

**AN OVERVIEW OF THE BUDGET PROPOSAL
FOR THE NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION FOR FISCAL YEAR 2017**

HEARING
BEFORE THE
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY
HOUSE OF REPRESENTATIVES
ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

March 17, 2016

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**AN OVERVIEW OF THE BUDGET PROPOSAL
FOR THE NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION
FOR FISCAL YEAR 2017**

THURSDAY, MARCH 17, 2016

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 10:04 a.m., in Room 2318, Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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***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. - 12:00 p.m.
2318 Rayburn House Office Building

Witness

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

**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	5,233.0	5,589.0	5,302.50	598.0	5,805.5	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	634.30	155.9	846.4	1,060.1	1,173.3	1,286.0
Space Technology	600.3	686.3	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	4,291.7
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	100.30	-	102.1	104.1	106.2	108.3
Sci, Sec. & Msn Serv	2,754.6	2,768.6	2,836.80	-	2,893.6	2,951.3	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 Acctg Comp & Resto	446.1	388.0	419.80	-	391.2	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	37.3	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

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 Successfully 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.thespaceview.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

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/idsys/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	4,245.6	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 2017²¹ 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 2023²³ 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.

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://oair.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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	Discretionary	Mandatory	2018	2019	2020	2021
Exploration	3542.7	4030.0	3163.9	173.0	3329.7	4081.7	4243.6	4261.7
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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	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
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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	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 billion. 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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	Discretionary	Mandatory	2018	2019	2020	2021
Total	5,233.0	5,539.0	5,312.5	298.0	5,308.5	5,316.7	5,627.0	5,732.6
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

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-2001 when Space Imaging (formerly EOSAT) returned the operations contract to the U.S. Government. See [NASA Landsat Science](http://landsat.gsfc.nasa.gov/?p=3178) 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.

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 (L₂) 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	346.4	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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	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		Notional			
			Discretionary	Mandatory	2018	2019	2020	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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	Discretionary	Mandatory	2018	2019	2020	2021
Construction and Environmental Compliance and Restoration	346.1	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	FY16	FY17 PBR		Notional			
	Op Plan	Enacted	Discretionary	Mandatory	2018	2019	2020	2021
Inspector General	37.0	37.3	38.1	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 in 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.

Chairman BABIN. Without objection, the Chair is authorized to declare recesses of the Subcommittee at any time.

I'd like to welcome everyone today to the hearing entitled "An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2017."

And I recognize myself for five minutes for an opening statement.

The first and perhaps most important point that I want to make today is that NASA is a worthwhile investment for the taxpayer and for our nation. Space is as important to our future as were the frontiers of land, sea, and air that we faced in the past. NASA's mission to explore outer space and to use outer space for the benefit of our nation and for mankind is an endeavor worthy of a great nation, which we are.

NASA as an agency, its employees, and contractors deserve our praise. I represent the 36th District of Texas and the home of the Johnson Space Center. I can say from personal experience talking with the folks out at Johnson that, regardless of the budgetary and policy differences in Congress and within the Administration, they are very passionate and are dedicated to NASA's mission.

Unfortunately, this Administration has once again done a disservice to NASA, its employees, and our nation by providing a budget request that ignores the budget agreement, requesting mandatory funding for NASA. I had hoped that the Administration would demonstrate leadership by proposing a realistic budget, but instead, we were presented with a list of unfunded priorities.

The Administration has also once again disregarded the priorities of previous bipartisan NASA funding bills that the President signed. For example, even if we include the so-called mandatory budget request, the budget proposal cuts the Space Launch System, or SLS, and Orion crew capsule by \$840 million and the Planetary Science Division by \$133 million. Without the mandatory funding, SLS and Orion are cut by \$1 billion. Planetary Science is cut by \$261 million. This is not acceptable. This is a budget that takes our human spaceflight program nowhere fast. This budget undermines our space program and diverts critical funding to lower-priority items.

I have been, and continue to be, concerned that the support in Congress and at NASA for the SLS and Orion programs is not matched by the Administration. The Administration consistently requests large reductions for these programs despite the insistence of Congress that they be priorities. Orion and SLS are strategic national assets and must be sufficiently funded.

Proposed cuts to the Planetary Science Division are equally disturbing. The pipeline for outer-planet missions has been woefully under-prioritized. It is critical that our nation maintain a robust outer-planet exploration program.

Already, the effects of this diminished cadence are being felt. To keep their staff employed, planetary science institutions increasingly seek funding from foreign space agencies to compensate for the lack of projects. This results in transference of valuable skills and knowledge out of the United States to countries like China. Experienced planetary scientists are also transitioning to other fields, while young scientists are choosing to not enter the field at all, gutting our national capacity in planetary science. This is dis-

turbing and unacceptable and just plain bad for America from many viewpoints.

It is important that NASA maintains a balanced portfolio of science activities. Unfortunately, year after year, this Administration has requested disproportionate increases for Earth science activities, activities that are already funded by more than a dozen other federal agencies. This year, the President's proposal seeks to increase the science budget by \$111 million, a six percent increase. This amounts to a 70 percent increase since 2007. If this money had been put toward our human spaceflight program, I don't think that we would be spending hundreds of millions on Russian launch services.

The request also dilutes NASA's existing Earth science research portfolio by conducting other agencies' work. It is developing climate sensors for NOAA and land-imaging capabilities for USGS. While NASA certainly has the expertise to do this work, they don't have the budget or the requirements. NOAA is tasked with maintaining operational climate measurements, and USGS is tasked to maintain Landsat measurements. This budget makes NASA the piggy bank for other agencies. That must end.

If NASA is tasked to do other agency's work, it should do so on a reimbursable basis, as it does successfully for other programs such as the Joint Polar Satellite System and the Geostationary Operational Environmental Satellite System.

Our nation has been spacefaring since 1958, only 58 years. And while we have accomplished great things in these 58 years, there is so much more to learn and to discover and to put to practical use for the benefit of our nation and all mankind. But we as a nation will not be leading this journey unless we adequately fund NASA's human spaceflight and planetary science missions.

Other nations, such as China, are working overtime to displace American and become the global leader in space exploration. The consequences of America getting it right or wrong are not immediate, but they are enormous. The rules are going to be made by those countries that are on the surface of the moon and Mars, not those that have stayed home.

I want to thank Administrator Bolden for his testimony, and I look forward to a robust discussion. Thank you.

[The prepared statement of Chairman Babin follows:]



COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
 Lamar Smith, Chairman

For Immediate Release
 March 17, 2016

Media Contact: Laura Crist
 (202) 225-6371

Statement of Chairman Brian Babin (R-Texas)

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

Chairman Babin: The first and perhaps most important point I want to make today is that NASA is a worthwhile investment for the taxpayer and our nation. Space is as important to our future as were the frontiers of land, sea, and air that we faced in the past. NASA's mission to explore outer space and to use outer space for the benefit of our nation and mankind is an endeavor worthy of our great nation.

NASA as an agency, its employees, and contractors deserve our praise. I represent the 36th district of Texas, the home of the Johnson Space Center. I can say from personal experience talking with the folks at Johnson that regardless of the budgetary and policy differences in Congress or within the Administration, they are passionate and dedicated to NASA's mission.

Unfortunately, this Administration has once again done a disservice to NASA, its employees, and our nation by providing a budget request that ignores the budget agreement, requesting mandatory funding for NASA. I had hoped that the Administration would demonstrate leadership by proposing a realistic budget, but instead we were presented with a list of unfunded priorities.

The Administration has also once again disregarded the priorities of previous bipartisan NASA funding bills that the President signed. For example, even if we include the so-called mandatory budget request, the budget proposal cuts the Space Launch System (SLS) and Orion crew capsule by \$840 million and the Planetary Science Division by \$133 million. Without the mandatory funding, SLS and Orion are cut by \$1 Billion. Planetary Science is cut by \$261 million. This is not acceptable. This is a budget that takes our human spaceflight program nowhere fast. This budget undermines our space program and diverts critical funding to lower priority items.

I have been, and continue to be, concerned that the support in Congress and at NASA for the SLS and Orion programs is not matched by the Administration. The Administration consistently requests large reductions for these programs despite the insistence of Congress that they be priorities. Orion and SLS are strategic national assets and must be sufficiently funded.

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Already the effects of this diminished cadence are being felt. To keep their staff employed, planetary science institutions increasingly seek funding from foreign space agencies to compensate for the lack of projects. This results in transference of valuable skills and knowledge out of the United States to countries like China. Experienced planetary scientists are also transitioning to other fields while young scientists are choosing not enter the field, gutting our national capacity in planetary science.

It is important that NASA maintains a balanced portfolio of science activities. Unfortunately, year after year, this Administration has requested disproportionate increases for earth science activities, activities that are already funded by more than a dozen other federal agencies. This year, the President's proposal seeks to increase the Earth Science budget by \$111 million, a six percent increase. This amounts to a 70 percent increase since 2007. If this money had been put toward our human spaceflight program, we wouldn't be spending hundreds of millions on Russian launch services.

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This budget makes NASA the piggy bank for other agencies. That must end. If NASA is tasked to do other agency's work, it should do so on a reimbursable basis as it does successfully for other programs such as the Joint Polar Satellite System, and the Geostationary Operational Environmental Satellite System.

Our nation has been spacefaring since 1958, only fifty-eight years. While we have accomplished great things in these fifty-eight years, there is so much more to learn, to discover, and to put to practical uses for the benefit of our nation and mankind. But we as a nation will not be leading this journey unless we adequately fund NASA's human spaceflight and planetary science missions. Other nations, such as China, are working adamantly to become the global leader in space exploration. The consequences of America getting it right or wrong are not immediate, but they are enormous. The rules are going to be made by those countries that are on the surface of the Moon and Mars, not those that stayed home.

I thank Administrator Bolden for his testimony and look forward to a robust discussion.

Chairman BABIN. And now, I recognize the Ranking Member, the gentlewoman from Maryland, for an opening statement.

Ms. EDWARDS. Thank you very much, Chairman Babin, and thank you for calling this hearing to examine the fiscal year 2017 budget request for the National Aeronautics and Space Administration, NASA.

I'd like to start by joining you in welcoming our good friend and inspiring leader and exemplar of public service, Administrator General Charlie Bolden. Thank you, General Bolden, for your service to our nation. And we are very fortunate to have you at the helm of our nation's space agency for your consistency, your steadfastness.

Mr. Chairman, our space program is a shining example of what we can accomplish as a nation when we harness the talents of our workforce and the capabilities of our industry, academia, and international partners.

The fiscal year 2017 budget request for NASA is \$19 billion, a 1.3 percent reduction from the enacted appropriation for fiscal year 2016. And I would like to say that I was very pleased with that enacted appropriation. And so while this proposal is a good starting point for the Administration for this morning's discussion, I hope that we can at least get to the \$19.3 billion level that Congress appropriated for NASA in fiscal year 2016. It's a gentle dance that we do every year.

I'm pleased that the request proposes to revitalize our nation's aeronautics research activities with an exciting initiative to use "X-planes" to demonstrate technologies leading to cleaner, quieter, and more efficient aircraft. Demonstrating and applying advanced technologies is important to maintaining our competitive edge and sustaining the significant economic benefits that commercial aviation provides.

And I'm heartened that the request proposes increases above the levels provided in the fiscal year 2016 appropriations for the safety, security, and mission services account, which, among other things, provides the funding to operate NASA's field centers, including the Goddard Space Flight Center in Maryland.

I'm also pleased that the request would sustain a robust science program composed of research and data analysis grants and small and medium and large missions, including development of high-priority missions such as the James Webb Space Telescope, the Wide-Field Infrared Survey Telescope, the Europa Clipper, the Mars 2020 Rover, and the Solar Probe Plus missions. NASA's science programs are furthering our knowledge of our home planet and opening new windows into our universe. And if humanity is one day to extend its presence beyond Earth, we will need the scientific understanding to do just that. We'll also need to take a series of steps along a pathway involving technology development, demonstration of operational capabilities, and development and testing of exploration systems to make that move.

And while NASA has developed a "Journey to Mars" strategy that provides an initial outline of a pathway to Mars, we shouldn't have to say it again, but we need a baseline roadmap and structure to support such a multi-decadal endeavor, and we need that now. Such a roadmap would help put in sharp focus the impacts that the

proposed reductions to the Space Launch System and the Orion crew vehicle, a combined 22 percent from the fiscal year 2016 enacted level, would have on making progress towards the humans-to-Mars goal.

Frankly, I'm a little bit puzzled by the *deja vu* we're experiencing with the proposed reductions to the SLS and Orion programs. I share that concern that the Chairman has expressed from the levels Congress appropriated just this past fiscal year in 2016.

Even more puzzling and somewhat concerning is a continued talk of targeting an internal date for the first crewed Orion and SLS flight and the EM-2 mission in 2021 when the resources being requested are actually geared to a 2023 date, and so that needs some explaining. The Aerospace Safety Advisory Panel raised caution about this kind of approach in its 2015 annual report when it said "NASA has briefed the ASAP on measures... that appear to be making safety tradeoffs in order to maintain a 2021 EM-2 launch schedule." The ASAP went on to say "while the desire to fly crew on Orion as soon as possible is understandable, NASA is building a long-term exploration program and adjustments to the near-term schedule or mission content that result in far safer systems can be an advantageous trade."

Mr. Chairman, I know that you and I and many of our colleagues here this morning want to get to Mars sooner rather than later, but we must establish an enduring system that will get us there and back safely time and time again. To do so, we need to ask ourselves some important questions. Will Congress and NASA be able to establish the budgetary and programmatic discipline required to meet this goal? Will this committee and the Congress be true to providing the funding stability, sustainability, and constancy of purpose that we and others have said are critical for NASA as we prepare to transition to a new Administration less than a year from now? How will we navigate the bifurcated 2017 budget request, including both mandatory and discretionary funding, to provide the necessary stability?

