlds: Europa Mission



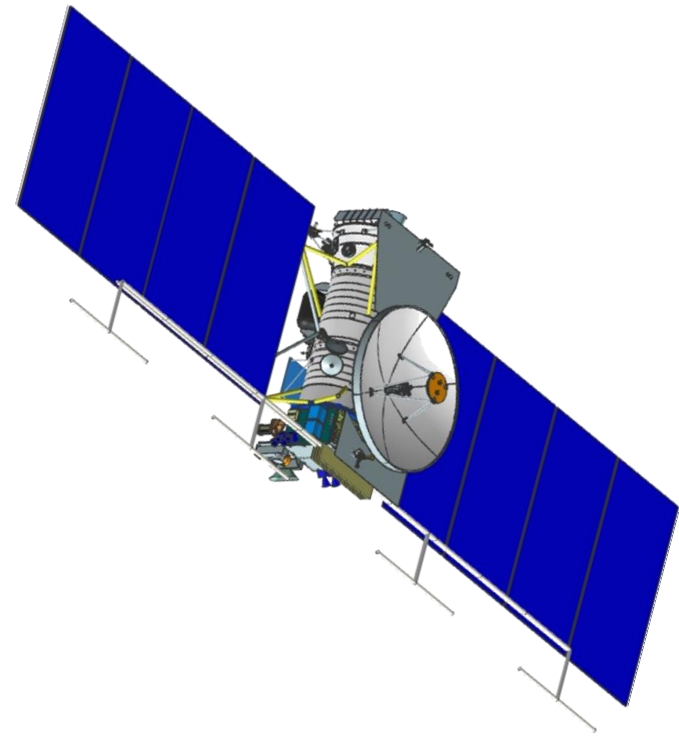
Science	
Objective	Description
Ice Shell & Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange
Composition	Understand the habitability of Europa's ocean through composition and chemistry.
Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.
Recon	Characterize scientifically compelling sites, and hazards for a potential future landed mission to Europa

Recent Accomplishments:

- Established an Outer Planets and Ocean Worlds Program
- The flyby concept takes advantage of solar power and requires no new technology development, despite the harsh radiation environment. Completed instrument accommodation studies.

FY16-17 Milestones:

- Enter Phase B for the flyby element in early FY17
- Complete lander studies



Planetary Science Program Content

	Actual FY 201	Enacted FY 201	Request FY 201	Notional			
				FY 201	FY 201	FY 202	FY 202
Planetary Science	1,446.7	1,631.0	1,518.7	1,439.7	1,520.1	1,575.5	1,625.7
<u>Planetary Science Research</u>	<u>252.</u>		<u>284.</u>	<u>271.</u>	<u>285.</u>	<u>281.</u>	<u>287.</u>
Planetary Science Research and Analysis	162.4		178.1	164.3	168.5	168.0	172.4
Near Earth Object Observations	40.0		50.0	50.0	50.0	50.0	50.0
Directorate Management	4.0		4.1	4.1	4.1	4.1	4.1
<u>Other Missions and Data Analysis</u>	<u>46.</u>		<u>52.</u>	<u>53.</u>	<u>63.</u>	<u>59.</u>	<u>60.</u>
Joint Robotics Program for Exploration	10.0		10.0	10.0	10.0	10.0	10.0
Rosetta	14.3		8.8	5.4	-	-	-
Planetary Data System	13.7		14.5	14.6	14.7	14.8	14.9
Astromaterial Curation	6.4		9.1	9.8	10.0	10.2	10.4
Science Data & Computing	2.0		2.4	2.5	2.7	2.7	2.8
Science Innovation Fund	-		5.0	6.0	6.0	6.0	6.0
Planetary Science Directed R&T	-		2.7	4.9	19.8	15.8	16.7

