U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE

An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2017

Thursday, March 17, 2016
10:00 a.m.
2318 Rayburn House Office Building

Purpose

On Thursday, March 17, 2016, the Space Subcommittee will hold a hearing titled *An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2017* in Room 2318 of the Rayburn House Office Building. The purpose of the hearing is to review the Administration's fiscal year 2017 (FY17) budget request for the National Aeronautics and Space Administration (NASA).

Witness

The Honorable Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration

Background

NASA is the world's leading civilian space agency; it employs approximately 17,200 civil servants and supports thousands more through contract work. In addition to its headquarters, the agency operates nine federal research facilities; Goddard Space Flight Center in Greenbelt, MD; Kennedy Space Center in Merritt Island, FL; Langley Research Center in Hampton, VA; Glenn Research Center in Cleveland, OH; Johnson Space Center in Houston, TX; Ames Research Center in Mountain View, CA; Armstrong Flight Research Center at Edwards Air Force Base, CA; Marshall Space Flight Center in Huntsville, AL; and, Stennis Space Center in Bay St. Louis, MS. The Jet Propulsion Laboratory (JPL) in Pasadena, CA is a NASA-sponsored Federally Funded Research and Development Center operated by the California Institute of Technology. NASA also owns the Wallops Flight Facility in Wallops Island, Virginia, and the Michoud Assembly Facility east of New Orleans, Louisiana.

The President's FY17 budget request was released on Tuesday, February 9, 2016. NASA requested $18.262 billion, a decrease of $1.023 billion from what was appropriated for the agency in FY16. For each of the fiscal years 2017 – 2021, the budget topline request includes modest increases for inflation (one-and-a-half percent). The agency considers the out-year funding levels to be "notional." In addition to the $18.262 billion request for discretionary funding, the Administration is also requesting an additional $763 million in proposed mandatory

funding. In the FY17 Budget Request, the President proposes both single-year mandatory funding, as well as additional multi-year mandatory funding.

For clarity, the tables in this charter reference both discretionary and mandatory spending requests. The substantive text of this charter reference and use discretionary funding requested, unless otherwise indicated. The last section of this charter, titled *Mandatory Spending Requests*, provides a summary of the mandatory spending requests.

Budget Request

Budget Authority ($ in millions)	FY15 Operating	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
NASA Total	18,010.2	19,285.0	18,262.00	763.0	18,826.6	19,399.9	19,879.9	20,367.5
Science	5,243.0	5,589.0	5,302.50	298.0	5,408.5	5,516.7	5,627.0	5,739.6
Earth Science	1,784.1		1,972.20	60.0	1,989.5	2,001.3	2,020.9	2,047.7
Planetary Science	1,446.7		1,390.70	128.0	1,439.7	1,520.1	1,575.5	1,625.7
Astrophysics	730.7		696.50	85.0	761.6	992.4	1,118.6	1,192.5
James Webb Space Telescope	645.4	620.0	569.40	-	533.7	304.6	197.2	149.8
Heliophysics	636.1		673.70	25.0	684.0	698.3	714.8	723.9
Aeronautics	642.0	640.0	634.50	155.9	846.4	1,060.1	1,173.3	1,286.9
Space Technology	600.3	686.5	690.60	136.1	704.4	718.5	732.9	747.5
Exploration	3,542.7	4,030.0	3,163.80	173.0	3,529.7	4,081.7	4,243.6	4,261.7
Exploration Systems Dev	3,211.5	3,680.0	2,686.50	173.0	2,922.5	3,061.6	3,092.2	3,142.3
Orion			1,053.40	66.4				
SLS			1,229.90	80.4				
Exploration Ground Systems			403.20	26.2				
Commercial Spaceflight	805.0	1,243.8	0.00	-				
Exploration R&D	331.2	350.0	477.30	-	607.2	1,020.1	1,151.4	1,119.5
Space Operations	4,625.5	5,029.2	5,075.80	-	4,912.8	4,529.7	4,540.1	4,697.6
Space Shuttle	7.7		0.00	-	0.0	0.0	0.0	0.0
International Space Station	1,524.8		1,430.70	-	1,554.7	1,536.8	1,539.3	1,585.2
Space Transportation	2,254.0		2,757.70	-	2,475.0	2,118.7	2,144.4	2,213.9
Crew and Cargo			1,572.80	-				
Commercial Crew Dev			1,184.80	-				
Space and Flight Support (SFS)	839.0		887.40	-	883.2	874.1	856.4	898.6
Education	119.0	115.0	100.10	-	102.1	104.1	106.2	108.3
Saf, Sec, & Msn Serv	2,754.6	2,768.6	2,836.80	-	2,893.6	2,951.5	3,010.4	3,070.6
Center Management and Ops	2,023.7		2,017.70	-	2,058.1	2,113.5	2,155.6	2,198.8
Agency Management and Ops	730.9		819.10	-	835.5	838.0	854.8	871.8
Const & Env Comp & Rest	446.1	388.9	419.80	-	390.2	398.0	406.0	414.1
Construction of Facilities	374.4		328.00	-	297.9	303.8	310.1	317.9
Enviro Comp and Resto	71.7		91.80	-	92.3	94.2	95.9	96.2
Inspector General	37.0	37.4	38.10	-	38.9	39.6	40.4	41.2
NASA Total	18,010.2	19,285.0	18,262.00	763.0	18,826.6	19,399.9	19,879.9	20,367.5

Note: The FY17 request represents a transfer of activities from the Commercial Spaceflight program line to the Space Transportation program line.

This year's request contains several items of note:

1. Congress has consistently appropriated close to $1.2 billion each year for the past four years for the development of the Orion Multipurpose Crew Vehicle ("Orion") to ensure Orion remains on schedule. However, year after year, NASA requests less than the prior

fiscal year's appropriated amount. In the FY17 PBR, NASA has requested approximately $215 million less than FY16 appropriations.

2. Congress had made clear in appropriation and authorization legislation that the Space Launch System is a top priority of the Human Exploration program, yet for the fifth year in a row, the Administration has reduced the budget request. The FY17 budget request seeks a reduction of approximately $770 million for launch vehicle development compared with the FY16 appropriation.
3. Although widely critiqued by its own advisory committees, NASA is requesting approximately $182.7 million to continue work on the Asteroid Retrieval and Redirect Mission. The Administration's FY 2017 request for the Asteroid Redirect Mission totals $182.7 million, and includes funds dispersed throughout the mission directorates. The request includes $66.7 million in the Human Exploration and Operations (HEO) Mission Directorate; $65 million in the Space Technology Mission Directorate (STMD) (all of which would be leveraged) for high-powered solar electric propulsion development and for RESTORE-L (a technology demonstration mission capable of servicing a U.S. government satellite in low Earth orbit); $50 million in the Science Mission Directorate (all of which would be leveraged) for near-Earth object observations; and $1 million for the Chief Technologist for Asteroid Grand Challenge prizes.
4. The budget request proposes continued funding the formulation of a Europa mission at $16.6 million. This is significantly lower than the $175 million appropriated by Congress in FY16.
5. NASA requested $2.757 billion for Space Transportation to procure crew access to the International Space Station (ISS) and deliver cargo. This $2.757 billion includes funding to purchase American astronauts seats on the Russian Soyuz crew spacecraft. In 2015, NASA extended its contract with Russia to fly astronauts to the ISS. This contract runs through 2019 and will cost up to $490 million.[1]