And, Mr. Chairman, we owe our next generation a vibrant space agency, in partnership with industry, academia, and international partners, to continue its historic mission and to pursue the goal of one day sending humans to the surface of Mars. The future is now. The choice is ours, and it's up to us to ensure the future of our space program is a bright one.

I want to also acknowledge the presence here today of our future, Kendra Wood, who's an intern in my office and a graduate of the University of Maryland Eastern Shore. She is a superstar, and we owe it to her generation, also to our visitors from Spelman College, a senior at Spelman, Antonia Hill, who's visiting with us here today. And so let's keep these young people in mind as we talk about the future of space.

And I yield the balance of my time.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE

RANKING MEMBER DONNA F. EDWARDS (D-MD)

Chairman Babin, thank you for calling this hearing to examine the Fiscal Year 2017 budget request for the National Aeronautics and Space Administration—NASA.

I'd like to start by joining you in welcoming a friend, an inspiring leader, and an exemplar of public service, Administrator Charlie Bolden. Thank you, General Bolden, for your service to our nation. We are fortunate to have you at the helm of our nation's space agency.

Mr. Chairman, our space program is a shining example of what we can accomplish as a nation when we harness the talents of our workforce and the capabilities of our industry, academia, and international partners.

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NASA's science programs are furthering our knowledge of our home planet and opening new windows into our universe. And, if humanity is to one day extend its presence beyond Earth, we will need the scientific understanding to do so.

We will also need to take a series of steps along a pathway involving technology development, demonstration of operational capabilities, and development and testing of exploration systems to make that move.

While NASA has developed a Journey to Mars strategy that provides an initial outline of a pathway to Mars, we need a baseline roadmap and structure to support such a multidecadal endeavor. Such a roadmap would help put in sharper focus the impacts that the proposed reductions to the Space Launch System (SLS) and the Orion crew vehicle—a combined 22 percent from the FY 2016 enacted level—would have on making progress toward the humans-to-Mars goal.

Frankly, I am puzzled by the *deja vu* we are experiencing with the proposed reductions to the SLS and Orion programs from the levels Congress appropriated for Fiscal Year 2016. Even more puzzling and somewhat concerning is the continued talk of targeting an internal date for the first crewed Orion and SLS flight—the EM-2 mission—in 2021 when the resources being requested are geared to a 2023 date.

The Aerospace Safety Advisory Panel raised caution about this approach in its 2015 Annual Report when it said, "NASA has briefed the ASAP on measures that appear to be making safety trade-offs in order to maintain a 2021 EM-2 launch schedule."

The ASAP went on to say, "While the desire to fly crew on Orion as soon as possible is understandable, NASA is building a long-term exploration program, and adjustments to the near-term schedule or mission content that result in far safer systems can be an advantageous trade."

Mr. Chairman, I know that you, I, and many of our colleagues here this morning want to get to Mars sooner rather than later. But we've got to establish an enduring system that will get us there and back safely, time and time again. To do so, we need to ask ourselves some important questions.

- Will Congress and NASA be able to establish the budgetary and programmatic discipline required to meet this goal?
- Will this Committee and Congress be true to providing the funding stability, sustainability and constancy of purpose that we and others have said are critical for NASA as we prepare to transition to a new Administration less than a year from now?

- How will we navigate the bifurcated FY 2017 budget request, including both “mandatory” and discretionary funding, to provide the necessary stability?

Mr. Chairman, we owe our next generation a vibrant space agency, in partnership with industry, academia, and international partners, to continue its historic mission and to pursue the goal of one day sending humans to the surface of Mars. The future is now. The choice is ours. It is up to us to ensure the future of our space program is a bright one.

Thank you and I yield back.

Chairman BABIN. Thank you, Ms. Edwards.

I now recognize the Chairman of our full committee, Mr. Smith. Chairman SMITH. Thank you, Mr. Chairman.

And Administrator Bolden, welcome. I'm glad you're here.

Mr. Chairman, this committee has demonstrated time and again that U.S. leadership in space is a bipartisan priority. I believe that many of the hardworking scientists, engineers, and innovators working at NASA share our interest in ensuring America leads the world in space.

There are some areas of agreement between the Committee and the Administration in NASA's fiscal year 2017 budget request. But this proposed budget continues to tie our astronauts' feet to the ground and makes a Mars mission all but impossible.

This budget cuts funding for human exploration by nearly \$1 billion, and robotic exploration by almost a quarter of a billion dollars. The budget request once again underfunds the Space Launch System and Orion programs. This Administration cannot continue to tout plans to send astronauts to Mars while strangling the programs that will take them there.

The Administration also attempts to redistribute funding within NASA's Science Mission Directorate. For example, Jupiter's moon Europa is one of the most promising destinations we have in our own solar system for finding life beyond our planet. However, this year's request of only \$17 million for the Europa mission is incredibly disappointing considering the mission's potential. This represents roughly a 90 percent reduction from the fiscal year 2016 level.

However, support for other priorities such as the James Webb Space Telescope, the Transitioning Exoplanet Survey Satellite, and the Wide-Field Infrared Space Telescope is encouraging. Missions like these, as well as their search for exoplanets and signs of life in other areas of our universe, captivate the American public's imagination.

Overall, though, there is a lack of balance in the science account request. One of the most glaring examples is the disproportionate increase in the Earth Science Division receives at the expense of other science divisions and human and robotic space exploration. This represents a 70 percent increase for the Earth Science Division since the fiscal year 2007 request. Over the same period, NASA's overall yearly budget has only increased 20 percent.

The Earth science budget request is 42 percent more than the planetary science budget request. In fact, the planetary science budget request is a reduction of \$113 million over last year's level. The Earth science request also is more than the Astrophysics Division, the James Webb Space Telescope, and the Heliophysics Division combined. There are 13 other federal agencies involved in Earth science research but only one that is responsible for space science and exploration, and that's NASA.

This budget also proposes \$223 million to fund the uninspiring Asteroid Retrieval and Redirect Mission. On April 15, 2010, the President directed NASA to conduct a crewed mission to an asteroid by 2025. Then, with the 2014 budget request, the Administration changed course and directed NASA to redirect an asteroid to orbit the moon and then visit that asteroid in lunar orbit. Then,

last year, NASA decided to only remove and redirect a boulder from a larger asteroid.

Originally scheduled for 2017, then 2020, this budget request now slips the first robotic launch to 2021. The crewed encounter will also slip to 2026 and more likely later based on SLS mission requirements. In practical terms, the President's own budget delays the ARM beyond the next Administration's second term.

All of NASA's advisory bodies have criticized the project. International interest is absent. The scientific community is unimpressed. The Administration continues to push this mission on NASA without any connection to a larger exploration roadmap and absent support from the scientific community or NASA's own advisory committees.

It is NASA's responsibility to provide a compelling plan for space exploration and execute it. It is Congress's responsibility to ensure NASA's budget is prioritized and funded. This committee will do everything in its power to support American leadership in space.

Mr. Chairman, before I yield back, let me compliment Administrator Bolden because I think he is a committed public servant. I think he is doing the best job anybody can do under the circumstances. And I have a hunch if he were writing this budget, it might vary slightly from the Administration's proposed budget.

You don't need to respond to that, Administrator Bolden, we all have our different priorities. But this is simply to say I appreciate the job that you're doing, and I continue to be impressed with your sincerity and dedication.

With that I'll yield back.

[The prepared statement of Chairman Smith follows:]



COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
 Lamar Smith, Chairman

For Immediate Release
 March 17, 2016

Media Contact: Laura Crist
 (202) 225-6371

Statement of Chairman Lamar Smith (R-Texas)

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

Chairman Smith: Thank you, Mr. Chairman. And Administrator Bolden, welcome. I'm glad you're here. Mr. Chairman, this Committee has demonstrated time and again that U.S. leadership in space is a bipartisan priority. I believe that many of the hard-working scientists, engineers and innovators working at NASA share our interest in ensuring America leads the world in space.

There are some areas of agreement between the Committee and the administration in NASA's Fiscal Year 2017 budget request. But this proposed budget continues to tie our astronauts' feet to the ground and makes a Mars mission all but impossible.

This budget cuts funding for human exploration by nearly 1 billion dollars, and robotic exploration by almost a quarter of a billion dollars.

The budget request once again underfunds the Space Launch System and Orion programs. This administration cannot continue to tout plans to send astronauts to Mars while strangling the programs that will take them there.

The administration also attempts to redistribute funding within NASA's Science Mission Directorate.

For example, Jupiter's moon Europa is one of the most promising destinations we have in our own solar system for finding life beyond our planet. However, this year's request of only \$17 million for the Europa mission is incredibly disappointing considering the mission's potential. This represents roughly a 90 percent reduction from the Fiscal Year 2016 level.

However, support for other priorities such as the James Webb Space Telescope, the Transitioning Exoplanet Survey Satellite, and the Wide Field Infrared Space Telescope is encouraging.

Missions like these, as well as the search for exoplanets and signs of life in other areas of our universe, captivate the American public's imagination.

Overall, though, there is a lack of balance in the science account request.

One of the most glaring examples is the disproportionate increase the Earth Science Division receives at the expense of other science divisions and human and robotic space exploration.

This represents a 70 percent increase for the Earth Science Division since the Fiscal Year 2007 request. Over the same period, NASA's overall yearly budget has only increased 20 percent.

The Earth science budget request is 42 percent more than the planetary science budget request. In fact, the planetary science budget request is a reduction of \$113 million over last year's level.

The Earth Science request also is more than the Astrophysics division, the James Webb Space Telescope, and the Heliophysics Division combined. There are 13 other federal agencies involved in earth science research, but only one that is responsible for space science and exploration, and that's NASA.

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Then last year NASA decided to only remove and redirect a boulder from a larger asteroid. Originally scheduled for 2017, then 2020, this budget request now slips the first robotic launch to 2021. The crewed encounter will also slip to 2026 – and more likely later based on SLS mission requirements.

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The administration continues to push this mission on NASA without any connection to a larger exploration roadmap and absent support from the scientific community or NASA's own advisory committees.

It is NASA's responsibility to provide a compelling plan for space exploration and execute it. It is Congress's responsibility to ensure NASA's budget is prioritized and funded. This Committee will do everything in its power to support American leadership in space.

Mr. Chairman, before I yield back, let me compliment Administrator Bolden because I think he is a committed public servant. I think he is doing the best job anybody can do under the circumstances. And I have a hunch if he were writing this budget, it might vary slightly from the administration's proposed budget. You don't need to respond to that Administrator Bolden. We all have our different priorities. But this is simply to say I appreciate the job that you're doing and I continue to be impressed with your sincerity and dedication.

With that I yield back.

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Chairman BABIN. Yes, sir. Thank you, Mr. Chairman. And I concur.

I now recognize the Ranking Member, Ms. Johnson of the full committee, for a five minute statement.

Ms. JOHNSON. Thank you very much, Mr. Chairman.

Let me comment before my time starts on how pleased I am to hear those remarks from my Chairman. And I really agree with him, and that's extraordinary.

Let me say good morning to everyone and to acknowledge that I have a student here with me today, Adia Moss, who is a senior at Spelman, and hasten to say that I appreciate the long and distinguished service to our nation and your steady leadership of NASA, General Bolden. We know that this is a challenging and exciting time in the agency's history. I know how passionately you care about the nation's space and aeronautics program, and I look forward to hearing your testimony today.

Today's hearing marks the beginning of the Committee's consideration of the President's fiscal year 2017 NASA budget request. The \$19 billion budget request is a strong endorsement by the President of the important role that NASA plays. We send budgets out of here with a lot less, and then we complain about what the President is doing, which is, to them, a lot less.

This is not to say that this is perfect for a NASA budget request, but I do agree with all the elements of it. It is a good starting point. It is Congress's deliberations. It is our responsibility to send what we feel is a responsible budget because it is what our focus should be today, what we want NASA to accomplish, and what we are willing to invest in NASA to do it so that we can achieve those objectives.

It may be tempting for some of us to spend our time criticizing the President for what they consider shortcomings in his budget request, but I think it's not a good use of anybody's time. The President has submitted his NASA budget request to Congress. It is now our job to determine the funding that NASA will receive and the policies it will follow. If we fail to do that, we will have no one to blame but ourselves.

That said, there is much to recommend in this NASA budget request. For example, I'm excited by the aeronautics initiative. I know the important role that aviation plays in our economy and our society, and NASA's R&D has long provided the underpinnings of new capabilities in aviation. I'm also pleased by the investments made in NASA's science and technology activities. History shows us that these investments will pay dividends in increased knowledge and new technological capabilities.

On the other hand, I'm disappointed that the funding for the Space Launch System and the Orion spacecraft, the systems that are essential elements of the nation's future human exploration initiatives, have been cut in this budget request. We can change that if we wish. Such cuts add just one more challenge to those already facing the team of dedicated men and women who are working so hard to turn these exploration goals into reality. I would anticipate that Congress will reaffirm its support for SLS and the Orion by the time this year's funding deliberations are complete.

Which brings me to one final observation, namely, we will have a new President by this time next year. I know that there are those in NASA who feel the pressure to accomplish as much as possible on the new exploration systems before a new Administrator takes power. That's understandable. But it can wind up doing more harm than good. In its latest report, the Aerospace Safety Advisory Panel has raised concerns that perceived schedule pressure, whether external or self-imposed, can lead to excessive levels of risk being taken on in order to try to meet arbitrary deadlines. That's not the path to a sustainable or a successful program.

I hope that NASA management and workers will heed the ASAP's concern and not defer needed testing or make overly optimistic commitments in a shortsighted attempt to keep those programs alive in advance of a new Presidential Administration taking power. To all those NASA and contract employees, I would simply say, Congress supports SLS and Orion and commercial crew, and we will continue to do so no matter what we say here to make the news or the record. We will do this in spite of a new President taking office. We know that what we do actually is rocket science. So take time and the testing needed to do it right.