Planetary Science Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
<u>Discovery</u>	<u>259.7</u>		<u>202.5</u>	<u>277.3</u>	<u>337.4</u>	<u>345.0</u>	<u>405.3</u>
InSight	170.0	92.1	13.3	8.7	9.0	9.0	-
<u>Other Missions and Data Analysis</u>	<u>89.7</u>		<u>189.2</u>	<u>268.6</u>	<u>328.4</u>	<u>336.0</u>	<u>405.3</u>
Discovery Future	25.0		136.1	212.1	289.9	300.9	371.4
International Mission Contributions	1.9		1.8	2.3	3.3	2.4	1.9
Strofi o	0.3		0.6	0.7	0.7	0.6	0.6
Lunar Reconnaissance Orbiter	19.8		20.0	20.0	-	-	-
Dawn	17.2		1.0	-	-	-	-
MESSENGER	6.0		-	-	-	-	-
Gravity Recovery and Interior Laboratory	2.4		-	-	-	-	-
Discovery Research	9.5		13.3	16.8	16.6	14.9	14.4
Discovery Management	7.6		-	-	-	-	-
Planetary Missions Program Office	-		16.4	16.7	17.9	17.2	17.0
<u>New Frontiers</u>	<u>286.0</u>		<u>144.0</u>	<u>81.6</u>	<u>90.7</u>	<u>142.8</u>	<u>234.0</u>
OSIRIS-REx	209.8	189.7	44.0	38.1	43.1	27.7	16.5
<u>Other Missions and Data Analysis</u>	<u>76.2</u>		<u>100.0</u>	<u>43.5</u>	<u>47.6</u>	<u>115.1</u>	<u>217.5</u>
New Frontiers Future Missions	12.0		42.6	12.0	28.1	90.2	203.5
Juno	35.4		39.1	14.5	-	-	-
New Horizons	28.8		14.0	12.0	12.0	12.0	-
New Frontiers Research	-		4.3	5.0	7.5	12.9	14.0

Planetary Science Program Content (cont'd)

	<u>Actual</u> <u>FY 201</u>	<u>Enacted</u> <u>FY 201</u>	<u>Request</u> <u>FY 201</u>	<u>Notional</u>			
				<u>FY 201</u>	<u>FY 201</u>	<u>FY 202</u>	<u>FY 202</u>
<u>Mars Exploratio</u>	<u>305.</u>		<u>584.</u>	<u>588.</u>	<u>565.</u>	<u>498.</u>	<u>279.</u>
Mars Rover 2020	103.6		377.5	409.0	381.0	322.0	140.0
<u>Other Missions and Data Analy</u>	<u>201.</u>		<u>207.</u>	<u>179.</u>	<u>184.</u>	<u>176.</u>	<u>139.</u>
Mars Future Missions	-		10.0	12.0	12.0	12.0	12.0
Aeroscience Ground Test Capabilities	-		14.6	15.5	21.5	22.2	22.2
Mars Technology	7.0		0.5	2.6	17.1	61.3	34.4
Mars Organic Molecule Analyzer (MOMA)	24.5		6.8	5.2	4.6	3.0	1.5
ExoMars	1.5		1.4	1.4	1.5	1.5	1.5
2011 Mars Science Lab	63.5		58.0	58.0	48.0	-	-
Mars Atmosphere & Volatile EvolutioN	13.8		28.0	26.0	20.0	18.0	18.0
Mars Reconnaissance Orbiter 2005 (MRO)	27.9		27.9	27.9	27.9	27.9	27.9
Mars Exploration Rover 2003	13.7		13.7	-	-	-	-
Mars Odyssey 2001	12.0		12.7	-	-	-	-
Mars Express	2.5		2.6	-	-	-	-
Mars Mission Operations	1.5		1.9	1.9	1.9	1.9	1.9
Mars Research and Analysis	10.0		9.3	9.6	9.7	9.7	9.7
Mars Program Management	23.5		19.9	19.7	19.8	18.9	10.8

Planetary Science Program Content (cont'd)