Asteroid Redirect/Retrieval Mission

On April 15th, 2010, President Obama gave a speech at Kennedy Space Center that provided the original vision and rationale for the Asteroid Redirect/Retrieval Mission. "I understand that some believe we should attempt a return to the surface of the Moon first, as previously planned. But I just have to say pretty bluntly here. We've been there before."[2] Instead, President Obama said U.S. astronauts will venture beyond Earth's orbit in 2025, starting with a crewed mission to an asteroid. "By 2025 we expect new spacecraft designed for long journeys to allow us to begin the first ever crewed missions beyond the Moon into deep space. So we'll start by sending astronauts to an asteroid for the first time in history."[3]

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[1] Jeff Foust, "NASA, Blaming Commercial Crew Cuts, Extends Soyuz Contract," *SpaceNews*, August 5, 2015. Retrieved at: http://spacenews.com/nasa-blaming-commercial-crew-cuts-extends-soyuz-contract/ (Last Accessed on March, 15th, 2016).
[2] Brian Berger, "Obama Pledges 2025 Mission to Asteroid." *SpaceNews*, April 15, 2010. Retrieved at: http://spacenews.com/obama-pledges-2025-mission-asteroid/ (Last Accessed on March, 15th, 2016).
[3] Ibid.

As part of the President's budget request for FY14, NASA announced the development of a new mission concept it referred to as the "Asteroid Redirect Mission" (ARM). The original mission concept proposed to capture and redirect a small near-Earth asteroid (NEA) of 7-10 meters in size to a deep retrograde lunar orbit. The mission concept has been altered significantly since it was first proposed. The mission now calls for a robotic probe to visit a NEA in its native orbit and retrieve a smaller boulder from the surface of that asteroid. The probe would then carry the rock into a lunar orbit to be visited by astronauts using Orion. This is in contrast to the original proposal to capture an asteroid in its native orbit to be "tugged" to lunar orbit.

NASA and other space agencies have done and are undertaking robotic asteroid sample return missions, raising the question of why NASA should fund a human spaceflight mission for an asteroid sample return. The NASA OSIRIS-REx mission, to be launched this year, will attempt to capture approximately 60 grams of regolith from the asteroid, Bennu, and return it to Earth robotically for less than one billion dollars.[4] In 2010, the Japanese Aerospace Exploration Agency (JAXA) Hayabusa spacecraft successfully returned a sample from asteroid Itokawa to Earth.[5] JAXA's Hayabusa 2 spacecraft is en route to asteroid 162173 Ryugu, scheduled to arrive in 2020.[6]

Although the mission concept has changed dramatically, the Administration continues to request funding for elements common to both the original and revised concept. The Administration again requested funding to search for an appropriate asteroid based on size, composition, and orbit, commonly referred to as "identifying and characterizing." This activity will be carried out by the Science Mission Directorate. Next, NASA intends to develop the robotic spacecraft necessary to capture and move the boulder into lunar orbit (Asteroid Redirect Robotic Mission, ARRM). The development of high-power solar electric propulsion (SEP) will be necessary to travel to the asteroid and then to transfer it to lunar orbit. This effort would be conducted by the Space Technology Mission Directorate. Finally, once in cis-lunar space, the mission concept will have astronauts explore the redirected asteroid via SLS rocket and Orion spacecraft and return samples to Earth (Asteroid Redirect Crewed Mission, ARCM), conducted by the Human Exploration and Operations Directorate.[7]

The original mission concept was based on a study by the Keck Institute for Space Studies (Keck Study) at the California Institute of Technology in partnership with the Jet

[4] OSIRIS-REx, NASA. Retrieved at: http://science.nasa.gov/missions/osiris-rex/ (Last Accessed on March, 15th, 2016).
[5] "Asteroid Dust Sucessfully Returned by Japanese Space Probe." *SpaceNews*, November 22, 2010. Retrieved at: http://spacenews.com/asteroid-dust-successfully-returned-japanese-space-probe/ (Last Accessed March 15, 2016).
[6] Stephen Clark, "Target of Japanese space mission named for dragon's palace." *Spaceflight Now*, October 5, 2015. Retrieved at: http://spaceflightnow.com/2015/10/05/target-of-japanese-space-mission-named-for-dragons-palace/ (Last Accessed on March, 15th, 2016).
[7] Jeff Foust, "To catch a planetoid." *The Space Review*, April 22, 2013. Retrieved at: http://www.thespacereview.com/article/2283/1 (Last Accessed on March, 15th, 2016).

Propulsion Laboratory.[8] NASA Associate Administrator Robert Lightfoot stated the robotic part of ARM would fit within a cost cap of $1.25 billion, excluding the launch vehicle and other leveraged costs.[9] The NASA Advisory Council (NAC) called for an independent cost and technical assessment of the mission options.[10] Additionally, the NAC proposed a finding that NASA would be better served by utilizing a SEP demonstration for a Mars mission rather than ARM.[11]

In December 2012, the National Academy of Sciences released a report about NASA's strategic direction. That report stated:

> "[t]he committee has seen little evidence that a current stated goal for NASA's human spaceflight program—namely, to visit an asteroid by 2025—has been widely accepted as a compelling destination by NASA's own workforce, by the nation as a whole, or by the international community. On the international front there appears to be continued enthusiasm for a mission to the Moon but not for an asteroid mission."[12]

The NASA Authorization Act of 2010 required NASA to contract with the National Academies of Science to review the future of human spaceflight.[13] That report found that several components of the ARM concept were considered "dead-end mission elements" that would not benefit NASA in developing the necessary skills and technologies to get humans to Mars.[14]

In 2013, the Small Bodies Assessment Group (SBAG), NASA's own advisory group focused on near Earth objects (NEO), found the ARM proposal "to be very interesting and entertaining," but that, "it was not considered to be a serious proposal."[15] More recently, in 2016, the SBAG reaffirmed that "consistent with previous findings, for science-driven missions, SBAG continues to support the priorities identified in the Decadal Survey to guide use of Planetary

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[8] "Asteroid Retrieval Feasibility Study." Keck Institute for Space Studies, April 2, 2012. Retrieved at: http://www.kiss.caltech.edu/study/asteroid/asteroid_final_report.pdf (Last Accessed on March, 15th, 2016).

[9] Jeff Foust, "NASA's Choice for Asteroid Redirect Mission May Not Sway Skeptics." *SpaceNews*, March 27, 2015. Retrieved at: http://spacenews.com/nasas-choice-for-asteroid-redirect-mission-may-not-sway-skeptics/ (Last Accessed on March, 9th, 2016).

[10] NASA's ARM team engaged in an "independent" cost assessment utilizing NASA expertise from outside the project (but inside NASA) as part of pre-formulation, which informed the selection of a robotic capture mission option for formulation.

[11] NASA Advisory Council letter to Charles Bolden. April 9-10, 2015. Retrieved at: http://www.spacepolicyonline.com/pages/images/stories/NAC%20letter%20to%20Bolden%20Apr%202015.pdf (Last Accessed on March, 15th, 2016).

[12] Committee on NASA's Strategic Direction; Division on Engineering and Physical Sciences; National Research Council, "NASA's Strategic Direction and the Need for a National Consensus." 2012. Retrieved at: http://www.nap.edu/catalog.php?record_id=18248 (Last Accessed on March, 9th, 2016).