With that, Administrator Bolden, I again want to welcome you. I look forward to your testimony. And I yield back.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF FULL COMMITTEE RANKING MEMBER

EDDIE BERNICE JOHNSON (D-TX)

Good morning. I would like to join the Chairman in welcoming Administrator Bolden to today's hearing.

Administrator Bolden, I appreciate your long and distinguished service to our nation and your steady leadership at NASA during a challenging and exciting time in the agency's history. I know how passionately you care about the nation's space and aeronautics programs, and I look forward to hearing your testimony today.

Today's hearing marks the beginning of the Committee's consideration of the President's FY 2017 NASA budget request. This \$19 billion budget request is a strong endorsement by the President of the important role that NASA plays in advancing America's R&D enterprise, and I appreciate his willingness to attach a high priority to NASA in this, his last Federal budget request.

That is not to say that it is a perfect NASA budget request or that I agree with all elements of it. But it is a good starting point for Congress's deliberations.

Because that is what our focus should be today—what do we want NASA to accomplish and what are we willing to invest in NASA so that it can achieve those objectives.

It may be tempting for some to want to spend their time criticizing the President for what they consider shortcomings in his budget request, but I think that is not a good use of anyone's time.

The President has submitted his NASA budget request to Congress. It is now our job to determine the funding NASA will receive and the policies it will follow. If we fail to do that, we will have no one to blame but ourselves.

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I hope that NASA management and workers will heed the ASAP's concerns and not defer needed testing or make over-optimistic commitments in a shortsighted attempt to keep those programs alive in advance of a new Presidential administration taking power. To all those NASA and contractor employees I would simply say: Congress supports SLS and Orion and Commercial Crew, and we will continue to do so when a new President takes office. We know that what you do actually is "rocket science", so take the time and the testing needed to do it right.

With that, Administrator Bolden, I again want to welcome you, and I look forward to your testimony.

Chairman BABIN. Thank you.

They have called votes, so we're going to move right along here.

I'd like to introduce our first and our only witness today, and that is Hon. Charles F. Bolden, Jr. General Bolden has been the Administrator of NASA since 2009, and he's a man who has devoted his entire career in service to our country, and I thank him for that.

Prior to becoming Administrator, General Bolden served for 34 years in the Marine Corps, including 14 years as a member of NASA's Astronaut Office. General Bolden has traveled to orbit four times aboard the space shuttle, including the flight that deployed the Hubble Space Telescope. General Bolden has several honorary doctorates from a variety of prestigious universities and received his bachelor's in electrical science from the U.S. Naval Academy.

I would add that General Bolden and I share the honor of having our sons graduate from the U.S. Naval Academy as well. His son Che is a Naval aviator currently, and my son Leif was a Navy SEAL.

Now, let's hear from General Bolden for the next five minutes. Thank you, General.

**TESTIMONY OF THE HON. CHARLES F. BOLDEN, JR.,
ADMINISTRATOR, NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION**

Hon. BOLDEN. Mr. Chairman, thank you very much. And to you and the Members of the Committee, it is indeed a pleasure and an honor to discuss with you today President Obama's \$19 billion fiscal year 2017 budget request for NASA.

And as I had to do the day before yesterday, I want to make sure that my position is not mischaracterized by the Chairman and others. This is my budget, and I had to battle—

Chairman SMITH. Then I'll have to retract all those nice compliments I gave you.

Hon. BOLDEN. That's why I want to make sure that the compliments are earned and not just said to be nice.

I am very proud of this budget, and I think all of you know that when it comes budget time, you go into deliberations, and I have two sets of deliberations. I go into deliberations with the Administration, and then I come and what I would like to do is be involved in the deliberations with the Congress on how the budget turns out.

So I'm very proud of the budget that we're presenting today because it builds on what I think was an incredible budget from this Congress in fiscal year 2016, and I cannot thank you enough for that. You made us feel needed and appreciated, and we want to keep doing that. So that's what we tried to do with this budget.

It's been my honor to serve as the NASA Administrator throughout the Obama Administration and, as we submit what is likely my final budget—yes, ma'am—I am proud of the many things this agency has accomplished on behalf of the American people with the resources the President and the Congress have committed to us over the past seven years. Together, we have enabled our nation to continue leading the world in space exploration and scientific discovery.

Two weeks ago, American astronaut Scott Kelly returned home from the International Space Station after 12 months working off the Earth for the Earth. His year in space will pay scientific and medical dividends for years to come, helping pave the way for future astronauts to travel to Mars and beyond. Commander Kelly significantly advanced our Journey to Mars, and I trust that you join me in saluting his service to our nation.

NASA is closer to sending American astronauts to Mars than at any point in human history, and this budget will keep us moving forward. The support of this committee and the Congress is essential to this journey. The International Space Station is the cornerstone of our exploration strategy. Thanks to the determination and ingenuity of American industry, we have returned space station cargo resupply launches to U.S. soil, in-sourced jobs, and helped establish a new private market in low-Earth orbit.

American companies are now ferrying supplies to our astronauts on the space station from the United States with Orbital ATK set to launch again later this month and SpaceX targeting a resupply mission in early April, both from the Kennedy Space Center. In July, Orbital will conduct a return-to-flight mission from the Wallops Flight Facility.

Thanks to the Administration's decision to invest in American industry and to the full funding we received from Congress for 2016, spearheaded by this Committee, this Committee was the first to propose full funding for the President's commercial crew program, and I really appreciate that. But now Boeing and SpaceX continue to make great progress towards certification in 2017 to safely transport our astronauts to the space station from U.S. soil, ending our sole reliance on Russia once and for all.

NASA is making significant progress on the Journey to Mars, developing our newest, most powerful rocket ever built, the Space Launch System and Orion crew vehicle, as part of the sustainable and affordable deep space exploration system. This budget supports the agency's baseline commitment for an un-crewed test flight of SLS and Orion in 2018 and a crewed flight by 2023. With addi-

tional funding provided by the Congress, the teams will continue to work toward an earlier launch date for the first crewed mission and are already designing and procuring long lead hardware for subsequent missions.

The budget also increases funding for habitation systems development, a key component of our steppingstone strategy to send humans to Mars. The President's budget funds a robust science program with dozens of operating missions studying our solar system, the universe, and the most important planet in our solar system, Earth. This coming July 4, Independence Day, the Juno spacecraft will orbit Jupiter while the Cassini spacecraft will prepare to execute its dramatic grand finale, orbits of Saturn. OSIRIS-REx will launch to a near-Earth asteroid to collect a sample for return to Earth in 2023. In 2017 and 2018, NASA will launch seven exciting space science missions, including the James Webb Space Telescope.

Before we send humans to Mars, robots are paving the way with Mars InSight now targeted for launch in 2018. Another Mars rover set to launch in 2020, joining the Curiosity and Opportunity rovers now exploring the red planet and work underway to define the next Mars mission for 2022.

We are formulating missions to explore Jupiter's moon Europa, as well as WFIRST designed to study dark energy, perform galactic and extragalactic surveys, and explore exoplanets. We're accelerating the building of Landsat 9 as part of our sustainable land-imaging architecture to continue our 40-year record of high-quality measurements of Earth's land cover.

NASA technology drives exploration. With this request, NASA will continue to conduct rapid development and incorporation of transformative missions—space technology missions to enable future human and robotic missions, increase capabilities of other U.S. agencies, and address aerospace industry challenges. Space technology investments will ensure that we continue to lead the world in exploration and scientific discovery.

NASA's aeronautics program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. With this request, NASA aeronautics is ready to take the next step to develop and fly X-plane demonstrators in partnership with industry and academia, including ultra-efficient subsonic transport experimental aircraft in the world's first low-boom supersonic flight demonstrator.

Mr. Chairman, I appreciate the support that we have received from this committee through the years, and I look forward to your questions. And I, too, would like to commend the young ladies who are in the audience today, all of them, but a special shout-out to the ones from Spelman since that is also the alma mater of my wife and my daughter.

Thank you, Mr. Chairman.

[The prepared statement of Mr. Bolden follows.]



National Aeronautics and
Space Administration

Hold for Release Until
Presented by Witness

March 17, 2016

**Subcommittee on Space
Committee on Science, Space and Technology**

U.S. House of Representatives

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

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UNTIL PRESENTED
BY WITNESS
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The Honorable Charles F. Bolden, Jr.
Administrator
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before the

Subcommittee on Space
Committee on Science, Space, and Technology
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Mr. Chairman and Members of the Committee, I am pleased to have this opportunity to discuss NASA's FY 2017 budget request. The President is proposing an FY 2017 budget of more than \$19 billion for NASA, building on the strong and consistent support NASA has received from this Committee and the Congress. This request, which includes both discretionary and mandatory funding, will allow NASA to continue to lead the world in space through a balanced program of exploration, science, technology, and aeronautics research.

Of note, within this request, NASA is proposing a ten-year plan that would significantly accelerate aeronautics research. We seek support from congress for a substantial increase in funding for aeronautics that will support a vigorous flight demonstration program to demonstrate and validate technologies to dramatically improve the aircraft of the future. We are ready to test these technologies and concepts as integrated systems by developing "X-plane" demonstrators. The United States leads the world in aviation, but this leadership can only be maintained by a vigorous program of research to create the efficient aircraft of the future.

NASA is positioned for a vibrant future, and we look forward to the long term support that will enable the Agency to continue leading the world into space and on the journey to Mars. We are on track for the key near-term steps on that journey with flight certification of our commercial crew transportation systems in 2017, and the launch of Exploration Mission 1 (EM-1) in 2018. In 2016, the Juno Spacecraft will orbit Jupiter while Cassini will execute its dramatic "Grand Finale" orbits of Saturn. The Solar Probe Plus (SPP), Transiting Exoplanet Survey Satellite (TESS) and the James Webb Space Telescope (JWST) are on track to launch in 2018, and a new Mars rover is in development for a 2020 launch on its way to join the spectacular Curiosity rover now exploring the planet. NASA's missions are providing the critical data we need to understand the home planet, our nearby star, every planet in the Solar system, and the universe. We are accomplishing all this while consistently improving program performance: GAO reports that overall development cost growth for the portfolio of major development programs it tracks, excluding the James Webb Space Telescope (JWST), fell to 1.3 percent, at or near the lowest levels we have reported since GAO began annual reviews in 2009. Relying on the consistent support of Congress, the Agency remains on a sustainable path to accomplish a world-leading program of exploration and discovery in space. The Agency is well positioned to continue on its long-term mission, and, by focusing on executing the plan we have laid out, we intend to earn the continued support of future Administrations and Congresses for this plan.

Human Exploration and Operations

The FY 2017 President's Budget Request continues NASA's Journey to Mars, extending our reach in space with the specific goal of sending human missions to Mars, and the broader aim of establishing a sustainable human presence beyond Earth. NASA's exploration strategy is to evolve from today's Earth-reliant posture to conducting missions in the Proving Ground of cislunar space and then to the Earth-independent capability needed to extend human presence into the solar system and to the surface of Mars. The FY 2017 request includes \$3,336.9 million for Exploration, with \$2,859.6 million for Exploration Systems Development, and \$477.3 million for Exploration Research and Development. The FY request also includes \$5,075.8 million for Space Operations, including \$1,430.7 million for the International Space Station (ISS), \$887.4 million for Space and Flight Support, and \$2,757.7 million for Space Transportation – both commercial crew system development and on-going crew and cargo transportation services that resupply ISS.

The first step on the Journey to Mars is our current activity in low Earth orbit (LEO), where research and technology development activities conducted aboard ISS are delivering the knowledge we need to keep our astronauts safe, healthy and productive on deep-space missions of increasing durations. ISS research is advancing the fundamental biological and physical sciences for the benefit of humanity, improving life on Earth and adding to our understanding of the universe. The ISS is the cornerstone of our exploration strategy, a nearby outpost in space where humanity is taking its early steps on its journey into the solar system, and we appreciate the action Congress took last year to authorize continued Station operations through at least 2024, consistent with the President's request.

Under the Commercial Resupply Services (CRS) contracts, our two commercial cargo partners, Space Exploration Technologies (SpaceX) and Orbital ATK, have demonstrated not only the ability to provide cargo deliveries to ISS, but also the flexibility to recover effectively from mishaps. Both companies have worked closely with NASA to understand the anomalies they experienced over the last year and a half. In developing the launch vehicles for their cargo spacecraft, SpaceX and Orbital ATK have also helped to bring some of the commercial satellite launch market back to the U.S., and helped to lower commercial launch costs. This January, through CRS-2, NASA contracted with SpaceX, Orbital ATK, and Sierra Nevada Corporation to ensure that critical science, research and technology demonstrations will be delivered to the ISS from 2019 through 2024. Our commercial crew partners, SpaceX and the Boeing Company, are developing the Crew Dragon and CST-100 Starliner spacecraft, respectively. The work, being done under two Federal Acquisition Regulation (FAR)-based, fixed-price Commercial Crew Transportation Capability (CCtCap) contracts, is expected to result in flight certification of their crew transportation systems by the end of calendar year 2017. In 2015, NASA ordered the initial post-certification missions, and in 2016, milestone completion and work are progressing well. 2017 will be an exciting and challenging year as we work with our partners to launch the first new human spaceflight capability in a generation.

Under the auspices of the ISS National Laboratory, managed by the Center for the Advancement of Science In Space (CASIS), NASA is encouraging broader use of the ISS by non-traditional companies and other Government agencies. The ISS National Lab has reached full capacity for allocated crew time for research that was both scientifically and economically reviewed for terrestrial benefit.