	Actual FY 201	Enacted FY 201	Request FY 201	Notional			
				FY 201	FY 201	FY 202	FY 202
<u>Outer Planets and Ocean World</u>	<u>184.</u>		<u>137.</u>	<u>56.</u>	<u>77.</u>	<u>128.</u>	<u>247.</u>
Jupiter Europa	100.0	175.0	49.6	24.2	65.2	117.5	236.5
JUICE - Jupiter Icy Moons Explorer	7.4		20.5	17.4	4.1	2.0	2.3
Cassini	68.1		58.7	5.9	-	-	-
Outer Planets Research	8.5		8.5	8.5	8.5	8.5	8.5
<u>Technology</u>	<u>159.</u>		<u>165.</u>	<u>164.</u>	<u>163.</u>	<u>179.</u>	<u>172.</u>
DOE Radioisotope Power Sys Infrastructure	57.4		56.0	59.1	59.1	60.1	61.6
Nuclear Power Radioisotope System Dev	25.2		29.3	29.3	29.4	29.6	30.5
Plutonium	17.0		15.0	15.0	19.0	19.0	19.5
Advanced Multi-Mission Operation System	35.4		37.2	38.0	38.8	39.6	40.4
Europa Technology	18.0		-	-	-	-	-
Advanced Technology	6.2		28.0	23.0	17.2	31.4	20.0

Earth Science Budget Features:

What's New

- **Successful Launches:** RapidScat, CATS, SMAP
- **Mission Selections:** 6 Earth Venture Sub-Orbital (EVS)-2 airborne investigations
- **Missions Ended:** Aquarius, TRMM (both in extended mission)
- **New Climate Missions Accommodated:** TSIS-1 completion, Jason-CS/Sentinel-6B
- **New Missions Initiated:** Landsat-9 (FY2021), PACE (FY2023); *Thermal Infrared Free-Flyer removed from Sustainable Land Imaging (SLI) plan*
- **RBI:** Augmented budget to accommodate development challenges
- **Venture Class Launch Services (VCLS):** ESD partnership with LSP for new, small launch vehicles – Virgin-Galactic, RocketLab, Firefly selected in FY15 and supported for launches before April 2018
- **Small Satellite Constellation Program Initiated:** To advance system design, technology, and launch/operations approaches for achieving key science measurements from paradigm-shifting constellations of small satellites

Sustainable Land Imaging (SLI)

- FY 2017 budget continues a multi-decadal Sustainable Land Imaging (SLI) program that provides high-quality, global land imaging measurements, involving accelerated Landsat 9 (fully Class-B rebuild of Landsat 8) to launch in FY21, Landsat 10 to launch in 2027-2028, and Land Imaging Technology and System Innovation investments to mature technologies for Landsat 10 and future missions.
- Landsat-9 development has been initiated and the mission will launch in FY2021
- Sustained, targeted technology investments are underway and will continue, to inform Landsat-10 architecture decisions by the end of this decade and to assure infusion of new technology throughout the SLI Program
- Landsat-10 architecture decisions and initial development within this budget window

Small Satellite Constellations

- Small satellite constellations new effort (\$30M)
- Potential small satellite constellation activities include
 - on-orbit technology validation and risk reduction for small instruments;
 - fostering commercial launch services dedicated to transporting small payloads into orbit; and
 - funding competitive grants for small satellite proposals.