[13] NASA Authorization Act of 2010 (P.L. 111-267). Retrieved at: http://www.gpo.gov/fdsys/pkg/PLAW-111publ267/pdf/PLAW-111publ267.pdf (Last Accessed on March, 9th, 2016).

[14] Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration. Retrieved at: http://www.nap.edu/catalog.php?record_id=18801 (Last Accessed on March, 9th, 2016).

[15] Findings of the Small Bodies Assessment Group meeting, Small Bodies Assessment Group, finding number three, March 20, 2013. Retrieved at: http://www.lpi.usra.edu/sbag/findings/ (Last Accessed on March, 9th, 2016).

Science Division (PSD) resources and funds."[16] Additionally, the NASA Advisory Council has warned that without a full understanding of the proposal, there is the potential that "a mission of significant cost and technical risk may be implemented without a full understanding of the potential for significant cost overrun or schedule slip."[17]

The Administration's FY 2017 request for the Asteroid Redirect Mission totals $182.7 million, and includes funds dispersed throughout the mission directorates. The request includes $66.7 million in the Human Exploration and Operations Mission Directorate; $65 million in the Space Technology Mission Directorate (all of which would be leveraged) for high-powered solar electric propulsion development and for RESTORE-L (a technology demonstration mission capable of servicing a U.S. government satellite in low Earth orbit); $50 million in the Science Mission Directorate (all of which would be leveraged) for near-Earth object observations; and $1 million for the Chief Technologist for Asteroid Grand Challenge prizes.[18]

The Asteroid Redirect Robotic Mission Key Decision Point - B (KDP-B)[19] is currently planned for the spring of 2016. NASA will continue formulation in FY17 leading to refinement of cost and schedule estimates, launch date, and spacecraft bus development start. NASA is scheduling to launch the Asteroid Redirect Robotic Mission (ARRM) in December 2021 and the Asteroid Redirect Crew Mission (ARCM) in December 2026. These target launch dates are still notional.[20]

[16] "Findings from the 14th Small Bodies Assessment Group (SBAG) Meeting." January 27-29, 2016. Retrieved at: http://www.lpi.usra.edu/sbag/meetings/jan2016/Findings.pdf (Last Accessed on March, 15th, 2016).

[17] NASA Advisory Council Recommendation, Asteroid Redirect Mission, 2014-02-02 (Council-02) Retrieved at: http://www.nasa.gov/sites/default/files/files/SquyresLetterToBolden_tagged.pdf (Last Accessed on March, 9th, 2016).

[18] NASA provided via email confirmation that $66.7 million in discretionary funding is being requested for ARRM under HEO and $65 million in discretionary funding is being requested for Restore-L under STMD.

[19] KDP-B is the program "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 responsible 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." (FY 2017 Budget Request, NASA, SUM-13)

[20] Jeff Foust, "NASA slips schedule of Asteroid Redirect Mission" *SpaceNews*, March 3, 2016. Retrieved at: http://spacenews.com/nasas-choice-for-asteroid-redirect-mission-may-not-sway-skeptics/ (Last Accessed on March, 9th, 2016).

Human Exploration and Operations Mission Directorate

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Exploration	3,542.7	4,030.0	3,163.9	173.0	3,529.7	4,081.7	4,243.6	4,261.7
Exploration Systems Development	3,211.5	3,680.0	2,686.6	173.0	2,922.5	3,061.6	3,092.2	3,142.3
Exploration R&D	331.2	350.0	477.3	-	607.2	1,020.1	1,151.4	1,119.5
Space Operations	4,625.5	5,029.2	5,075.8	-	4,912.8	4,529.7	4,540.1	4,697.6
Space Shuttle	7.7	-	0.0	-	0.0	0.0	0.0	0.0
International Space Station	1,524.8	-	1,430.7	-	1,554.7	1,536.8	1,539.3	1,585.2
Space Transportation	2,254.0	-	2,757.7	-	2,475.0	2,118.7	2,144.4	2,213.9
Space and Flight Support (SFS)	839.0	-	887.4	-	883.2	874.1	856.4	898.6

The Human Exploration and Operations Mission Directorate is responsible for five broad human spaceflight areas at NASA; Exploration Systems Development, Exploration Research and Development, International Space Station, Commercial Space Transportation, and Space & Flight Support (SFS). NASA is requesting a decrease of $866.1 million (21 percent) in the Exploration account and an increase of $46.6 (0.9 percent) in the Space Operations Account.

Exploration Systems Development

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Exploration	3,542.7	4,030.0	3,163.9	173.0	3,529.7	4,081.7	4,243.6	4,261.7
Exploration Systems Development	**3,211.5**	**3,680.0**	**2,686.6**	**173.0**	**2,922.5**	**3,061.6**	**3,092.2**	**3,142.3**
Orion Program	1,190.2	1,270.0	1,053.4	66.4	1,119.9	1,123.9	1,135.1	1,153.3
Space Launch System (SLS)	1,678.6	2,000.0	1,229.9	80.4	1,361.4	1,484.7	1,499.6	1,524.2
Exploration Ground Systems (EGS)	342.8	410.0	403.1	26.2	441.2	453.0	457.5	464.7

The Exploration Systems Development program is responsible for the design, construction, and integration of the next step in human exploration beyond low Earth orbit (LEO). There are three separate systems that make up the program; SLS, Orion, and Exploration Ground Systems (EGS). The total request for Exploration Systems Development is $2.69 billion, a $993.4 million decrease (27 percent reduction) from the FY16 appropriation. On August 27, 2014, NASA announced a one year slip of EM-1, the first launch of SLS, from 2017[21] to 2018.[22] This announcement was made despite numerous statements from NASA officials to Congress that the program was on schedule and that no additional funding was needed. In 2015, NASA made a similar announcement about the Orion, pushing the launch

[21] Verbal testimony of NASA Administrator Charles F. Bolden during question and answer period before the House Committee on Science, Space, and Technology, Hearing Titled "An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2014," April 24, 2013.

[22] NASA Press Release, August 27, 2014, "NASA Completes Key Review of World's Most Powerful Rocket in Support of Journey to Mars." Retrieved at: https://www.nasa.gov/press/2014/august/nasa-completes-key-review-of-world-s-most-powerful-rocket-in-support-of-journey-to (Last Accessed on March, 9th, 2016).

readiness date for Exploration Mission-2 (EM-2) back two years to no later than 2023[23] from an original date of 2021.[24] NASA program managers contend that there is a two-pronged process to manage the SLS and Orion programs.[25] NASA has formally committed to the 2018 and 2023 as the agency baseline used for cost controls and accounting measures required under federal law;[26] however, NASA contends that they are planning towards a separate "management agreement" or "internal planning date" that keeps the program on track for a launch of EM-1 earlier in 2018 and a launch of EM-2 in 2021.[27]

Prior to the 2016 omnibus spending bill, NASA intended to use the Interim Cryogenic Propulsion Stage (ICPS), which is derived from the Delta IV's upper stage, on both EM-1 and EM-2. In its 2015 report, the Aerospace Safety Advisory Panel noted that using the ICPS for EM-2 poses a risk to future astronauts because the stage is not human-rated. In the recent omnibus bill, Congress directed NASA to spend $85 million developing an Exploration Upper Stage (EUS), which, as ASAP said in the report, "would have the potential advantage of being designed, built, tested, and certified for human missions from the very beginning."[28]The 2017 PBR requests no funding for EUS but instead requests funding for the ICPS, disregarding the FY16 Congressional appropriation directive.[29]

Orion Crew Vehicle – The Orion is the next generation crew vehicle that will carry astronauts beyond LEO. Although Congress has consistently appropriated roughly $1.2 billion for the development of Orion in recent years, NASA requested a reduction in funding for the fifth year in a row. The discretionary request of $1.05 billion is a reduction of $216.6 million (approximately 17 percent) from the FY16 enacted levels.