As we move out into the Proving Ground of cislunar space, we will employ new deep-space systems, including the heavy-lift Space Launch System (SLS), Orion crew vehicle, the Exploration Ground Systems (EGS) that support them, and new deep space habitation capabilities developed through public-private partnerships. We will also continue to invest in exploration research and development that will make future missions safer, more reliable, and more affordable. NASA's initial deep-space mission,

EM-1, is on track to launch to a distant retrograde orbit in the Proving Ground around the Moon in 2018. In 2015, the Agency conducted a key decision point review of the Orion program, establishing an Agency baseline commitment level for Orion that supports a 2023 launch readiness date for EM-2. The FY 2017 budget fully funds the Agency baseline commitment level. In the initial phase of our Proving Ground operations, NASA will use this region of space to test and demonstrate flight and mission operations and staging of human-rated vehicles farther from Earth than ever before. Crewed Orion missions launched on the SLS in the 2020s will establish our capability to operate safely and productively in deep space.

SLS and Orion are critical to human spaceflight beyond LEO. The NASA-Industry teams building SLS and Orion have made tremendous progress over the last year in building and testing vehicle components. For SLS, the Core Stage qualification and EM-1 flight barrels are awaiting vertical welding at the Michoud Assembly Facility (MAF), the RS-25 flight engines are all assembled and awaiting engine controller installation, and production of the final booster qualification motor is nearly complete. For Orion, the EM-1 Crew Module pressure vessel welding is complete, the European Service Module structural testing is in progress, and software testing is underway in the Integrated Test Lab. In EGS, Mobile Launcher structural mods are complete, the Vehicle Assembly Building High Bay 3 platforms are being installed, and Crawler Transporter mods are underway.

Subsequent missions in the Proving Ground will target challenges and strategic knowledge gaps while helping develop the core capabilities necessary to expand human activity farther into deep space, culminating in demonstration of a long-duration (one-year plus) deep-space habitation capability, critical preparation for crewed missions to Mars. The FY 2017 request includes the funding to support work on the required habitation systems. Our FY 2017 budget includes \$90 million to support habitation systems development. This work includes the second phase of the Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement, an effort to stimulate deep-space capability development across the aerospace industry. Through these initial public-private partnerships, NextSTEP partners will provide advanced concept studies, technology development projects, and significant measurements in key areas, including habitat concepts, environmental control and life support systems, advanced in-space propulsion, and small spacecraft to conduct missions related to Strategic Knowledge Gaps. The NextSTEP efforts are a key component of our overall strategy to move into the Proving Ground.

NASA will continue to develop the Asteroid Redirect Mission. This will include a robotic mission that will remove a multi-ton boulder from a target asteroid and use solar-electric propulsion to move the boulder into lunar orbit. A human mission using the SLS and Orion vehicles will then rendezvous with and take samples from this asteroidal mass. The mission demonstrates the use of advanced solar-electric propulsion, automated rendezvous and complex crew operations in the Proving Ground of lunar orbit, and improves NASA's ability to identify and respond to potentially dangerous asteroids.

Space Technology

NASA's FY 2017 request includes \$826.7 million for Space Technology to conduct rapid development and incorporation of transformative space technologies to enable NASA's future missions, increase the capabilities of other US agencies, and address aerospace industry challenges. NASA's Space Technology program has developed a diverse portfolio creating a technology pipeline to solve the Agency and Nation's most difficult challenges in space. Space Technology will continue to prioritize "tipping point" technologies and early-stage innovation with approximately 600 awards to industry and small businesses, private innovators, and academia to spark new ideas for the benefit of NASA as well as the broader US aerospace and high tech sectors. As efforts complete, appropriate technologies will be transferred and commercialized to benefit a wide range of users ensuring the nation realizes the full economic value and societal benefit of these innovations. Technology drives exploration by continuing maturation of enabling

technologies for future human and robotic exploration missions including deep space optical communications to return more data and improve operations; improved carbon dioxide removal and oxygen recovery systems for more efficient life support and environmental control capabilities; nuclear thermal propulsion technologies for rapid in-space transit; robotics and autonomy to reduce mission cost and risk; and advancements in remote sensing instruments and spacecraft subsystems to reduce size, weight and power requirements enabling lower cost missions utilizing small spacecraft.

The program will take a major step early next year with the launch of the Green Propellant Infusion Mission (GPIM). GPIM will demonstrate on-orbit a propellant that has higher performance and is much safer to handle than the hydrazine fuel that is now commonly used for in-space propulsion systems.

In FY 2017, building on the Robotic Refueling Mission technology demonstrations on ISS, the program will continue mission formulation for Restore-L, a mission to advance and demonstrate the capability to service and refuel satellites on orbit with the potential to add life to existing satellites worth billions of dollars.

In support of the Asteroid Redirect Robotic Mission (ARRM), Space Technology continues development of high-powered solar electric propulsion technologies that will enable extremely efficient orbit transfer and accommodate increasing power demands for government and commercial satellites.

Also in FY 2017, the Mars Oxygen In Situ Resource Utilization Experiment (MOXIE) payload on the Mars 2020 mission will hold a Critical Design Review. The payload will demonstrate the in situ production of oxygen on Mars, a technology that could furnish oxygen for breathing and fuel on future Mars missions. The Laser Communications Relay Demonstration project will complete its Critical Design Review and Key Decision Point - C, and will continue hardware fabrication to support a late CY 2019 launch readiness date.

Science

NASA's science vision is to use the vantage point of space to achieve with the science community and our partners a deep scientific understanding of our home planet, the Sun and its effects on the solar system, other planets and solar system bodies, the interplanetary environment, and the universe beyond. The President's FY 2017 budget requests \$5,600.5 million for NASA's Science program including \$2,032.2 million for Earth Science, \$1,518.7 million for Planetary Science, \$781.5 for Astrophysics, \$569.4 million for the James Webb Space Telescope, and \$698.7 million for Heliophysics.

From orbit, NASA satellites advance our knowledge of our dynamic and complex home planet, Earth. In addition to driving scientific discoveries, NASA Earth-observing research satellite missions collect essential measurements that serve national interests. Our NASA satellites monitor regional and global food and water security and air quality, support disaster response, and contribute to economic growth. Nineteen NASA research missions – five of which were launched in a span of 11 months from 2014 to 2015 – are orbiting the Earth and providing key measurements today. The Global Precipitation Measurement mission has already produced the first global rain and snowfall map, and the constellation routinely observes precipitation over the entire globe every 2-3 hours. The ISS Rapid Scatterometer, the first science payload to be robotically assembled in space since the ISS itself, measures surface ocean wind speeds and directions. And the Soil Moisture Active and Passive mission provides global, high-accuracy soil moisture and sea-surface salinity measurements at 35 km resolution.

In 2016, three launches will add significantly to our capabilities. On January 17, NASA launched the Jason-3 satellite, a mission led by NOAA and EUMETSAT, along with our French partner CNES. Jason-3 is the fourth mission in a U.S.-European series using precision altimetry to measure ocean surface

topography – the hills and valleys of the ocean surface. Later in the year, the SAGE-III (Stratospheric Aerosol and Gas Experiment-III) instrument will launch to the ISS to obtain atmospheric trace gas profile data, including ozone measurements, with the Lightning Imaging Sensor as a secondary payload. In October, a constellation of eight micro-satellites called the Cyclone Global Navigation Satellite System (CYGNSS) will become NASA's first Earth Venture Mission small-sat constellation, to investigate the evolution of tropical cyclones and hurricanes. The FY 2017 request supports development of new missions including the Ice, Cloud, and land Elevation Satellite-2 (ICESAT-2) and the Gravity Recovery and Climate Experiment Follow-on (GRACE-FO) that provide continuity for key long-term measurements.

NASA is building Landsat 9 as part of our Sustainable Land Imaging (SLI) architecture that will continue our Nation's accurate measurement of Earth's land cover. NASA and the U.S. Geological Survey (USGS) initiated Landsat 9 in March 2015 and it is being built as a near-copy of Landsat 8 for launch in the 2021 timeframe. The SLI program will work closely with industry to support and infuse advanced satellite, scientific instrument, and overall system technologies into future missions. The robust SLI architecture ensures that high-quality Landsat imagery, freely accessible in an open archive, will continue to be available for critical uses such as monitoring the irrigation of farmland in the American West.

NASA's Astrophysics program continues to operate the Hubble, Chandra, Spitzer, Fermi, and Kepler space telescopes, the Stratospheric Observatory for Infrared Astronomy (SOFIA) airborne observatory, and other missions that together comprise an unrivaled resource for the study of our universe. NASA's next strategic Astrophysics mission, the James Webb Space Telescope, continues on schedule for its 2018 launch and remains within budget.

With this year's request, NASA will continue developing the Transiting Exoplanet Survey Satellite (TESS) for launch in 2018. TESS will extend the pioneering exoplanet discoveries of the Kepler Space Telescope by looking for rocky exoplanets orbiting the nearest and brightest stars in the sky in time for Webb to conduct follow-up observations. During FY 2017, NASA will also continue formulation of the Wide-Field Infrared Survey Telescope (WFIRST), the top priority for large-scale missions of the most recent National Academy of Science Decadal Survey in Astronomy and Astrophysics.

With the FY 2017 budget request, NASA will broaden its reach into the Solar System with increasingly capable missions and continue to produce a series of exciting achievements in planetary science. In one of the biggest stories of the past year, NASA's New Horizons spacecraft captured our imaginations by showing us the complexity of one of our most distant and smallest neighbors. And despite being far beyond Pluto now, the intrepid probe continues to send volumes of pictures and other data over a radio link to Earth stretching billions of miles. At the same time, the Juno spacecraft is on its way to Jupiter where it will achieve a first-ever polar orbit of the gas giant this July 4th. And just two short months later, NASA's robotic asteroid rendezvous and sample return mission, dubbed OSIRIS-REx, will launch to the near Earth asteroid, Bennu, where it will collect a sample for return to Earth in 2023. In late 2016, after more than ten years of exploration, the Cassini spacecraft will begin a daring set of orbits called the Grand Finale that is, in some ways, like a whole new mission. The spacecraft will repeatedly climb high above Saturn's poles before probing the water-rich plume of the active geysers on the planet's intriguing moon Enceladus, fly by Titan, and then dive between the planet and its innermost ring 22 times. No other mission has explored this unique region so close to the planet. Moreover, the FY 2017 request supports several other missions operating throughout the Solar System. These include the Curiosity rover at Mars, the Lunar Reconnaissance Orbiter, the Dawn spacecraft currently at Ceres, and the Mars Atmosphere and Volatile Evolution (MAVEN) orbiter.

Looking to the future, the FY 2017 request continues development of a new rover that in 2020 will carry seven carefully selected instruments to conduct exceptional science as well as for the first time ever,

cache a Mars sample for a potential later return to Earth. The budget also continues formulation for a mission to Jupiter's moon, Europa, to explore the most likely host of current life beyond Earth. In addition, this year's request releases a new announcement of opportunity for NASA's New Frontiers Program and selects at least one new Discovery mission for development – ensuring this essential path of exploration for the next decade.

NASA's Heliophysics program operates 18 active missions comprising 28 spacecraft, called the Heliophysics System Observatory (HSO), to understand the Sun and its interactions with Earth and the solar system, including space weather. NASA continues to gain important insight from the HSO, including new observations from the Magnetospheric Multiscale (MMS) Mission, which entered full science mode September 1, 2015. The FY 2017 request supports the continued development of the Solar Probe Plus (SPP) mission, planned for launch in 2018. SPP will fly closer to the Sun than any previous mission to study its outer atmosphere. The request will enable the continued development of critical instruments for the NASA-ESA Solar Orbiter Collaboration mission scheduled for launch in 2018. NASA will continue development of the Ionospheric Connection (ICON) and Global-scale Observations of the Limb and Disk (GOLD) missions. ICON will investigate the interaction of solar forces and Earth's weather systems that drive extreme and unpredicted variability. GOLD will measure densities and temperatures in Earth's thermosphere and ionosphere to improve our understanding and potentially our predictive capabilities of activity in this region.

Aeronautics

NASA's Aeronautics program advances U.S. global leadership by developing and transferring key enabling technologies to make aviation safer, more efficient, and more environmentally friendly. With a request of \$790.4 million for Aeronautics, NASA will initiate a bold series of experimental aircraft and systems demonstrations as part of the President's 21st Century Clean Transportation Plan. NASA has laid the groundwork for this initiative through years of research at the component level, through computer modeling, ground tests, and flight tests. In partnership with industry and academia, we have developed technologies and designs that have the very real potential to dramatically reduce fuel consumption, harmful emissions, and noise. NASA is ready to take the next step. With the FY 2017 request we will move out on a plan to develop and fly "X-plane" demonstrators. We will demonstrate and validate transformative concepts and technologies as integrated systems in flight to meet the most challenging needs of aviation. NASA will begin the development of a series of ultra-efficient subsonic transport experimental aircraft, and initiate the detailed design and build of the world's first low boom supersonic flight demonstrator.

NASA's request for Aeronautics also increases investment in developing revolutionary tools and technologies to support X-plane developments, enabling further advances for future transformative vehicle concepts, nurturing university leadership in innovation that will also foster and train the future workforce, and leverages non-aerospace technology advancements.

NASA will continue to advance research and development into the next generation air traffic management system to realize the full vision of Next Generation Air Transportation System (NextGen) NASA will complete a series of major flight tests to demonstrate significantly more efficient arrival and departure operations in full partnership with Federal Aviation Administration (FAA) and industry. NASA will also continue to lead the world for enabling safe UAS operations by developing key technologies that will integrate UAS operations in the National Air Space and realize small UAS operations safely at low altitude operations.

In conclusion, the program of exploration we propose to execute with the FY 2017 request is the envy of the world, and should be a source of pride to the Committee, the Congress, and the American people.

With constancy of purpose and consistent support from the Congress, we look forward to extending human presence into deep space, over the course of the next decade.