Earth Science Program Content

	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional			
				FY 2018	FY 2019	FY 2020	FY 2021
Earth Science	1,784.1		2,032.2	1,989.5	2,001.3	2,020.9	2,047.7
<u>Earth Science Research</u>	<u>453.2</u>		<u>501.7</u>	<u>472.9</u>	<u>461.3</u>	<u>475.9</u>	<u>484.2</u>
<u>Earth Science Research and Analysis</u>	<u>331.6</u>		<u>360.7</u>	<u>322.6</u>	<u>312.4</u>	<u>322.4</u>	<u>326.7</u>
Earth Science R&A	149.6		168.1	138.7	139.7	148.8	150.9
Interdisciplinary Science	66.7		80.3	72.4	68.7	73.1	74.1
Airborne Science	49.2		48.2	47.2	39.8	34.3	34.9
Space Geodesy	27.9		25.0	24.0	24.0	25.5	25.9
Global Modeling & Assimilation Office	10.8		10.4	10.4	10.4	10.7	10.9
Carbon Monitoring System	10.0		10.0	10.0	10.0	10.0	10.0
Fellowships and New Investigators	6.5		7.8	8.9	8.9	8.9	8.9
GLOBE	6.0		6.0	6.0	6.0	6.0	6.0
Carbon Cycle Science Team	2.5		2.5	2.5	2.5	2.5	2.6
Ozone Trends Science	2.5		2.5	2.5	2.5	2.5	2.6
<u>Computing and Management</u>	<u>121.7</u>		<u>141.0</u>	<u>150.3</u>	<u>148.8</u>	<u>153.5</u>	<u>157.5</u>
High End Computing Capability	44.9		47.4	47.5	47.5	48.4	49.1
Scientific Computing	22.4		22.3	21.8	21.5	23.2	23.5
Directorate Support	54.4		56.8	59.1	61.0	59.5	61.2
Earth Sci Directed Research & Technology	-		14.5	22.0	18.8	22.4	23.7

Earth Science Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
<u>Earth Systematic Missions</u>	<u>827.3</u>		<u>933.0</u>	<u>965.5</u>	<u>1,021.3</u>	<u>1,005.0</u>	<u>1,000.1</u>
Ice, Cloud, and land Elevation Satellite (ICESat-2)	126.5	117.4	112.4	66.6	14.2	14.2	14.4
GRACE Follow -On	84.7	59.9	33.7	20.5	11.3	12.3	12.2
Surface Water and Ocean Topography	83.8		83.7	105.9	126.3	81.0	42.0
NASA-ISRO SAR	50.6		68.5	85.0	150.0	145.0	100.0
<u>Other Missions and Data Analysis</u>	<u>481.8</u>		<u>634.7</u>	<u>687.5</u>	<u>719.5</u>	<u>752.6</u>	<u>831.6</u>
Decadal Survey Missions	25.8		15.4	14.4	15.5	38.8	204.2
Landsat 9	60.3		130.8	179.3	166.4	128.3	109.0
Sustainable Land Imaging	3.8		5.8	11.0	11.1	36.0	64.9
Pre-Aerosol, Clouds, and Ocean Ecosystem	20.0		88.8	78.8	144.4	196.0	137.1
Radiation Budget Instrument (RBI)	44.7		54.3	46.0	17.2	9.4	6.8
Sentinel-6	-		42.5	56.4	71.3	66.5	37.2
Total Solar Irradiance Sensor-1 (TSIS-1)	1.0		19.6	4.2	3.4	3.4	3.5
CLARREO Pathfinder	-		19.3	27.9	15.4	2.1	0.2
Total Solar Irradiance Sensor-2 (TSIS-2)	-		9.6	23.9	36.9	26.5	17.0
Sage III	24.3		4.6	4.8	4.6	4.6	4.6
Ozone Mapping and Profiler Suite (OMPS)	4.3		2.2	0.3	-	-	-
Aqua	27.8		28.1	27.3	27.3	27.8	28.3
Terra	26.2		26.1	25.3	25.3	25.9	26.3
Aura	26.8		23.9	25.9	25.9	26.4	29.8
Global Precipitation Measurement (GPM)	21.2		21.1	20.0	20.0	20.1	20.0

(continued on next slide)

Earth Science Program Content (cont'd)