Space Launch System – The SLS is the next generation heavy lift launch vehicle that will carry astronauts beyond LEO and will eventually have a 130 ton lift to low-Earth orbit capability.

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[23] NASA Press Release, September 16, 2015, "NASA Completes Key Milestone for Orion Spacecraft in Support of Journey to Mars." Retrieved at: https://www.nasa.gov/press-release/nasa-completes-key-milestone-for-orion-spacecraft-in-support-of-journey-to-mars (Last Accessed on March, 9th, 2016).

[24] Verbal testimony of NASA Administrator Charles F. Bolden during question and answer period before the House Committee on Science, Space, and Technology, Hearing Titled "An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2014," April 24, 2013.

[25] NASA Associate Administrator Bill Gerstenmaier testified that NASA was internally planning to a different launch readiness date for the SLS than was in the agency baseline commitment; Verbal testimony to question and answer period, Hearing titled "An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities," House Committee on Science, Space and Technology, Subcommittee on Space, December 10, 2014; Hearing transcript retrieved at http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg92331/html/CHRG-113hhrg92331.htm.

[26] 51 USC 30104

[27] Testimony of Bill Gerstenmaier, Associate Administrator, NASA, Hearing titled "An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities," House Committee on Science, Space and Technology, Subcommittee on Space, December 10, 2014; Hearing transcript retrieved at http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg92331/html/CHRG-113hhrg92331.htm.

[28] Aerospace Safety Advisory Panel Annual Report. January, 2015. Retrieved at: http://oiir.hq.nasa.gov/asap/documents/2015_ASAP_Annual_Report.pdf (Last Accessed on March, 9th, 2016). p. 10.

[29] Jeff Foust, "SLS upper stage caught in political tug-of-war." *SpaceNews*. February 19, 2016. Retrieved at: http://spacenews.com/sls-upper-stage-caught-in-political-tug-of-war/ (Last Accessed on March, 9th, 2016).

This year's request includes a decrease of approximately $770 million (38.5 percent) relative to the enacted fiscal year 2016 levels, despite insistence from Congress that SLS be a top priority.

Exploration Ground Systems - The President's budget request for Exploration Ground Systems decreases $6.8 million despite continued work at the Kennedy Space Center to ensure the facility is prepared to handle the SLS in 2018. NASA has stated that this work is on track for that launch date. Both the Government Accountability Office and the NASA Inspector General have cautioned that potential schedule risks for the ground systems program could delay EM-1.[30,31]

Exploration Research and Development

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Exploration	3,542.7	4,030.0	3,163.9	173.0	3,529.7	4,081.7	4,243.6	4,261.7
Exploration R&D	**331.2**	**350.0**	**477.3**	**-**	**607.2**	**1,020.1**	**1,151.4**	**1,119.5**
Human Research Program	142.0	-	153.3	-	178.2	178.2	180.0	182.8
Advanced Exploration Systems	189.2	-	324.1	-	429.0	842.0	971.4	936.6

The President's FY17 budget request for Exploration Research and Development is $477.3 million, an increase of $127.3 million (36 percent) above FY16. NASA's Exploration Research and Development program funds the development of new technologies needed to enable extended human space exploration. The program is comprised of two parts: Human Research Program and Advanced Exploration Systems.

Human Research Program – This program seeks to answer the most difficult questions about extended human operations in space such as the effects of microgravity, radiation, and other related environmental factors on the body. Additionally, this program addresses medical treatment, human factors, and behavioral health support.

Advanced Exploration Systems – This program began in 2012 and represents an approach to developing foundational technologies that will become the building blocks for future space missions. The AES program focuses on crewed systems for deep space, next generation space suits, habitation modules, as well as robotic precursor missions to gather critical knowledge about potential destinations in advance of crewed missions. NASA recently cancelled ongoing work on the Constellation Space Suit System. The recent omnibus appropriations act directed NASA to demonstrate a deep space habitation capability by 2018 and appropriated funds for that purpose. The FY17 PBR increase for the AES program is largely driven by funding for the Asteroid Redirect Robotic Mission (ARRM).

[30] Testimony of Cristina T. Chaplain, Director, Acquisition and Sourcing Management, before the House Committee on Science, Space and Technology, December 10, 2014. Retrieved at: http://gao.gov/assets/670/667350.pdf (Last Accessed on March, 9th, 2016).
[31] NASA's Launch Support and Infrastructure Modernization: Assessment of the Ground Systems Needed to Launch SLS and Orion. NASA Office of Inspector General. Retrieved at: http://oig.nasa.gov/audits/reports/FY15/IG-15-012.pdf (Last Accessed on March, 9th, 2016).

Space Operations

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Space Operations	4,625.5	5,029.2	5,075.8	-	4,912.8	4,529.7	4,540.1	4,697.6
Space Shuttle	7.7	-	0.0	-	0.0	0.0	0.0	0.0
International Space Station	1,524.8	-	1,430.7	-	1,554.7	1,536.8	1,539.3	1,585.2
Space Transportation	2,254.0	-	2,757.7	-	2,475.0	2,118.7	2,144.4	2,213.9
Space and Flight Support (SFS)	839.0	-	887.4	-	883.2	874.1	856.4	898.6

The Space Operations Account funds activities for the International Space Station, commercial crew development, cargo delivery, and Space Flight and Support. While under a different account, the activities all fall under the Human Exploration and Operations Mission Directorate. The President's budget request for FY17 is $5.075 billion, which represents an increase of $46.6 million.

International Space Station (ISS) – The ISS is a permanently crewed microgravity laboratory and technology test-bed for exploration and international cooperation. The ISS also includes a National Laboratory for non-NASA and non-governmental users. The NASA Authorization Act of 2010 required NASA to compete a contract for management of the National Laboratory. The Center for the Advancement of Science in Space (CASIS) was subsequently selected for this purpose. The ISS program contains two major projects: Systems Operations and Maintenance (O&M), Research. The President's FY17 budget request for the International Space Station is $1.430 billion.

Space Transportation – The FY16 Omnibus Appropriation Act moved funding for commercial spaceflight activities (Commercial Crew and Crew and Cargo) to the Space Operations account. The FY17 PBR follows this format and renames the effort "Space Transportation."