Mr. Chairman, I would be pleased to respond to your questions and those of other Members of the Subcommittee.

National Aeronautics and Space Administration



Charles F. Bolden, Jr.

Nominated by President Barack Obama and confirmed by the U.S. Senate, retired Marine Corps Maj. Gen. Charles Frank Bolden, Jr., began his duties as the twelfth Administrator of the National Aeronautics and Space Administration on July 17, 2009. As Administrator, he leads the NASA team and manages its resources to advance the agency's missions and goals.

Bolden's confirmation marks the beginning of his second stint with the nation's space agency. His 34-year career with the Marine Corps included 14 years as a member of NASA's Astronaut Office. After joining the office in 1980, he traveled to orbit four times aboard the space shuttle between 1986 and 1994, commanding two of the missions. His flights included deployment of the Hubble Space Telescope and the first joint U.S.-Russian shuttle mission, which featured a cosmonaut as a member of his crew. Prior to Bolden's nomination for the NASA Administrator's job, he was employed as the Chief Executive Officer of JACKandPANTHER LLC, a small business enterprise providing leadership, military and aerospace consulting, and motivational speaking.



A resident of Houston, Bolden was born Aug. 19, 1946, in Columbia, S.C. He graduated from C. A. Johnson High School in 1964 and received an appointment to the U.S. Naval Academy. Bolden earned a bachelor of science degree in electrical science in 1968 and was commissioned as a second lieutenant in the Marine Corps. After completing flight training in 1970, he became a naval aviator. Bolden flew more than 100 combat missions in North and South Vietnam, Laos, and Cambodia, while stationed in Namphong, Thailand, from 1972-1973.

After returning to the U.S., Bolden served in a variety of positions in the Marine Corps in California and earned a master of science degree in systems management from the University of Southern California in 1977. Following graduation, he was assigned to the Naval Test Pilot School at Patuxent River, Md., and completed his training in 1979. While working at the Naval Air Test Center's Systems Engineering and Strike Aircraft Test Directorates, he tested a variety of ground attack aircraft until his selection as an astronaut candidate in 1980.

Bolden's NASA astronaut career included technical assignments as the Astronaut Office Safety Officer; Technical Assistant to the director of Flight Crew Operations; Special Assistant to the Director of the Johnson Space Center; Chief of the Safety Division at Johnson (overseeing safety efforts for the return to flight after the 1986 Challenger accident); lead astronaut for vehicle test and checkout at the Kennedy Space Center; and Assistant Deputy Administrator at NASA Headquarters. After his final space shuttle flight in 1994, he left the agency to return to active duty the operating forces in the Marine Corps as the Deputy Commandant of Midshipmen at the U.S. Naval Academy.

Bolden was assigned as the Deputy Commanding General of the 1st Marine Expeditionary Force in the Pacific in 1997. During the first half of 1998, he served as Commanding General of the 1st Marine Expeditionary Force Forward in support of Operation Desert Thunder in Kuwait. Bolden was promoted to his final rank of major general in July 1998 and named Deputy Commander of U.S. Forces in Japan. He later served as the Commanding General of the 3rd Marine Aircraft Wing at Marine Corps Air Station Miramar in San Diego, Calif., from 2000 until 2002, before retiring from the Marine Corps in 2003. Bolden's many military decorations include the Defense Superior Service Medal and the Distinguished Flying Cross. He was inducted into the U.S. Astronaut Hall of Fame in May 2006.

Bolden is married to the former Alexis (Jackie) Walker of Columbia, S.C. The couple has two children: Anthony Che, a lieutenant colonel in the Marine Corps who is married to the former Penelope McDougal of Sydney, Australia, and Kelly Michelle, a medical doctor now serving a fellowship in plastic surgery.

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NASA Administrator

Chairman BABIN. Yes, sir, thank you. I appreciate you very, very much.

And we stand adjourned—excuse me. We stand in recess until five minutes after this vote, okay?

Ms. EDWARDS. He was like, easy.

Chairman BABIN. No, don't go anywhere, General. All right.

[Recess.]

Chairman BABIN. I would like to call us back to order after our recess and again thank General Bolden for his testimony.

And now I'd like to recognize myself for five minutes of questions.

And again, thank you for being here, General Bolden. I'd like to ask you a question about the budget, of course. The former space shuttle commander Eileen Collins was testifying before our committee probably less than, what, three weeks ago maybe about the decision to cancel the Constellation program. That was not made by NASA at all but by the White House. She said, "I believe the program cancellation decisions that are made by bureaucracies behind closed doors and without input by the people are divisive, damaging," and she said "cowardly, and many times more expensive in the long run." Similar complaints of White House meddling with NASA's programs counter to NASA's own program managers surrounds the SÓFIA telescope aircraft, the Orion crew vehicle, Space Launch System, and various Mars missions.

The point here is that this White House ignores NASA's input but then tells you and your Associate Administrators to defend their decisions before Congress. And as you mentioned a while ago, maybe it's not just all of his decisions. That's what we'd like to find out.

Did the White House consult you about this idea to fund NASA through mandatory spending accounts?

Hon. BOLDEN. No, sir, they did not, but we had extensive discussions after we saw the budget and—because I asked the question of what's the difference when I had my conversation or at least passing words between me and the OMB Director, I was assured that our budget is \$19 billion. And so if you ask me to define for you what the difference is between mandatory and discretionary, I'm going to take it for the record—

Chairman BABIN. Right.

Hon. BOLDEN. —because my budget is \$19 billion.

Chairman BABIN. Okay. And then without this mandatory spending, it looks like the White House's proposed budget for NASA is about \$1 billion less than Congress appropriated last year, which was \$19.2 billion. The White House is wasting everyone's time with its mandatory spending proposal and trying to obfuscate that they're proposing to cut NASA's budget by \$1 billion. A continuing resolution would be better than this request. And why are you advocating a cut to NASA?

Hon. BOLDEN. Mr. Chairman, I'm not advocating a cut to NASA. We are advocating a \$19 billion budget, and to be quite honest, the reason it wasn't \$19.3 billion was because we had no idea that the '16 budget was going to be \$19.3 billion. As I said before, we were all startled pleasantly to receive a \$19.3 billion budget from the Congress. Had we had to pass our final numbers in prior to—had

we had the benefit of knowing what the '16 budget was going to be, we would have asked for even more.

But as I said before, I am very happy with the \$19 billion settlement that we came up with in our negotiations with the Administration. And, you know, I think there are many other things that had to be compensated for, and that's the reason that I think they chose to use mandatory and discretionary.

There are some things that we didn't count on last year, dealing with the census, dealing with some of our partners, for example, dealing with refugees. There are a lot of different issues that come up that come from the discretionary spending pool, and so, you know, the President has really tried to push research and development, technology development from the moment he became President, and this represented a way to do that.

And I think if you look at what is in the mandatory section, it is mostly technology development, engineering type things, whether it's in human exploration, science, or anywhere.

Chairman BABIN. I understand, but with a nearly \$20 trillion national debt, and the biggest problem being mandatory spending side of spending, that's a tough nut to crack.

Hon. BOLDEN. Yes, sir.

Chairman BABIN. And I'd like to ask you about SLS and Orion. In this year's budget request the Administration continues to play the game of back-and-forth with Congress on SLS and Orion funding, negatively impacting the schedule for getting American astronauts back into deep space exploration.

NASA is formally committed to launch the first crewed mission of SLS and Orion known as EM-2 no later than 2023. The fiscal year 2017 request funds this commitment. At the same time, NASA says that it is internally planning for an EM-1 launch in 2021. Why doesn't NASA simply request funding for a 2021 launch date?

Hon. BOLDEN. Mr. Chairman, the funds that we requested and came in the President's budget request support our detailed estimate of how much it would cost and what the time would be to fly the first human mission in SLS and Orion, and that is 2023, utilizing a process that we call joint confidence level process, and it gives us a 70 percent confidence that our numbers are correct. So when we went through the formal process of evaluating based on what we assume the budget might be, that's how we came up with the 2023 time.

The Congress, when they appropriated more than was requested, that's the number that we use when we say we're working an internal number. You know, if the Congress decides that they want to plus SLS up every year, you would be on a path to an earlier launch. And the earlier launch, I don't know what that date would be, but it would be earlier than the President's budget request number.

Chairman BABIN. Okay. Thank you very much.

I'd like to recognize the gentlewoman from Maryland, please, for—

Ms. EDWARDS. Thank you very much, Mr. Chairman.

I want to follow on this date of the internal 2021 date versus the external 2023, but I want to go to a different place. The Aerospace Safety Advisory Panel in its 2015 annual report said that "NASA

had briefed the ASAP on measures... that appear to be making safety tradeoffs in order to maintain a 2021 EM-2 launch schedule.” And if ASAP thought it was important enough to raise, General Bolden, the question is whether there is pressure that’s been either perceived or real with regard to safety tradeoffs.

And so I wonder if you’ve had an opportunity to talk to ASAP about this and what are you doing to ensure that the agency isn’t making near-term trades in trying to meet a schedule that could wind up negatively affecting the safety needed throughout a long-term exploration program?

Hon. BOLDEN. Ms. Edwards, I talk to the ASAP all the time. I generally make the ASAP meetings when I travel to wherever they are, and Admiral Dyer and I have phone calls back and forth.

I would emphasize to everyone, though, as the ASAP states in their report, we have done an awful lot over the last 5, six years. When you look at SLS core stages in production at Michoud, we just had a big test firing, 500-second firing on the main engine down at Stennis. The well for the Orion crew module was completed, and it’s been shipped to the cape so—

Ms. EDWARDS. Right. So those are the technologies.

Hon. BOLDEN. Those are our accomplishments.

Ms. EDWARDS. I’m talking about safety and the ASAP’s—

Hon. BOLDEN. Yes.

Ms. EDWARDS. —concern with safety and whether this pressure to meet a 2023 external goal—2021 rather, whether that is too much to ensure the safety of the mission.

Hon. BOLDEN. No one puts more emphasis on safety than the Administrator, than I do, and I share the ASAP’s concern that we not be blindly progressing toward a particular date, and that’s the reason that we have emphasized to the Congress before that, as far as we are concerned, as far as the date that the agency is committed to, it’s 2023.

You know, if we are able to—there are two things that the ASAP pointed out in the report that you cite, and I’ll use the terms they use. They talked about sufficiency and timing when it comes to their concern about safety. Sufficiency is the level of funding we get. The most important thing is timing. When you get appropriations late each year, that means we’re operating with less money than we need. We’re holding on purchasing long lead items. We’re holding on everything. It’s disastrous to industry. They can’t plan. So that’s the concern that the ASAP has.

And I think—I hope the Congress doesn’t miss their message. It’s a message to all of us that it’s not just important—it’s not just important to have a certain amount of money, but you need to be able to have a program, a development program that can count on getting the money when you need it. We went through this with—

Ms. EDWARDS. Well, I—

Hon. BOLDEN. —commercial crew and—

Ms. EDWARDS. I mean, look, I share that concern, but let’s remember that we also went through, for different reasons, the Columbia disaster or Challenger disaster where there were these pressures for time—

Hon. BOLDEN. Yes.

Ms. EDWARDS. —that ended up in what ultimately sacrificed safety and cost lives. And I just want to make sure that we are paying attention to those things here.

I want to go on to another—it would be great, I think, Mr. Chairman, if you were to hold a hearing at some point or other just examining this specific concern around safety that ASAP has raised and maybe we can get to the bottom of this.

I want to ask you about Earth science in my time remaining. Some people have criticized the level of funding that's been given to Earth science in the 2017 budget request. We heard that here today. And I think what's so often not understood is how NASA's Earth science missions and research affect the daily lives of Americans. And so I would like you to give us some concrete example of how Earth science missions and research have actually benefited the American people and our economy.

Hon. BOLDEN. I'll give you two, I think, really good examples. We have two missions. One is called SMAP, Soil Moisture Active Passive. The other one is called GRACE, and I don't remember what the acronym stands for, but it looks at changes in Earth's gravity, and it can therefore tell us what's in a water reservoir under the surface of Earth. Those two missions have been used to help us with water issues out on the West Coast, as well as around the world. So they have both economic and strategic value.

We look at a program called SERVIR that Earth science supports where we provide 30 years of archived Earth science data and real-time data from our Earth science satellites around the world to help farmers in crop planting, water resources management, disaster relief. An earthquake occurs somewhere and an Earth science satellite is put, you know, at work right away to try to help the disaster managers determine what to do. So those are just a couple of examples of what is done.

Today, for example, in Texas and Louisiana we probably have a UAVSAR mission. It's an airborne mission, not a satellite, airborne mission out of Armstrong with a synthetic aperture radar—

Chairman BABIN. That is happening.

Hon. BOLDEN. —that's helping to look at levees and dams and the like to detect where there may be leaks so that we can warn a community if—you know, we don't do the warning but we provide the data to the state and local leaders so that they can make decisions.

We've been credited with contributing to saving thousands of lives in Bangladesh last year with SMAP because it predicted it would—it enabled us to predict floods—flooding in the annual rains in Bangladesh. So those are concrete examples of how our Earth science program is not just a national program, it is an international program highly respected and counted on by nations around the world.

Ms. EDWARDS. Thank you very much.

Thank you, Mr. Chairman.

Chairman BABIN. Thank you, Ms. Edwards.

Let's see. The next one is Mr. Rohrabacher, the gentleman from California.

Mr. ROHRBACHER. All right. Thank you very much.

General, I notice—welcome. Important I share the Chairman's and other people's admiration and gratitude to you—

Hon. BOLDEN. Thank you.

Mr. ROHRABACHER. —for the service you've been to our country both as a Marine and both in your current position. I notice you're wearing a green tie.

Hon. BOLDEN. Yes, sir.

Mr. ROHRABACHER. Does that mean you're Irish?