	Actual FY 2015	Enacted FY 2016	Request FY 2017	Notional			
				FY 2018	FY 2019	FY 2020	FY 2021
(ESM OM&DA, cont'd)							
Soil Moisture Active and Passive (SMAP)	63.1		8.4	11.3	11.3	11.5	11.7
SORCE	5.4		5.4	4.7	-	-	-
Earth from ISS	3.8		3.5	2.8	2.6	2.6	2.6
Suomi National Polar-Orbiting Partnership	4.0		3.4	3.4	3.5	3.6	3.7
Tropical Rainfall Measuring Mission	10.1		3.2	-	-	-	-
Landsat 8	2.2		2.4	2.4	-	-	-
Deep Space Climate Observatory	2.9		1.7	1.2	1.2	0.8	-
Ocean Surface Topography Mission (OSTM)	2.2		1.5	2.3	2.3	2.3	2.4
Earth Observing-1	2.6		1.4	-	-	-	-
Quick Scatterometer	2.1		-	-	-	-	-
ACRIMSAT	0.6		-	-	-	-	-
Earth Observations Systems Research	23.1		22.7	20.7	17.7	18.8	19.0
Earth Systematic Missions (ESM) Research	12.8		18.6	18.6	23.8	26.2	26.5
Earth Radiation Budget Science	11.8		14.0	13.7	13.6	13.8	14.0
Precipitation Science Team	7.3		6.9	6.9	6.9	7.1	7.2
Ocean Surface Topography Science Team	6.1		5.7	5.7	5.7	5.9	5.9
Ocean Winds Science Team	4.5		4.2	4.2	4.2	4.3	4.4
Ocean Salinity Science Team	-		3.9	7.8	7.8	8.0	8.1
Land Cover Science Project Office	1.5		1.5	1.5	1.5	1.6	1.6
Earth Science Program Management	29.5		34.0	34.6	32.6	34.3	35.5

Earth Science Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<u>Earth System Science Pathfinder</u>	<u>223.8</u>		<u>296.0</u>	<u>248.6</u>	<u>216.7</u>	<u>227.8</u>	<u>245.1</u>
<u>Venture Class Missions</u>	<u>169.1</u>		<u>194.3</u>	<u>199.6</u>	<u>174.7</u>	<u>184.3</u>	<u>199.9</u>
Venture Class Missions	27.3		70.0	124.3	121.9	145.7	171.7
Earth Venture Suborbital-2	20.7		37.0	31.5	16.7	3.2	-
Global Ecosystem Dynamics Investigation	22.6		34.8	10.9	5.2	0.4	-
CYGNSS	26.1		20.8	4.9	2.5	0.4	-
ECOsystem Spaceborne Thermal Radiometer	15.5		12.8	5.7	0.4	-	-
TEMPO	34.4		12.5	16.3	22.2	30.4	26.4
Earth Venture Management	22.5		6.3	6.1	5.9	4.2	1.8
<u>Other Missions and Data Analysis</u>	<u>54.6</u>		<u>101.7</u>	<u>49.0</u>	<u>42.0</u>	<u>43.5</u>	<u>45.2</u>
Small Satellite Constellation Initiative	-		30.0	-	-	-	-
Orbiting Carbon Observatory-3	1.5		26.3	9.5	4.2	6.6	6.8
OCO-2	17.5		10.2	10.1	10.4	10.0	10.2
CloudSat	7.5		8.5	4.1	2.0	-	-
GRACE	5.0		5.4	2.3	1.3	-	-
CALIPSO	6.4		5.1	7.1	7.1	7.2	7.3
Aquarius	3.4		3.0	-	-	-	-
ESSP Missions Research	13.4		13.2	15.9	17.0	19.7	21.0

Earth Science Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
<u>Earth Science Multi-Mission Operations</u>	<u>179.7</u>		<u>191.8</u>	<u>194.3</u>	<u>193.6</u>	<u>197.9</u>	<u>202.6</u>
Multi-Mission Operations	155.4		159.2	160.7	160.3	163.9	168.2
EOSDIS	24.3		32.6	33.6	33.3	34.0	34.5
<u>Earth Science Technology</u>	<u>59.7</u>		<u>61.4</u>	<u>60.4</u>	<u>59.7</u>	<u>62.7</u>	<u>63.7</u>
Instrument Incubator	27.8		28.6	28.6	28.6	29.5	29.9
Advanced Technology Initiatives	18.4		18.8	17.7	17.1	18.8	19.1
Advanced Info Systems technology	13.6		14.1	14.1	14.1	14.5	14.7
<u>Applied Sciences</u>	<u>40.4</u>		<u>48.2</u>	<u>47.9</u>	<u>48.7</u>	<u>51.5</u>	<u>52.0</u>
Applications	18.8		26.4	26.3	26.0	26.2	26.3
Capacity Building	9.9		10.9	11.1	13.2	14.1	14.3
Mission and Applied Research	8.8		5.5	5.0	4.0	5.7	5.7
Disaster Support	3.0		5.5	5.5	5.5	5.5	5.7