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Space Operations	4,625.5	5,029.2	5,075.8	-	4,912.8	4,529.7	4,540.1	4,697.6
Space Transportation	**2,254.0**	**-**	**2,757.7**	**-**	**2,475.0**	**2,118.7**	**2,144.4**	**2,213.9**
Commercial Crew	805.0	-	1,184.8	-	731.9	173.1	35.8	36.3
Crew and Cargo	1,449.0	-	1,572.8	-	1,743.0	1,945.6	2,108.6	2,177.6

Commercial Crew – The purpose of this program is to develop a crew transportation system (CTS) that can be procured on a fixed price contract after certification by NASA. While each partner company is investing varying levels of funding to develop these systems, a significant portion of the development costs for each system, as well as their certification for flight to ISS, is being shouldered by NASA. NASA officials have testified before the Committee that the

percentage of NASA government funding for the Commercial Crew Program is as high as 90 percent compared to the private sector investment.[32]

NASA has awarded services contracts to two of the final competitors in the Commercial Crew Program, the Boeing Company (Boeing) and Space Exploration Technologies Corporation (SpaceX). The final phase of the program, Commercial Crew Transportation Capability (CCtCap) provides significant government funding to finalize designs, test various elements, and certify each of the crew systems. The firm-fixed price contract guarantees each company at least two flights to the ISS and as many as six for a total of 12 possible flights. The potential contract value is $4.2 billion for Boeing and $2.6 billion for SpaceX.

The Commercial Crew request of $1.18 billion is a decrease of $63 million (5 percent) over FY16, which is in line with previous out-year projections that planned for a reduction. The FY16 PBR planned for a FY17 request of $1.18 million. NASA still has not conducted an independent cost estimate for the program.[33]

Crew and Cargo - The Commercial Spaceflight program at NASA began in 2006 by funding multiple companies to develop systems for transporting cargo to the ISS with an eye towards eventually having multiple carriers compete for the resupply contract. This was accomplished through the Commercial Orbital Transportation Services (COTS) and Cargo Resupply Services (CRS) programs. At this point, both of the companies involved, Space Exploration Technologies Corporation (or SpaceX) and Orbital-ATK, have successfully delivered cargo to the ISS. While the SpaceX contract includes a down-mass capability (returns cargo to Earth), Orbital-ATK's Cygnus spacecraft (like the European Space Agency's ATV or the Japanese Space Agency's HTV) has no down-mass capability. In 2008, NASA signed two CRS contracts. The original SpaceX contract was valued at $1.6 billion for 12 missions and Orbital contract was valued at $1.9 billion for 8 missions. Through contract extensions, NASA has since awarded SpaceX eight additional and Orbital-ATK two additional space station cargo-supply missions. In January, 2016, NASA awarded CRS-2 contracts to SpaceX, Orbital ATK, and Sierra Nevada Corporation. The CRS-2 awardees will each fly at least six cargo missions, starting in late 2019 and going until 2024.[34] The Crew and Cargo program budget also funds the existing contract with Russia

[32] Testimony of Associate Administrator Bill Gerstenmaier before the House Committee on Science, Space, and Technology, September 14, 2012. Retrieved at: http://www.gpo.gov/fdsys/pkg/CHRG-112hhrg76234/pdf/CHRG-112hhrg76234.pdf. (Last Accessed on March, 9th, 2016).

[33] NASA contracted with Booz|Allen|Hamilton to complete an independent cost assessment of the program which was released on March 1, 2013 and can be found here http://www.nasa.gov/pdf/741617main_CCP-ICA-DRD-2e-Public-Releaseable-Final-Report-3-5-13-508.pdf. (Last Accessed on March, 9th, 2016) However, as noted by the NASA Inspector General (IG), "the assessment found that the estimates were optimistic, and that the Program was likely to experience cost growth. In addition, Booz Allen noted that without costs projected over the life of the Program, NASA officials will not be able to independently evaluate each partner's progress." The IG report also noted that "…despite completion of Preliminary Design Review by NASA's commercial crew partners, Agency officials have yet to develop a life cycle cost estimate for the Program." See "NASA's Management of the Commercial Crew Program," IG-14-001, NASA Office of the Inspector General, November 13, 2013.

[34] NASA Press Release, "NASA Awards International Space Station Cargo Transportation Contracts." January 14, 2016. Retrieved at: http://www.nasa.gov/press-release/nasa-awards-international-space-station-cargo-transport-contracts (Last Accessed on March, 15th, 2016).

for transportation services to the ISS through 2018 (and crew rescue and return through mid - 2019), which is valued at $490 million.[35]

Space and Flight Support – This program is made up of a number of divisions providing capabilities that play critical roles in several NASA missions including: 21st Century Space Launch Complex, Space Communications and Navigation, Human Space Flight operations, Launch Services, and Rocket Propulsion Test. The 21st Century Space Launch Complex program funds modernization at the Kennedy Space Center and Cape Canaveral Air Force Station to benefit multiple users. The Space Communications and Navigation program operates NASA's extensive network of ground-based and orbiting communications hardware and software necessary to receive vast quantities of data generated by NASA's fleet of crewed vehicles and robotic spacecraft. The Human Space Flight Operations (HSFO) program ensures that NASA's astronauts are prepared to safely carry out current and future missions. The Launch Support Program funds various NASA missions that require expendable launch vehicle services. The Rocket Propulsion Test program maintains NASA's wide variety of test facilities for use by NASA, other agencies, and commercial partners.

Science Mission Directorate

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR Discretionary	FY17 PBR Mandatory	Notional 2018	Notional 2019	Notional 2020	Notional 2021
Science	5,243.0	5,589.0	5,302.5	298.0	5,408.5	5,516.7	5,627.0	5,739.6
Earth Science	1,784.1	-	1,972.2	60.0	1,989.5	2,001.3	2,020.9	2,047.7
Planetary Science	1,446.7	-	1,390.7	128.0	1,439.7	1,520.1	1,575.5	1,625.7
Astrophysics	730.7	-	696.5	85.0	761.6	992.4	1,118.6	1,192.5
James Webb Space Telescope	645.4	620.0	569.4	-	533.7	304.6	197.2	149.8
Heliophysics	636.1	-	673.7	25.0	684.0	698.3	714.8	723.9

The Science Mission Directorate (SMD) conducts scientific exploration enabled by the 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. The directorate has four divisions: Earth Science, Planetary Science, Astrophysics and Heliophysics. The James Webb Space Telescope (JWST) is a separate line-item to allow NASA leadership greater insight and oversight of the historically troubled program. The President is requesting $5.6 billion for SMD this year, which is an increase of $11.5 million (about two-tenths of one percent, 0.2) above the FY16 enacted.

Earth Science – The Earth Science division at NASA advances the state of Earth system science by advancing the understanding of environmental change through data acquisition, scientific and application research and analysis, and predictive modeling. NASA uses on-orbit satellite missions to provide near real-time data for use by U.S. and international partners for weather forecasting and disaster response. These satellites monitor sea levels and salinity, groundwater depletion rates, sea ice erosion, carbon dioxide levels, and many other phenomena.

[35] Letter from the Honorable Charles Bolden, Administrator, NASA, to Rep. Lamar Smith, Chairman, House Science, Space, and Technology Committee, August 5, 2015.