Hon. BOLDEN. I am Irish through my daughter Kelly, who was born today. So—

Mr. ROHRABACHER. All right. Kelly—

Hon. BOLDEN. —she is Kelly O'Bolden, born on St. Patrick's Day.

Mr. ROHRABACHER. Now, let's see, there's Kelly and there's—and then we have Scott Kelly.

Hon. BOLDEN. Scott Kelly, yes.

Mr. ROHRABACHER. So maybe you could answer me. The question is I understand that the Mars rover has picked up these pictures that have been identified as various elements of a former civilization, and I do understand that they have found an ancient bottle of Guinness on Mars, is that correct?

Hon. BOLDEN. I will go back and check that.

Mr. ROHRABACHER. All right.

Hon. BOLDEN. I'll take that for the record.

Mr. ROHRABACHER. And could it be that leprechauns were ancient aliens, space aliens?

Hon. BOLDEN. I will take that for the record also, sir.

Mr. ROHRABACHER. All right. Let me know about the line of questioning that we just had, and that is the projects that you outlined and our friends on the other side of the aisle are pushing for NASA to be involved in. We have no question about whether there is value to these Earth-related projects. The question is only whether they should be part of the NASA budget, and that's our main area of debate here.

And certainly if—now, I won't put you on the spot, but the fact is if we weren't doing some of the Earth science things and NASA's budget could stay the same. If we took those items and put them into NOAA and other places that they belong or the USGS, for example, you know, then I would take it that you would not be as adamantly insisting how important they are, but maybe somebody else could be paying for it.

Hon. BOLDEN. I would still insist that they're critically important. Some of you may remember that in 2014 the President's budget request proposed that funding for sustained land imaging, the Landsat program, come from the Department of Interior, from USGS's budget—

Mr. ROHRABACHER. Right.

Hon. BOLDEN. —and the Congress rejected that—

Mr. ROHRABACHER. Well—

Hon. BOLDEN. —and put the funds back in NASA—

Mr. ROHRABACHER. Right.

Hon. BOLDEN. —simply because they felt that we were the appropriate organization to have it.

The other agencies of the government, we provide the design, the build, the production and checkout for all the imaging satellites, almost all that are——

Mr. ROHRABACHER. Yes.

Hon. BOLDEN. —in the civil sector. The other agencies don't have that capability, and so it's a partnership, and it's worked for 43 years now in the case of Landsat. And, you know, NOAA today has an effective orbiting weather satellite——

Mr. ROHRABACHER. Right.

Hon. BOLDEN. —when they're a little bit better off than folk on——

Mr. ROHRABACHER. I do understand NOAA aren't you compensated from the NOAA budget for what you're doing with NOAA there, as compared to the Geological Survey?

Hon. BOLDEN. We are indeed.

Mr. ROHRABACHER. So I would imagine that if we could actually fund these other—the Earth sciences and not take it out of your budget, that it would be something that would be positive, but I won't put you on the spot on that.

The—let's note that another thing that's saving us money, however, is the commercial crew. And I want to thank all of my colleagues and thank you for the leadership that you've shown in trying to show this cost-saving methodology of bringing the private sector in when we can and then letting NASA focus on those things that the private sector can't do.

And I know that Virgin Galactic right now is deeply involved in developing suborbital space transportation, which is terrific. I would hope that we could also, for example, have a commercial approach perhaps to lunar missions. And I know that NASA is not focused on lunar missions right now, but perhaps the private sector could be involved with lunar missions, and we could have some kind of involvement there or coordination but let the private sector pick up some of the cost of going back to the moon if we can do that.

Hon. BOLDEN. Mr. Rohrabacher, you're absolutely right, and I would say, you know, NASA is on a Journey to Mars. Our destination for the nation—this is what we recommended and what—I have to compliment—Chairman Smith isn't here right now. I complimented Mr. Perlmutter. They wrote an absolutely incredible op-ed or an article on, you know, the fact that we are the greatest nation in the world. We need to be going to Mars.

But everyone should understand—and I think we're mischaracterized when they said we're ignoring the moon. We're going to spend ten years, a decade of the '20s, in cislunar space. And we call it the proving ground. And that is a period of time when, if everything works the way we hope, commercial entities, entrepreneurial entities, maybe even some of our international partners will ask us to assist them in preparing things like landers that may put humans back on the surface of the moon on the way to Mars. But——

Mr. ROHRABACHER. Well——

Hon. BOLDEN. —this nation has to focus on the big thing, which is Mars.

Mr. ROHRABACHER. Why——

Hon. BOLDEN. If we don't, then nobody goes there.

Mr. ROHRABACHER. Well, General, I think it's possible to focus on the very next step in the stairway rather than—

Hon. BOLDEN. And that's the ten years in the proving ground.

Mr. ROHRABACHER. —rather than focusing on—

Hon. BOLDEN. That is the next step.

Mr. ROHRABACHER. —the—where you're going at the end of the stairwell.

One last note very quickly because my time is up, and that is I hope that—one of the things we really need is to make sure our country and the world is prepared for a possible collision with some space rock that could kill millions of people.

Hon. BOLDEN. Yes, sir.

Mr. ROHRABACHER. I applaud you, I want to work with you on making sure that NASA is playing its role in this global defense against an asteroid or—

Hon. BOLDEN. Yes, sir.

Mr. ROHRABACHER. —a meteor. So thank you very much.

Hon. BOLDEN. Yes, sir. Thank you.

Chairman BABIN. Thank you.

And I'd like to recognize the gentlewoman from Texas, Ms. Johnson.

Ms. JOHNSON. Thank you very much.

General Bolden, the New Aviation Horizons project is certainly an exciting initiative, and this is a decade-long initiative based on funding offsets that are part of the Administration's 21st century "clean transportation" plan. What are the potential benefits of the X-plane flight demonstrations included in the plan?

Hon. BOLDEN. Well, there are four demonstrations—demonstrators that we have, you know, right now that we would really like to do. The one that we're attacking first is the low-boom supersonic demonstrator. And people ask why that one first, and it's because industry is poised to help us design and build a low-boom supersonic demonstrator. It's going to increase their ability to compete around the world in supersonic transport.

And we've been working on this for number of years now, and there are a number of companies like Lockheed, Boeing, Gulfstream that have plans on the drawing board, and they just need a demonstrator to help us change—get the FAA to change the regulations prohibiting supersonic flight over ground.

The other one is Hybrid Wing Body. The Department of Defense is very interested—not just civilian aviation but the Department of Defense in terms of transport, cargo transport. Hybrid Wing Body changes the efficiency of an airplane, increases our fuel efficiency, gives them longer range, so that's a second thing that's going to have an economic and strategic impact for the nation.

And then finally, hybrid electric systems where we actually sometimes you mix electric engines with regular turbine engine and other times you just use electric engines. We've been collaborating with our partners in the German space agency because they are also—they were out in front of us, and so this initiative will allow us to kind of catch up with them and assume some of the leadership in looking at hybrid electric systems.

Ms. JOHNSON. What are the implications of not sustaining this project over the decade should the funding fluctuate over time?

Hon. BOLDEN. The bottom-line implication is that the United States will lose its place as the leader in aviation and aeronautics. We're struggling to maintain that right now, and that was one of the driving forces behind aeronautics coming up with a new strategic plan in 2014 with the six strategic thrusts that were a part of that plan. And now, being able to announce with industry, academia, and others about two weeks ago that the President supported this New Aviation Horizons initiative that's going to allow the United States to maintain their leadership.

Aviation accounts for the largest balance of trade item in this country by a long shot, and if we don't get out in front of everybody and do the types of development that will be covered in the New Aviation Horizons, we'll lose that edge.

Ms. JOHNSON. Does it seem to have the possibility of attracting young people to aeronautics—

Hon. BOLDEN. No question whatsoever. I go to college campuses today, and it hasn't been that long since we started talking about this initiative. Students who are in—studying aeronautical engineering are—they're ecstatic. They're beside themselves.

I had a special assistant from Langley by the name of Mr. Erik Axdahl, who is a hypersonics specialist. After his 6 months up here with me, he left semi-depressed because he did not hear that the United States was going to invest in hypersonics. He now, you know, is a little bit happier camper because he feels that he has not gone to school and been educated and done stuff because the United States is going to maintain their leadership in hypersonics because of that.

And every one of you, hopefully, has a copy of our little flyer here and it's got information on the back, and we'd be more than happy to come to your district or to your office or anywhere and help you understand some of this. Thanks very much.

Ms. JOHNSON. Thank you. Thank you very much. Thank you, Mr. Chairman.

Chairman BABIN. Thank you.

I'd now like to recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

Administrator Bolden, first, I'd like to applaud your choice of Todd May as Director of the Marshall Space Flight Center located in my district. And I'd also like to thank his predecessor, Patrick Scheuermann, for his many years of service and leadership at NASA, especially at the Marshall Space Flight Center. I'm excited about the continued success at Marshall and throughout NASA.

That having been said, have you designated a NASA center lead for rocket propulsion that would be able to integrate all of NASA's expertise in deep space travel on the Journey to Mars?

Hon. BOLDEN. Congressman, we don't use the term "lead center" anymore. It has a bad connotation for people who were around at the time of Challenger.

But what we have done is we have an effort ongoing. It started out as something we call TCAT that I think we explained it to everybody. Now, it's just baseline services assessment where we're

trying to identify centers who have the highest level of capability in a particular field. There is no question that the Marshall Space Flight Center is the—one of their core capabilities is propulsion, and so no question whether we're talking to DOD or anybody else outside of NASA that Marshall is the place that people go when they want to discuss in space and leaving the Earth propulsion issues.

Mr. BROOKS. Well, for lack of a better word, I'm going to use it again in my next question. While I'm asking about program leads, who is program lead for Europa?

Hon. BOLDEN. The program lead for Europa presently if I—and I'll—let me take it for the record, but as my memory serves me, the Jet Propulsion Lab is the lead for procurement things like the spacecraft “bus” and others, and then we have other centers that are contributing to that. But JPL in your terms would be considered the lead, although they're an FFRDC, but it's because of their expertise in planetary travel.

Mr. BROOKS. Well, isn't JPL a federally funded research and development center?

Hon. BOLDEN. Yes, sir.

Mr. BROOKS. And my impression, and correct me if I'm wrong, is that federally funded research and development centers, by their nature, can only supply one-of-a-kind research and development and not be a program manager.

Hon. BOLDEN. That is—I don't think that is—let me take that for the record. The definition of a program manager—I don't think there's a prohibition because of their unique experience and expertise in planetary flight, for example, Curiosity and most of our Mars missions. JPL is the center that has achieved that for NASA for decades. We have been providing precursors on the way to Mars since the '60s, and Jet Propulsion Lab has generally been the lead in doing that work.

So I'll take it for the record for your strict definition of who can be a program manager, but program managers for planetary missions have not always—have dominantly been at JPL.

Mr. BROOKS. Thank you. I'll move on to another area.

Earlier this week at an appropriations hearing you spoke about the need for “game-changing” propulsion. Do you support nuclear thermal propulsion and what role do you see it playing in the Journey to Mars?

Hon. BOLDEN. We are on a Journey to Mars, and most people believe that in the end, nuclear thermal propulsion will probably be the most effective form of propulsion to get there. Right now, we are funding at a very low level. Development of low-grade nuclear fuel so that we don't have to go through what we go through today. So we're taking a step-by-step approach to getting to nuclear thermal—to the use of nuclear thermal propulsion, but we are years away from doing that.

Again, Marshall is the dominant center. They have most of the capability there, and they're working with some of their local contractors who are helping them with developing nuclear thermal propulsion.

Mr. BROOKS. Congress authorized \$20 million for nuclear thermal propulsion for fiscal year 2016. How much is NASA planning on spending in fiscal year 2016 on nuclear thermal propulsion?

Hon. BOLDEN. I'll take that for the record, Congressman. I'll just take it for the record. I think I remember, but I don't want to guess.

Mr. BROOKS. All right. Thank you, Mr. Chairman. I yield back.

Chairman BABIN. Thank you.

I'd like to recognize the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman, very much. Thank you, Administrator Bolden, for being with us again.

The planetary sciences come up again and again, and I think in the opening Chairman's remarks he talked about why is NASA paying for NOAA's satellite research? Why is NASA paying for USGS's Landsat stuff? So why? Why don't they pay for—

Hon. BOLDEN. In the case of USGS and Landsat it is because the Congress refused the President's budget request to transfer money for Landsat into the Department of interior. So this Congress decided that sustained land imaging is really important, and they put the money back in the—you know, according to my budget people, they put the money back into NASA because we've done it for so long. I'll go back and double-check my memory, but I think that—that's pretty simple in that case.

Mr. BEYER. So you'd be fine to have it in the USGS budget as long as we put up there?

Hon. BOLDEN. As long as the nation continues to do sustained land imaging and weather and those kinds of things, I think any Administrator is perfectly happy to make sure that we support whoever's doing it. You would also have to transfer the people from NASA when you talk about the design and build of satellites because those agencies don't have the capability to do that.

Mr. BEYER. Okay.

Hon. BOLDEN. So this is—we have expertise, and that's, I think, why Congress comes back to us and puts the money in the NASA budget. So you're talking about a little bit more than just transferring money. You're probably going to transfer people if you really want those agencies to do what we do.

Mr. BEYER. So on the case of the mandatory spending, the \$733 million from—

Hon. BOLDEN. Yes, sir.

Mr. BEYER. —cuts, consolidation, savings, did you do that or did the budget—in order to adapt to BCA, the Budget Control Act?

Hon. BOLDEN. I am told that the Budget Control Act was a large factor in the Office of Management and Budget deciding on how to divide the money. That is immaterial to me as the NASA Administrator. My conversations with the Director of OMB through his senior people was, look, you have \$19 billion that the President is supporting, so that's—I didn't—I don't work with mandatory discretionary.