Heliophysics Changes from the FY16 Budget

- Missions in Development

- SPP launch vehicle award requires re-phase of payments from plan at confirmation with no change in life-cycle costs
- SOC re-phase to accommodate LRD delay to October 2018 Agency Baseline Commitment
- GOLD funding profile changed to match KDP-C Confirmation
- ICON minor re-phase of launch vehicle payment schedule

- Missions in Prime Ops

- MMS out-year funding identified for Extended Ops after FY18. MMS life-cycle cost also decreased as a result of launch vehicle savings.
- SDO funding identified to allow transition from Prime Ops to Extended Ops during FY15

- Research and analysis augmentation

- To support development of innovative CubeSats as part of overall Low-Cost Access to Space (LCAS)
- Space Weather Action Plan (SWAP)

Heliophysics Program Content

	Actual	Enacted	Request	Notional			
	<u>FY 2015</u>	<u>FY 2016</u>	<u>FY 2017</u>	<u>FY 2018</u>	<u>FY 2019</u>	<u>FY 2020</u>	<u>FY 2021</u>
Heliophysics	636.1		698.7	684.0	698.3	714.8	723.9
<u>Heliophysics Research</u>	<u>192.0</u>		<u>180.1</u>	<u>192.0</u>	<u>210.0</u>	<u>215.9</u>	<u>214.2</u>
Heliophysics Research and Analysis	34.1		38.9	48.9	53.9	53.9	53.9
Sounding Rockets	66.2		53.3	59.0	61.1	63.1	63.1
Research Range	21.3		21.7	21.7	25.1	25.1	25.2
<u>Other Missions and Data Analysis</u>	<u>70.4</u>		<u>66.2</u>	<u>62.4</u>	<u>70.0</u>	<u>73.7</u>	<u>71.9</u>
CubeSat	6.5		15.0	5.0	5.0	5.0	5.0
Voyager	5.5		5.6	5.5	5.6	5.5	5.5
SOHO	2.2		2.3	2.2	2.3	2.3	2.3
Wind	1.8		2.2	2.2	2.2	2.2	2.2
Geotail	0.2		0.2	0.2	0.2	0.2	0.2
Cluster-II	0.2		-	-	-	-	-
Space Science Mission Ops Services	11.3		11.5	11.5	11.6	11.9	11.9
Data & Modeling Services	2.0		2.8	2.7	3.0	3.0	3.0
Space Physics Data Archive	2.0		2.3	2.3	2.3	2.3	2.3
Community Coordinated Modeling Center	2.2		2.2	2.2	2.3	2.4	2.4
Solar Data Center	0.9		1.1	1.2	1.3	1.1	1.2
Guest Investigator Program	10.8		10.3	15.2	24.3	24.7	24.7
Science Planning and Research Support	6.5		6.7	6.8	6.8	6.8	6.8
Directed Research & Technology	18.4		3.9	5.4	3.2	6.3	4.5

Heliophysics Program Content (cont'd)