Historically, new Earth remote sensing capabilities have been developed in a process whereby NASA develops first-of-a-kind instruments that, once proved, are considered for continuation by NOAA or the USGS.[36] NASA has viewed extended-phase operations for Earth science missions as "operational" and therefore the purview of NOAA.[37] However, recently NASA's Earth science portfolio has expanded to include new responsibilities for the continuation of several previously initiated measurements that were formerly assigned to other agencies, including data continuity and application focused satellite observation programs.[38] For example, the President's FY16 Budget Request redefined NASA and NOAA Earth-observing satellite responsibilities. Under the proposed framework, NOAA is responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts and warning to protect life and property. NASA is responsible for all other non-defense Earth-observing satellite missions. The near term impact of this revised framework includes the transfer of responsibility for TSIS-1 (Total and Spectral Solar Irradiance Sensor), Ozone Mapping & Profile Suite (OMPS), JPSS-2 Radiation Budget Instrument (RBI), and future ocean altimetry missions to NASA.[39]

Another example of increased NASA responsibilities is the Sustainable Land Imaging (SLI) program. The purpose of SLI is to provide data continuity to the Landsat missions. Landsat has provided 42 years of space-based medium resolution (15-30 meters) global land-remote sensing measurements. Landsat is a unique resource for those who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research. Under SLI, NASA is responsible for development, launch, and check-out of Landsat 9, along with technology investments and detailed system engineering to design and building a full-capability Landsat 10 satellite.[40,41] However, in the past, both USGS and NOAA have been responsible for development and operation of Landsat satellites.[42]

The President's FY17 budget request includes $130.8 million for Landsat-9.[43] Landsat-9 is an upgraded rebuild of the Landsat-8 earth observation satellite that NASA wants to launch in

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[36] National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (2007), at pg. xiii in the preamble. Retrieved at: http://www.nap.edu/catalog/11820/earth-science-and-applications-from-space-national-imperatives-for-the (Last Accessed on March, 9th, 2016).

[37] Ibid.

[38] National Academies of Sciences, *Continuity of NASA Earth Observations from Space: A Value Framework* (2015) at pg.1.Retrieved at: http://www.nap.edu/catalog/21789/continuity-of-nasa-earth-observations-from-space-a-value-framework (Last Accessed on March, 9th, 2016).

[39] President's Budget Request for NASA Fiscal Year 2016 for the Earth Science's Program at ES 37.

[40] President's Budget Request for NASA Fiscal Year 2016 at SCMD 5.

[41] Ibid.

[42] Under Presidential Directive/NSC-54 (Nov. 16, 1979) NOAA was assigned management responsibility for civil operational land remote sensing activities. However, operational management was not transferred from NASA to NOAA until 1983. In 1998, the management of the Landsat 4 (and Landsat 5) operations contract was transferred from NOAA to the USGS; operations were continued by the private sector until mid-2001when Space Imaging (formerly EOSAT) returned the operations contract to the U.S. Government. See NASA Landsat Science website: http://landsat.gsfc.nasa.gov/?p=3178 (Last Accessed on March, 9th, 2016).

[43] The FY17 PBR is not clear as to the allocation of discretionary vs. mandatory spending requested for this program.

2021. In 2015, the Committee held hearings on the utility of NASA exploring public-private partnership alternatives to building a follow-on Landsat. However, there is no mention in the FY17 President's budget request of the Administration exploring public-private partnership alternatives to building a follow-on Landsat, despite recommendations from witnesses at hearings held by the Committee on Science, Space, and Technology and Executive branch guidance on the subject.

The President's FY17 budget request also includes $88.8 to initiate the Pre-Aerosol, Clouds, and ocean Ecosystem (PACE) mission.[44] PACE 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. The PACE mission will serve to make these measurements until the more advanced Aerosol, Cloud, and Ecosystems (ACE) mission (recommended by the National Academies Decadal Survey for its Tier 2 mission set) is ready.

The Administration continues to request a disproportionate amount of funding for Earth Science relative to Planetary Science and Astrophysics (including the James Webb Space Telescope), which have been used to fund other agency priorities such as the National Oceanic and Atmospheric Administration's climate sensors and the US Geologic Survey's moderate resolution land imaging satellite, Landsat. The President is requesting $1.972 billion for Earth Science, an increase of approximately $51 million from FY16 appropriations. This represents a 65 percent increase for the Earth Science Division from the FY07 requested level.[45]

Planetary Science – The Planetary Science division is responsible for monitoring and analyzing data collected from NASA missions exploring the solar system and beyond in the search for the content, origin, and evolution of the solar system as well as the potential for life. Additionally, Planetary Science is responsible for the Near Earth Object Observations program. The Planetary Science division was again targeted this year for budget cuts as the Administration prioritized missions in NASA Earth Science for funding compared to Planetary Science. The FY17 President's Budget Request for Planetary Science is $1.391 billion, a decrease of fifteen percent ($240 million) from the FY16 appropriation of $1.631 billion.

On July 14, 2015, New Horizons performed the first-ever flyby of Pluto, travelling within 7,800 miles (12,500 kilometers) of its frigid surface. It made numerous observations, including close-up images in visible and near-infrared wavelengths depicting surface features as small as 200 feet across, and as well as many other new discoveries. New Horizons is extending its mission to fly by Kuiper Belt Object 2014MU69 in January 2019. The President's FY17 budget request includes $13 million for this extended mission.

On July 4, 2016, the Juno spacecraft is scheduled to enter a polar orbit around Jupiter. Launched on August 5, 2011, the mission was the second planetary science mission selected

[44] The FY17 PBR is not clear as to the allocation of discretionary vs. mandatory spending requested for this program.
[45] The FY07 PBR requested $1.1985 Billion for NASA's Earth Science Division.

under the New Frontiers Program. The mission will be the second spacecraft to orbit Jupiter after Galileo, and is designed to study the gas giant's composition, gravity field, magnetic field, and polar magnetosphere.

The Origins-Spectral-Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) mission is scheduled to launch in 2016 and will examine the asteroid Bennu and return a physical sample of the asteroid to Earth. It is the third planetary science mission selected in the New Frontiers Program, after Juno and New Horizons. The development cost of Osiris-Rex is estimated at $709.7 million.[46]

InSight is a Mars lander mission, and was expected to launch in spring 2016. InSight's mission is to study the interior of Mars to understand how rocky planets (like Earth and Mars) were formed, and investigate possible tectonic activity. The InSight spacecraft and a majority of science payload were developed and delivered to the launch site on schedule. However, the vacuum sphere for the Seismic Experiment for Interior Structure (SEIS) instrument provided by the French Space Agency (CNES) experienced numerous leaks and was unable to meet the 2016 launch opportunity. As a result, InSight's launch readiness date (LRD) milestone of March 2016 was suspended and any potential future LRD is delayed beyond six months. The President's FY17 budget request includes $13.3 million for InSight, but this funding level is subject to future decisions about the mission. NASA is in the process of implementing a plan with CNES to overcome these technical challenges and launch Insight in 2018. Press reports indicate that this revised plan could cost approximately $150 million.[47]

Work also continues on the Mars Rover 2020, NASA's next flagship mission to Mars. The Mars 2020 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 a flight opportunity for payloads provided by the HEOMD and the Space Technology Mission Directorate (STMD). NASA's Mars 2020 mission will build upon many discoveries from the Mars Curiosity rover and the two Mars Exploration Rovers, Spirit and Opportunity. The Mars Rover 2020 will seek signs of past life on Mars, collect and store a set of samples for potential return to Earth in the future, and test new technology to benefit future robotic and human exploration of Mars. The President's FY17 budget request for Mars Rover 2020 is $377.5 million.