Mr. BEYER. Okay.

Hon. BOLDEN. My Chief Financial Officer, he can understand—

Mr. BEYER. Different question then.

Hon. BOLDEN. Yes.

Mr. BEYER. You mentioned in your testimony that because we were on a continuing resolution we didn't get the omnibus spending until just before Christmas. Would you have requested north of the \$19.285 billion if you'd known when you were putting the budget together that we were going to authorize or actually appropriate \$19.285 billion?

Hon. BOLDEN. Congressman Beyer, I always request more money than we get and, you know, any Administrator, Director, or anybody that doesn't go in with a significantly higher number than they expect they're going to get is asking not to get anything. I—you know, I think anybody would tell you the NASA Administrator always comes in with a higher number than I ultimately get.

Mr. BEYER. So that's—

Hon. BOLDEN. I do the same thing with the Congress.

Mr. BEYER. So it's safe to say that this 1.3 percent reduction is at least partly based on the absence of the information about where we're going to end up in fiscal year 2016?

Hon. BOLDEN. Largely based on that.

Mr. BEYER. Yes.

Hon. BOLDEN. Had we known that the Congress was going to appropriate \$19.3 billion, I would have been comfortable going in and asking for even more than we asked for.

Mr. BEYER. So there are some cynics who suggested that OMB and NASA deliberately understated deep space exploration, Space Launch System, Orion, because they knew that the Space Committee and Congress love those and would push them back.

Hon. BOLDEN. That is—I've heard that stated before, but as I said again, at the President's requested budget level, we are on target and we will produce the first flight of SLS and Orion with a human crew in 2023, and we have a 70 percent confidence level that we can do that. That's how we came up with the 2023 and, you know, we decided 70 percent was the number we want to make, and it's a lot more fancy than I can explain in this hearing, but that's the number we came up with. And if all we got was the President's budget request, we would be launching EM-2 in 2023.

I do have to say, we are focused on a program to get humans to Mars, not the first two flights, and we could spend everything in the world on EM-1 and EM-2 and then have nothing left for a sustained program. So we're using—if you gave me more money, I'd buy down risk, go back to Ms. Edwards' question. There is always risk, and more money for me means I can spend more to buy down risk. And it—

Mr. BEYER. We only have 20 seconds left so very quickly, the roadmap, the Journey to Mars, many people have criticized that we're—Congress and NASA are not yet on the same page in terms of what that roadmap needs to be.

Hon. BOLDEN. I think we're much more on the same page than most people are willing to admit. We don't know how—ultimately how we're going to make the final step from cislunar space to Mars. We just don't know, and it would be irresponsible of me as the NASA Administrator to pick a particular design reference mission the way we've always done in NASA and try to hold everybody to that to try to determine what the final architecture is going to be.

If we decided right now, the question that the Congressman from Alabama asked, that says nuclear thermal propulsion is out because I don't have a budget that sustains nuclear thermal propulsion or VASIMR or any of those advanced propulsion systems now. But I'm an optimistic person, and I think that by the time we reach the end of the 2020s, the middle of the 2020s, we will have gotten sufficient funding from the Congress and the Administration that we'll be well on the way to new types of in-space propulsion. We'll be able to have much more robust environmental control and life support systems, and that just—we're not there yet, and so it would be irresponsible of me to try to give you an architecture and a roadmap that has milestone flights with a design of a vehicle. We're just not there yet.

Mr. BEYER. Thank you, sir, very much. Thanks, Mr. Chairman.

Chairman BABIN. Yes, sir, thank you. I'd now like to recognize the gentleman from California, Mr. Knight.

Mr. KNIGHT. Thank you, Mr. Chair, and thank you for having this.

Administrator Bolden, I want to thank you. You know I'm going to talk about the big A—

Hon. BOLDEN. Yes, sir.

Mr. KNIGHT. —and I appreciate this picture very much. You put an American hero on here. He is not looking at green there. He's looking at a lake bed—

Hon. BOLDEN. I think he's—

Mr. KNIGHT. —and he's looking at a B-52. But Bill Dana is an American hero and I thank you for putting him on there.

From 1968 to about 2000 or 2002, hypersonic research went from about the height to almost to zero and then we jumped again with the X-43 program. We went from the X-43 to the X-51 and then again we decided that either money or it wasn't worth our while. Probably the first was the reason why we weren't going to go into hypersonic research.

Can you tell me what a commitment is from NASA, what a commitment is from Congress to make sure that we continue on with hypersonic research so America will be the leaders on hypersonics and not China or someone else?

Hon. BOLDEN. If Congress accepts the President's proposed budget, particularly the part that deals with aeronautics, it's a \$25 million annual amount that NASA's commitment to DOD, to the integrated government—you know, DOD, intelligence community, everybody else that needs hypersonics, \$25 million allows us to maintain our expertise but most importantly our facilities at Langley, at Glenn, at Ames. Anything less than that and we're going to be back where we were in those times that you describe where we're down. We're going to be back where we were when Erik Axdahl left to go back to Langley when he felt that there was no future in hypersonics.

\$25 million is the base that NASA needs to retain the nation's primary capability for fundamental hypersonics research. That is us. We do that. Nobody else does that.

Mr. KNIGHT. Perfect statement. You do that. We want NASA to be on the leading edge. I think that there are civilian companies that would like to jump into that realm at some point, but remem-

ber, typically, NASA will do an awful lot of R&D before private companies will jump into the mix.

Hon. BOLDEN. Yes, sir.

Mr. KNIGHT. And that is the case here.

Two other programs I'd like to talk about because you know I'm going to talk about aeronautics quite a bit. The first one is the low-boom demonstrator. Now, again, we went through adjusting program for about a three-year period where we put a big old almost pitot tube at the end of an F-15 and did some jousting to do a low boom so that hopefully us Congressmen from the West Coast can fly across this country in 2 hours one day, and we will alleviate that restriction from the FAA that's been going on since 1974 and all of these things that—you know, if any of you have ever heard of sonic boom, I know you've probably heard a thousand and I've heard a thousand. They're disrupting, but with a low-boom demonstrator is almost a hum, or a very—you almost—

Hon. BOLDEN. Murmur.

Mr. KNIGHT. —wouldn't know it. It's a murmur, exactly. Explain how important that would be to the economics of this country, the economics of the world if we could get there.

Hon. BOLDEN. Congressman Knight, it would be critically important to this nation economically because right now, the European space agency—well, European aeronautics companies because most of their flight is over water. They have said we don't care. You know, we don't have the regulation that the FAA has put on American aircraft not to fly supersonically over ground.

So, as you said, the low-boom technology has allowed us to really reduce its energy from sound that breaks windows and stuff. The low-boom configuration actually causes it to be just a murmur and comfortable to people.

We will have aircraft that will be able to get places much faster. Businessmen, for example, can do their business—they can get around the world in six hours instead of however much time it takes today. Yes, I mean, anybody.

And, you know, there's a common misconception. I've heard it said one of the reasons that people resisted our efforts in this regard was because they said, well, the only reason for having supersonic airplanes is so that rich people can go places fast.

Mr. KNIGHT. Not true.

Hon. BOLDEN. That's—you know, some of us normal people want to go places—

Mr. KNIGHT. That's right.

Hon. BOLDEN. —fast—

Mr. KNIGHT. Some of us normal people want to go—

Hon. BOLDEN. —also. And I do a lot of intercontinental travel. I would love to be able to get into an airplane and go from here to Moscow or wherever else I'm going in a couple hours instead of the 14 hours that it takes today.

Mr. KNIGHT. And lastly, in my 15 seconds I'm just going to thank you. We fully funded SOFIA again.

Hon. BOLDEN. Yes.

Mr. KNIGHT. SOFIA is, to me, a moving classroom. It's not unlike the space shuttle. We used the space shuttle in the beginning for an awful lot of research and astronauts, but we put teachers on.

We did many things, as you know, with the space shuttle program. We're doing that with SOFIA, so we take fifth-grade teachers in there. They go back and they inspire our fifth-graders to now be the next Charlie Bolden. They inspire them to be an astronaut. And that is exactly what these types of programs are doing. They're benefiting the country, not just the science that we're getting out of SOFIA. So I want to thank you for that, too.

Hon. BOLDEN. Thank you for your support.

Mr. KNIGHT. Thank you, Mr. Chair.

Chairman BABIN. Thank you.

I'd now like to recognize the gentleman from California, Mr. Bera. He's not here? Okay.

Mr. Perlmutter from Colorado.

Mr. PERLMUTTER. Thank you.

Chairman BABIN. Yes, sir.

Mr. PERLMUTTER. I'm from Colorado and I'm a lot better looking than Bera, so it's okay.

Mr. Knight sort of highlighted some of the things that have been so inspirational recently, whether it's New Horizons or talking about the SOFIA, things like that. And that's—I got to tell you, I serve on two committees. My colleagues have heard this before. One is Financial Services, the other is this committee, the Science, Space, and Technology Committee. And the way we are pushing the horizon and moving forward with our science, even though it's kind of herky-jerky at times, we are doing it. And it really—that's what Americans want to see us do, you know, whether it's in a caucus in, you know, suburban Denver or primary, people want us to know—want to know that we can work together.

And on this Committee, you know, there are places where we fight but we work together on a lot of issues. And want to keep an eye on the budget obviously. That's part of our job as Members of Congress, want to have good people in an agency like yours who we can trust to be good engineers, scientists, mathematicians, technicians, to take on these major tasks which you said and everybody knows are not without risk. So the Chairman and I wrote this op-ed—

Hon. BOLDEN. Right.

Mr. PERLMUTTER. —this article on getting us to Mars by 2033. And it came from information that we had at a hearing about 3, 4 months ago. And I just—I'd like to use my prop, this bumper sticker, "2033, We Can Do This" because we can. And the responsibility of those of us up here is to provide the financial platform for you all to design your program and the building blocks that go into place.

Mr. Rohrabacher was talking about the moon. That may be part of your building blocks. I am not a scientist. I can't determine how you want to build the program that gets our astronauts to Mars by 2033, but I can help you by assuring your agency that Democrats and Republicans, Congresses from now until 2033 and Administrations from now until '33 really do have a major effort in place.

So how does NASA look at us when we say something like, yes, get there by 2033? Is it with a little bit of skepticism I would imagine?

Hon. BOLDEN. Not at all. When—you know, to have a Member of Congress who has a bumper sticker that says we can do this, we don't see—the American public doesn't see that enough. You know, in this day and age what they—what the young people sitting here see and hear all the time is we can't do this, we are not a great nation, we are going to be but we're not right now. That's just bunk.

We're the greatest nation in the world. We always have been. And if we stay focused—Congressman Edwards used the term constancy of purpose. She probably got that from the same person I did, from Admiral Joe Dyer, the Chairman of my ASAP. Constancy of purpose means exactly what you and Chairman Smith wrote. And you—but you've got to believe that. The Congress and the Administration have got to come together and they've got to set long-term vision that's going to go beyond that Administration. Most of what I do today I'm never going to see it, you know, but I'm doing it for my grandchildren.

That's what you all should be doing. You know, you should be looking out and saying whoever takes my place, I'm going to brief them on why I supported this and make sure that they do it. We plan to do the same thing with the incoming Administration, the incoming candidates to be quite honest. We want to let them know what NASA is doing and what the Congress and the Administration, in spite of what everybody says, you all work pretty well together now and then.

And so you have set us on a course to Mars. We can get there in the 2030s, but it's a long, hard, risky slog and we've got to do things on the International Space Station, we've got to spend ten years in cislunar space. That's going to allow people like Congressman Rohrabacher talked about who have these visions of doing what we once did, putting humans on the surface of the moon.

NASA can help them, but NASA can't stop at the moon. If we set the moon as our primary objective, that's it. We're not going any farther than that. So that's why we're focused on Mars. And we've got a pretty good plan that will get us there, but it is step-by-step. We've just got to stay together in doing that.

Mr. PERLMUTTER. No, and I appreciate that. I mean, so for us, our problem is a pretty, you know, substantial one, which is to find the billions of dollars that will, you know, support the effort. And I've learned some new terms. You know, one-year appropriations, multiyear appropriations, and something called no-year appropriations, which I still don't quite understand. So—but we're working on it, and I think we're working together and we want to get this done. So thank you, sir, for your service.

Hon. BOLDEN. Thank you.

Chairman BABIN. Thank you.

I'd now like to recognize the gentleman from Florida, Mr. Posey.

Mr. POSEY. Thank you, Mr. Chairman. And thank you, General, for your service to our armed forces and NASA.

Hon. BOLDEN. Thank you.

Mr. POSEY. I'd like to focus just for a moment on Exploration Mission 1 referred to in all our paperwork as EM-1, the first time that you'll fly SLS and Orion together hopefully in 2018. The Government Accountability Office—let me just look at—get his quote—

and the NASA Inspector General have both cautioned us that Exploration Mission 1 could be delayed because of potential risks for the exploration ground systems program. The Administration is requesting \$403 million in discretionary spending in fiscal year 2017, a reduction of \$6.8 million from fiscal year 2016. How will this request impact the Exploration 1 schedule? I mean, I understand we can fully fund Orion—

Hon. BOLDEN. Yes, sir.

Mr. POSEY. —we can fully fund SLS, we can fully fund all the airplane research, we can fully fund all the weather stuff, but if we don't have the ground systems in place, nothing's going to get off the ground, General.

Hon. BOLDEN. Mr. Posey, you're preaching to the choir. And this is what I've said to this and other committees for many years. It is great to be focused on the vehicles, but unless you have a launch complex like the Kennedy Space Center, the world's most incredible multiuser launch complex, unless you have that, you're going nowhere.

Mr. POSEY. Yes.