	Actual	Enacted	Request	Notional			
	FY 201	FY 201	FY 201	FY 201	FY 201	FY 202	FY 202
<u>Living with a Star</u>	<u>263.</u>		<u>374.</u>	<u>398.</u>	<u>244.</u>	<u>135.</u>	<u>127.</u>
Solar Probe Plus	193.7	238.6	232.5	289.7	100.4	30.6	22.1
Solar Orbiter Collaboration	20.5	49.8	80.7	51.4	66.3	2.3	2.4
<u>Other Missions and Data Analysis</u>	<u>49.</u>		<u>61.</u>	<u>57.</u>	<u>77.</u>	<u>103.</u>	<u>102.</u>
Van Allen Probes (RBSP)	13.0		13.3	13.0	13.0	9.0	-
Solar Dynamics Observatory (SDO)	13.1		12.0	11.8	12.0	12.0	12.0
LWS Space Environment Testbeds	0.4		0.4	-	-	-	-
BARREL	0.2		-	-	-	-	-
LWS Science	17.4		27.5	24.0	30.5	30.3	30.3
LWS Management and Future Missions	5.3		7.8	8.9	22.3	51.7	60.5
<u>Solar Terrestrial Probe</u>	<u>70.</u>		<u>39.</u>	<u>38.</u>	<u>127.</u>	<u>179.</u>	<u>198.</u>
Magnetospheric Multiscale (MMS)	52.4		17.4	14.6	11.0	11.0	4.0
STEREO	7.5		9.5	9.3	9.5	9.5	9.5
Hinode (Solar B)	7.5		7.0	6.8	7.0	7.0	7.0
TIMED	2.8		2.6	2.4	2.5	2.5	2.5
STP Management and Future Missions	0.4		3.4	5.7	97.4	149.4	175.4

Heliophysics Program Content (cont'd)

	<u>Actual</u> <u>FY 201</u>	<u>Enacted</u> <u>FY 201</u>	<u>Request</u> <u>FY 201</u>	<u>Notional</u>			
				<u>FY 201</u>	<u>FY 201</u>	<u>FY 202</u>	<u>FY 202</u>
<u>Heliophysics Explorer Program</u>	<u>110.</u>		<u>104.</u>	<u>54.</u>	<u>116.</u>	<u>183.</u>	<u>184.</u>
ICON	61.0	48.4	49.4	9.0	4.5	1.3	-
<u>Other Missions and Data Analy</u>	<u>48.</u>		<u>55.</u>	<u>45.</u>	<u>111.</u>	<u>182.</u>	<u>184.</u>
Heliophysics Explorer Future Missions	-		3.3	8.5	74.5	149.3	156.1
GOLD	13.9		16.3	8.6	4.6	2.0	-
Interface Region Imaging Spectogr (IRIS)	8.2		7.7	6.8	7.0	6.5	6.5
THEMIS	5.4		5.4	5.0	5.1	4.5	4.5
Interstellar Boundary Explorer (IBEX)	3.4		3.4	3.3	3.4	3.4	3.4
ACE	3.0		3.0	2.9	3.0	3.0	3.0
Aeronomy of Ice in Mesosphere (AIM)	3.0		3.0	2.9	3.0	3.0	3.0
RHESSI	1.8		1.9	1.9	1.9	1.9	1.9
TWINS	0.6		0.6	0.6	0.6	0.6	0.6
CINDI	1.2		0.3	0.2	-	-	-
Heliophysics Explorer Program Management	8.5		10.4	4.8	8.8	8.3	5.0

SMD Science Education Restructuring

- FY17 request provides \$25M for SMD Science Education activities
- Additional \$6M for GLOBE within Earth Science budget
- Competitively-selected awardees in the restructured program will enable NASA science experts and content to engage more effectively and efficiently with learners of all ages.
- SMD's new strategic approach transitions from mission-based content to science discipline-based content more consistent with stakeholder priorities and user needs. Approach reduces fragmentation and ensures more collaboration over a longer term.
- Objectives:
 - Enable STEM Education
 - Improve US Scientific Literacy
 - Advance National Educational Goals
 - Leverage Through Partnerships
- Awards completed early 2016

FY17 Budget Request - Summary

This is a good budget request for Science!

- \$5.6B request is consistent with actual FY16 Appropriation, about 6% over the FY15 level
- Request maintains balance between and within themes
- Request accelerates Landsat 9 and makes progress on WFIRST and Europa formulation
- Good cost and schedule performance on existing commitments continues to provide stability

END