The President's FY17 budget request includes a line item of $16.6 million to continue designing a mission to Europa. Congress has consistently supported the National Academies' recommendation of this mission. The FY17 funding request is a decrease of 91 percent ($158.4 million) of the $175 million Congress appropriated for a Europa mission in FY16.

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[46] GAO, *NASA Assessments of Selected Large-Scale Projects* (GAO-15-320SP)

[47] Jeff Foust, "NASA decision on InSight Mars lander's future expected soon" *SpaceNews*, March 2, 2016. Retrieved at: http://spacenews.com/nasa-decision-on-insight-mars-landers-future-expected-soon/ (Last Accessed on March 9th, 2016).

Astrophysics – The Astrophysics Division analyzes data from NASA missions to understand astronomical events such as the explosion of a star, the birth of a distant galaxy, or the nature of planets circling other stars.

The Astrophysics Division operates the Hubble Space Telescope, which continues to provide spectacular science. One of NASA's most successful and resilient science missions, the Hubble Space Telescope, has transmitted hundreds of thousands of images back to Earth, helping resolve many of the great mysteries of astronomy. The FY17 budget request for Hubble Space Telescope is $97.3 million.

The President's FY17 budget request funds the Stratospheric Observatory for Infrared Astronomy (SOFIA) mission at $83.8 million. The President's FY15 budget request significantly under-funded SOFIA, leading the scientific community to believe the mission would be cancelled. Congress appropriated funds to maintain the mission. The SOFIA mission, a unique airborne infrared observatory flown in a modified Boeing 747 airplane above the dust and water vapor of Earth's atmosphere, reached full operational capability in February 2014. Developed and operated in partnership with the German Aerospace Agency (DLR), SOFIA is expected to operate for 20 years.

The FY17 President's budget request includes $14 million of discretionary spending for continued formulation of an AFTA-WFIRST telescope, the follow-on telescope to the James Webb Space Telescope (JWST).

The FY17 PBR requests $87 million for the Transiting Exoplanet Survey Satellite (TESS) a $13.5 million increase over FY16 appropriated funds. TESS is scheduled to launch in 2017, and will hunt for exoplanets. JWST is expected to help characterize planets found by TESS during its scientific survey.

James Webb Space Telescope (JWST) – JWST is the follow on to the Hubble Space Telescope and will be able to stare deep into space picking up the faintest infrared light which could give astronomers and cosmologists new clues into the beginnings of the universe. The telescope will look for answers to questions such as: How did the universe make galaxies? How are stars made? Are there other planets that can support life? JWST was called out by the National Research Council's 2001 Decadal Survey as the top priority of the science community and that priority was reaffirmed by the 2010 Decadal Survey. JWST will be stationed at the Earth-Sun Lagrange point (L_2) approximately 930,000 miles from the Earth and stands three stories high, spanning the size of a tennis court. Beginning in FY12, JWST was taken out of the Astrophysics division in the budget and was given its own budget line. After an extensive re-planning effort, NASA re-baselined JWST to a total life-cycle cost of $8.8 billion and a launch readiness date of October 2018. Based on this effort, the funding profile for FY13 and beyond increased significantly, with the bulk of the increases in the early years of the re-plan. While a decrease from past years, the President's FY17 budget request of $569.4 million is in line with projected development costs. In FY17 the main thrust of work will be integrating and testing the instruments, telescope, and spacecraft bus, to prepare it for the October 2018 launch.

Heliophysics – The Heliophysics division seeks to understand the Sun and its interactions with the Earth and the solar system. The President's FY17 budget request $698.7 million for the Heliophysics division. In FY17 the Heliophysics Research Program will collect science from 20 active space missions, including Interface Region Imaging Spectrograph (IRIS), Magnetic Multiscale Mission (MMS), and the Voyager 2 spacecraft, among others. Solar Probe Plus (SPP), the flagship mission to explore the Sun's outer atmosphere and get closer to the Sun than any previous mission, will continue system integration and testing. SPP is scheduled to launch in August 2018. FY17 funding requested for SPP is $232.5 million.

Aeronautics Research Mission Directorate

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Aeronautics	642.0	640.0	634.5	155.9	846.4	1,060.1	1,173.3	1,286.9
Airspace Operations and Safety Program	154.0	-	141.4	18.0	159.2	176.2	189.1	221.5
Advanced Air Vehicles Program	240.6	-	268.6	30.0	277.4	308.8	311.6	312.6
Integrated Aviation Systems Program	150.0	-	117.1	92.9	255.4	381.4	493.0	556.7
Transformative Aero Concepts Program	97.4	-	107.3	15.0	154.4	193.8	179.7	196.2

NASA's Aeronautics Research Mission Directorate (ARMD) conducts aeronautics research to improve aviation safety, efficiency, and air traffic management, and to develop game-changing technology to facilitate the continued growth of the U.S. aviation industry. The FY17 budget request for ARMD is $634.5 million, 5.5 million below the $640 million included in the FY16 appropriations act.

With this request, NASA proposes to begin a major new initiative, New Aviation Horizons (NAH). The NAH initiative proposes to demonstrate and validate transformative concepts with integrated, advanced technologies to meet long term needs of aviation and sustain U.S. technological leadership. NAH would develop a series of transformative hybrid electric propulsion demonstrators, starting at small scale for risk reduction, learning, and for early applications, and then transitioning to a larger scale X-Plane demonstration focused on propulsion innovation for subsonic transport class aircraft. NAH also includes the development of a Low Boom Flight Demonstrator (LBFD) project to demonstrate quieter supersonic flight.

NASA is also proposing to establish a Hypersonics Technology (HT) Project, balancing investments that support and leverage the work of the Department of Defense (DoD) with investments in fundamental hypersonics research.

Space Technology Mission Directorate

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Space Technology	600.3	686.5	690.6	136.1	704.4	718.5	732.9	747.5
Agency Technology and Innovation	31.3	-	34.3	-	35.0	35.7	36.4	37.1
SBIR and STTR	190.7	-	213.0	-	213.2	213.5	213.8	213.8
Space Technology Research and Development	378.3	-	443.3	136.1	456.2	469.3	482.7	496.6

The request for the Space Technology Mission Directorate includes three main programs: Agency Technology and Innovation; Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR); and, Space Technology Research and Development. NASA requested $690.6 million this year for Space Technology which is an increase of $4.1 million relative to the FY16 enacted funding.

Agency Technology and Innovation – This program is host to the Office of the Chief Technologist (OCT). The Chief Technologist is the principal advisor to the Administrator on matters concerning agency-wide technology policies and programs. The OCT provides strategy and leadership that guides open innovation activities, technology transfer, and commercialization of technologies.

The OCT has four primary functions: strategic technology integration, to enable technology transfer, to administer prizes and challenges, and to provide analytical support for decision makers on the growth of the entrepreneurial space communities.

SBIR & STTR – The SBIR and STTR programs are required by federal law for federal agencies. These programs fulfill a requirement to support early stage research and development through investments in small businesses. Under the recent SBIR reauthorization, NASA is required to invest three percent of agency research and development dollars relative to extramural agency research and development through these two programs.

Space Technology Research & Development – This program supports early stage conceptual studies that focus on discovering, developing, testing, and demonstrating new technologies. The program supports projects at all technology readiness levels to create a technology pipeline, starting with innovation and resulting in ready-to-utilize technologies that improve the nation's in-space capabilities.

The portfolio includes nine main areas: Game Changing Development, Technology Demonstration Missions, Small Spacecraft Technologies, Space Technology Research Grant, NASA Innovative Advanced Concepts, Center Innovation fund, Centennial Challenges Prize, Small Business Innovation Research & Small Business Technology Transfer, and Flight Opportunities Program.

There are also eight major thrust areas that NASA focuses its space technology investments on and are considered key to future NASA missions and enhance national space

capabilities. They are: 1) In-Space Propulsion; 2) High Bandwidth Space Comm; 3) Advanced Life Support and Resource Utilization; 4) Entry Descent and Landing Systems; 5) Space Robotic Systems; 6) Lightweight Space Structures; 7) Deep Space Navigation; and 8) Space Observatory Systems.

Education

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR Discretionary	FY17 PBR Mandatory	Notional 2018	Notional 2019	Notional 2020	Notional 2021
Education	119.0	115.0	100.1	-	102.1	104.1	106.2	108.3
Aerospace Research and Career Development	58.0	-	33.0	-	33.0	33.0	33.0	33.0
STEM Education and Accountability	61.0	-	67.1	-	69.1	71.1	73.2	75.3

The President's FY17 request for NASA's Education program is $100.1 million, a 13 percent ($14.9 million) decrease from the FY16 enacted levels.

The two main programs which make up the Education Mission Directorate are the Aerospace Research & Career Development Program (ARCD) and the STEM Education & Accountability Program (SEA).

Within the ARCD are two specialized grant programs, the National Space Grant College and Fellowship project and the Experimental Project to Stimulate Competitive Research (EPSCoR). NASA Space Grant is a competitive grant program supporting science and engineering education and research efforts for educators and students by leveraging the resource capabilities and technologies of universities, museums, science center, and local governments. The Administration requested $24 million for Space Grant, a program that is consistently appropriated higher than Administration requests, most recently $40 million for FY16. The second program in ARCD is EPSCoR, which is a competitive grant project that establishes partnerships between government, higher education, and industry to promote research and development (R&D) capacity in individual states or regions. EPSCoR has historically funded regions or states that do not typically participate equitably in federal aerospace and aerospace-related research activities. The Administration request for the EPSCoR was $9 million. The program received $18 million in FY16.

The SEA provides funding for NASA-unique STEM education opportunities, including internships, launch initiatives, and grants, and provides students and educators with NASA's STEM content. There are two main initiatives in SEA, the Minority University Research Education Project (MUREP) and the STEM Education and Accountability Projects (SEAP). MUREP supports multi-year research grants at Historically Black Colleges and Universities, Hispanic Serving Institutions, and Tribal Colleges. Additionally, MUREP funds scholarships, internships, and mentoring for K-12 students. SEAP supports the application of NASA assets, missions, and discoveries to advance the Administration's education goals. NASA intends to work with other agencies to support the goals of the Five-Year Federal Strategic Plan on STEM Education. In FY17 the President's budget requests $67.1 million.

Safety, Security, and Mission Services (SSMS)

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Safety, Security, and Mission Services	2,754.6	2,768.6	2,836.8	-	2,893.6	2,951.5	3,010.4	3,070.6
Center Management and Operations	2,023.7	-	2,017.7	-	2,058.1	2,113.5	2,155.6	2,198.8
Agency Management and Operations	730.9	-	819.1	-	835.5	838.0	854.8	871.8

Formerly named Cross Agency Support, SSMS activities include the administration of the agency, operations and maintenance of the NASA Centers, and facilities, including Headquarters, and provide oversight to reduce risk to life and mission for all NASA programs. This includes information technology (IT) infrastructure, security, safety and mission assurance, human capital management, finance, procurement, and engineering. The Administration requested $2.836 billion for SSMS in FY17, an increase of $68.2 million or 2.4 percent.

Construction & Environmental Compliance and Restoration (CECR)

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Construction and Environmental Compliance and Restoration	446.1	388.9	419.8	-	390.2	398.0	406.0	414.1
Construction of Facilities	374.4	-	328.0	-	297.9	303.8	310.1	317.9
Environmental Compliance and Restoration	71.7	-	91.8	-	92.3	94.2	95.9	96.2

The CECR account is comprised of two elements, Construction of Facilities (CoF) and Environmental Compliance and Restoration (ECR). CoF is responsible for making capital repairs and improvements to infrastructure and provides NASA programs with test, research, and operational facilities that they require to accomplish their missions. About 80 percent of NASA's infrastructure is beyond its constructed design life.[48] ECR is responsible for cleaning up pollutants released into the environment during past activities.

The President's request for FY17 provides an increase to the CECR account of $30.9 million or 8 percent.

[48] Testimony of Paul Martin before the Subcommittee on Space, Committee on Science, Space, and Technology. September 20, 2013. Retrieved at: https://oig.nasa.gov/congressional/NASAIGMartin_09_20_2013.pdf (Last Accessed on March, 15th, 2016).

Inspector General

Budget Authority ($ in millions)	FY15 Op Plan	FY16 Enacted	FY17 PBR		Notional			
			Discretionary	Mandatory	2018	2019	2020	2021
Inspector General	37.0	37.4	38.1	-	38.9	39.6	40.4	41.2

The Office of the Inspector General conducts audits, investigations, and reviews NASA programs to prevent and detect waste, fraud, abuse and mismanagement. The Administration requested $38.1 million in FY16, which represents a 1.9 percent increase from previous year funding.

Mandatory Spending Requests

The FY17 PBR contains $763 million is mandatory spending, representing 4 percent of the total $19.025 billion requested.

Exploration: $173 million in mandatory spending is requested for the Human Exploration and Operations account (HEO) (6 percent of the Exploration Systems Development budget total request and 5 percent of the HEO budget total request). The Orion program request of $66.4 million in mandatory spending is 6 percent of the total Orion request. The SLS program request of $80.4 million in mandatory spending is 6 percent of the total SLS request. The ESD program request of $26.2 million in mandatory spending is 6 percent of the total ESD request.

Science Mission Directorate: $298 million in mandatory spending is requested for the Science Mission Directorate (SMD) (5.3 percent of SMD's total request). The Earth Science Division request of $60 million in mandatory spending is 3 percent of the total Earth Science funding requested. The Heliophysics Division request of $25 million in mandatory spending is 3.6 percent of the total Heliophysics funding requested. The Planetary Science Division request of $128 million in mandatory spending is 8.4 percent of the total Planetary Science funding requested. The Astrophysics Division request of $85 million in mandatory spending is 10.9 percent of the total Astrophysics funding requested.

Aeronautics: $156 million in mandatory spending is requested for the Aeronautics Mission Directorate (ARMD). The ARMD request of $156 million is 19.7 percent of total ARMD funding requested.

Space Technology: $136 million in mandatory spending is requested for the Space Technology Mission Directorate (STMD). The STMD request of $136 million is 16.5 percent of total STMD funding requested.

Exploration: $173 million in mandatory spending is requested for Human Exploration and Operations Mission Directorate (HEO), exploration accounts. The HEO request of $173 million is 5.2 percent of total exploration funding requested.

There are no mandatory spending requested for the space operations, education, safety, security, and missions services, construction and EC&R, or inspector general accounts.