Hon. BOLDEN. And that's—you know, when people talk about—a critical part of SLS is the ground system. SLS with no ground system is worthless. So we're given a limited budget, we try to take the funds that are in the big category of exploration and use them so that the ground system, the rocket, and the module get to launch day together. And that requires doing what Bob Cabana is doing in an incredibly fine manner down at the Kennedy Space Center.

The other thing that has helped is having commercial entities that now provide access to low-Earth orbit so that we don't have to worry about that. If you go down to Kennedy now and you look at Launch Complex 39A from where Neil Armstrong launched, that's now American ingenuity. That's SpaceX. And I haven't seen it recently, but everybody tells me it is mind-boggling what they're doing to 39A. That's American ingenuity, and that's what's going to take us to Mars. So I could not agree with you more. We've got to focus on the infrastructure, and that's exploration ground systems.

So when I say I want to take \$1 million or whatever it is that's—that people think is designated for the rocket because I want to upgrade the security on the exploration ground system, we're not doing that because we're being frivolous. We see that EGS is not going to be ready in time to meet the rocket's date—

Mr. POSEY. Exactly.

Hon. BOLDEN. —unless we do it that way so—

Mr. POSEY. Well, thank you. Those are magic words to my ears, General. So I assume, then, that I can be assured that we're not going to end up with an SLS and Orion and lack a ground system that's ready to launch.

Hon. BOLDEN. I can assure you, sir, that with the President's budget request at that level, the exploration ground system, SLS, and Orion will be ready to launch in 2018 together.

Mr. POSEY. Okay. Thank you for that assurance.

Hon. BOLDEN. Yes, sir.

Mr. POSEY. Thank you. The Orion program received \$1.27 billion in fiscal year 2016. The discretionary request from NASA for fiscal year 2017 is \$1.05 billion. Will this request delay EM-2, Exploration Mission 2, where we're actually going to put men in here? If NASA received \$1.27 billion in fiscal year 2017 for Orion, would EM-2 be delayed?

Hon. BOLDEN. At the President's budget request, EM-2 is scheduled to go in 2023, and that's our commitment to the President, to the Congress, to the nation. As I commented to Congresswoman Edwards, if you gave me the levels that you continue to give, then we're going to make sure that we will make 2023. We could make it earlier, but I want to get away from people focusing on an earlier date because that does bring concerns about safety into the mix, and that's what the ASAP was talking about.

You know, 2023 is a great date. If that's what we think we can meet with a 70 percent confidence level, increased funding even makes it even more certain we're going to make that date. But the team always works to be ready earlier than projected, so we probably could launch earlier than 2023 with increased funding, but we have committed to 2023 and we'll make that at the President's budget request.

Mr. POSEY. Thank you, Mr. Chairman. I see I'm out of time.

Chairman BABIN. Yes, sir. Thank you.

I think we've got enough time for us to go back through one more time. Or do we—did somebody just come in? Yes, we've got every—I think everybody has already asked question, but let's go back through one more time and let's may be limit it to about two minutes if that's okay.

So my question would be on the mandatory spending, and I'd like to—everybody to know the implications of this. And I'm just wondering if the President and the Administration and you are fully aware because I heard you mention a while ago whether it's mandatory or discretionary, it doesn't matter to you, you just want the money, but as us, as Members of Congress, I would like for you to be fully aware of the consequences for tapping into mandatory spending.

The budget request includes funding derived from mandatory spending such as—and this will be—let me just tell you, Social Security, Medicaid, Medicare, they're subject to the PAYGO rule, which means that any new entitlement program must be accompanied by a corresponding cut to an existing entitlement or an increase in taxes. In other words, we've got to pay for this.

In order to pay for NASA's entitlement spending, the President's budget request calls for skyrocketing tax increases across the board, as well as cuts to Social Security, Medicare, Medicaid. And other proposed cuts include reduction to student loans, their program, unemployment insurance, and veterans' benefits. It would also create new fees for farmers, hunters, air travelers, increase military health care copayments, and federal employee health care and retirement costs. It would increase the cost of our Postal Service, mail, reduce U.S. postal services. These proposals would increase the cost of every American's electricity bill, as well as the price they pay at the pump.

Just a few months ago Congress fully funded NASA at \$19.28 billion without any budget gimmicks, tax increases, or entitlement cuts, and now the President is requesting a \$1 billion cut to NASA and discretionary spending and asking for pie-in-the-sky tax increases, cuts to mandatory benefits, and increased entitlements with this mandatory side.

Why should Americans agree to this budget request when NASA would receive more money under a CR, continuing resolution, without any of the pain that this budget request would cause? And I would invite you to please look at the President's budget right here and take a look at table S-9, page 129 of the President's budget. We will have nine pages of tax increases and billions of dollars in cuts to programs that are already there or increases in taxes.

So why should Americans agree to this budget request, when we have more money under the proposed CR and not have any of the pain that this budget request would cause?

Hon. BOLDEN. Mr. Chairman, I'm not a budgeteer.

Chairman BABIN. Okay.

Hon. BOLDEN. I don't—

Chairman BABIN. Well, I just wanted you to know—

Hon. BOLDEN. Yes, sir.

Chairman. BABIN. —okay, because we have to look at this. When it says mandatory spending, there are implications. There are consequences to this, and the consequences—you're a veteran.

Hon. BOLDEN. Yes, sir.

Chairman BABIN. That's just one little aspect of some of the consequences that it would hit veterans.

Hon. BOLDEN. Mr. Chairman, I would—if I may, I would say one thing—

Chairman BABIN. Sure.

Hon. BOLDEN. —and that was when we started the budget process, we started several billion dollars below where we are because we were told that sequester is still a possibility. And it still is a possibility. It is not off the table, and that's something that I think the budgeteers at least, you know, when I talk to my guys, they are—they always remind me, you know, we do have this thing called sequester. So in defense of the budgeteers, I think they're trying to work with the Congress and find a way to get that. It's a limit, but it can be solved somehow.

Chairman BABIN. Right.

Hon. BOLDEN. I don't know how to do that.

Chairman BABIN. Okay.

I now recognize the gentlewoman, Ms. Edwards from Maryland. Ms. EDWARDS. Thank you, Mr. Chairman.

And just a really quick question. We spent some time over the last several Congresses really going to bat for the education budget within NASA. Across the aisle, Republicans and Democrats, we felt very, very strongly about keeping those within NASA. I noticed that this year's budget request is—one, it's \$5 million less than what was enacted in 2016, which is problematic. And what I really notice is that the Minority University Research Education project is down \$2 million. I see a plus up in STEM education and then a significant decrease in the Space Grants.

And I want to speak to the Minority University Research Education because I have been really privileged to see some of the fruits of this labor at Morgan State University, which is conducting some joint research with NASA. I think it is a great way to get this next generation to find these engineers and researchers who are out there who are minorities, women, other underserved communities.

And so this university research education project plays a tremendous role with Historically Black Colleges and Universities and underserved—and minority populations and with getting women also engaged in the STEM fields. And so I'm concerned about the decreases. I think this is where the next generation is going to come from. And I'll just let you comment on that.

Hon. BOLDEN. I share your concern, Congresswoman Edwards. Every year, you know, I have to sign a report on funding for HBCUs. And it's either the same or a little bit less, and so that is troubling, but when we look at funds that are available—so what we've tried to do is we've tried to let some innovative ways to ensure that we can make HBCUs and minority-serving institutions more competitive. One of the ways is in small business. So whereas most HBCUs and minority-serving institutions today look for grants, we are trying to team them with larger research institutions so that they can learn how to go after contracts so that they can enter into contracts with—to allow their professors to actually do like—Congressman Perlmutter knows this. The University of Colorado Boulder, MAVEN—MAVEN is the University of Colorado Boulder. That was the—that's the principal investigator is a professor—this is a Mars—a critical Mars satellite.

We ought to be able to get HBCUs and minority-serving institutions to learn from Colorado Boulder so that they can compete for contracts so that the students who want to be engineers can actually build satellites. We're starting little. We're starting with SmallSats or CubeSats. And so while it's not for MUREP or other kinds of programs, we're finding alternative ways to get money to minority campuses. We're not there yet, but we're trying to do that.

We call it Mentor-Protege where a large college takes a small HBCU and tries to bring them along. Alabama Huntsville, Morgan State, Hampton, they're unusual. They know how to—you know, they have contract offices. Most HBCUs don't even have a clue, and that's not—that is not a slight on the HBCU. It's just that they've never known that that's available to them also. And so we've got to spend time doing it. I share your concern.

Chairman BABIN. Thank you.

I'll now recognize Mr. Posey from Florida.

Mr. POSEY. Thank you, Mr. Chairman.

General, just to kind of pick up where we left off last time when I ran out of time, let's suppose that NASA received an extra \$1.35 billion in fiscal year 2017. What would that get spent on?

Hon. BOLDEN. The first thing it would be spent on buying down risk across the board in our programs, and a large portion of it would go into human spaceflight.

And what does that mean, buying down risk? We would go out and purchase long lead items for downstream vehicles so that EM-3, EM-4, EM-5 would be—the vehicles for those flights would be

able to begin construction now rather than waiting three or four or five years from now.

We would probably put more money into beefing up our Safety and Mission Assurance organization or the Engineering organization to make sure that we satisfy Congresswoman Edwards' concern and that of the ASAP that we don't let launch fever or those kinds of things happen. And of course, we would try to get as much done quickly so that we could launch sooner. But the big focus would be on buying down risk.

Mr. POSEY. Thank you. For a long time we talked about EM-2 being in 2021 and now we're a big bump to 2023. Could just a matter of funding put that back on track?

Hon. BOLDEN. Yes, a matter of funding could put EM-2 back on track, but all the funding would not go to doing that, again, as I said, because what I don't want to do is put a bundle of money on EM-2, have no long lead items having been procured, have tests that need to be done and don't get done and we launch EM-2 earlier and we're stopped. So—

Mr. POSEY. I get that.

Hon. BOLDEN. —it's not as—

Mr. POSEY. I get that.

Hon. BOLDEN. It's not black and white.

Mr. POSEY. And the economy of having more closer together is there, too. I mean, I understand the economic benefits of doing that.

Hon. BOLDEN. Yes. You know, development curve—a funding curve for development program has a little hump in it. None of ours ever have that. Ours is always straight line.

Mr. POSEY. Yes.

Hon. BOLDEN. The work that people like Bob Cabana and Todd May and Ellen Ochoa and the program managers do every single year, Bill Gerstenmaier, in fitting a development program—and we have, I think, five human spaceflight development programs underway, never been done by this agency before. When you talk about commercial crew, commercial cargo, suborbital flight, Orion, SLS, EGS, and not to mention the science programs, we've got a lot of stuff that we're trying to do and all of it is incredibly valuable. We don't have anything that I would say, you know, let's stop doing it because it's all important for the nation.

Mr. POSEY. Great. Thank you very much.

Chairman BABIN. Thank you.

Let's see. Now, the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman.

General, Congress has expressed in the past—or the concerns have been expressed that it's not safe to have missile rocket launches and offshore oil rigs in the same area. In 2015, NASA stated that the presence of either temporary or fixed structures at or below the sea surface within our range hazard areas, would have significant detrimental effects on our ability to conduct aerospace test activities." In addition, there was a warning that "impact with an oil platform would cause catastrophic damage and would result in the complete loss of expensive launch vehicles." So Tuesday, the Administration, Secretary Jewell, reversed course on mid-Atlantic oil and gas leasing program, at least through 2022. Could

you tell us if offshore oil and gas drilling and exploration off Virginia's coast is consistent with the activity of NASA Wallops?

Hon. BOLDEN. Mr. Beyer, I'll take that for the record. I will say one thing about the comment you made. Any spacecraft that impacts anything here on Earth is bad for the—whether there's an oil well there or not, if it comes back to Earth, it's a bad day. So having an oil well there doesn't make a difference, but I'll take it for the record to find the answer to your specific question.

Mr. BEYER. Okay. Good. Because I was trying to quote NASA there as much as I could so—

Hon. BOLDEN. Yes, sir. And I understand that. I have some incredible people, a lot smarter than I am, and so they're going to educate me so I can answer your question.

Mr. BEYER. Okay. Good. How about a brief progress report on James Webb Telescope, and are we still on track for launch October 2018?

Hon. BOLDEN. We are on track for launch October 2018, and we actually have—I'll try to get this right—about a 7-1/2 month cost and schedule reserve, which we—in all probability we'll need because there are some critical tests upcoming when we move the spacecraft down to the Johnson Space Center, and there's always something that comes up that you don't anticipate. So it's the place you want to be. But we're on track right now for 2018.

Mr. BEYER. It's very exciting. Thank you, General.

Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir. Thank you. And I believe Mr. Perlmutter, the gentleman from Colorado.

Mr. PERLMUTTER. Thanks, Mr. Chairman. And I just have a few thank-yous I want to give. One is to Scott Kelly and his recent record-setting journey on the Space Station. And for a short guy like me, it was encouraging to hear that he was 2 inches taller when he came down than his identical twin brother.

Hon. BOLDEN. Only temporary.

Mr. PERLMUTTER. I know. It didn't last long, but still, there's hope. And I want to thank NASA. And yesterday, we had another astronaut here testifying, Kathy Sullivan on behalf of NOAA, and both of your agencies helped my office recently with major weather—giant weather system Cyclone Winston that clobbered Fiji. And we had some constituents who were missing for several days, and we were able to get some pictures from your agency, NOAA, some others to at least give the family comfort that the part of the island where they were wasn't completely flattened. And after several days and—the communications were restored, but it gave comfort to the families. So I want to thank you for that.

Also thank you with respect to the cargo missions. You know, recently one of the companies in Colorado was awarded one of the contracts to deliver cargo, Sierra Nevada, up to the space station.

And lastly, you mentioned the University of Colorado, and they're playing the University of Connecticut today in the first round of the NCAA, so I do want to say go Buffs. But TSIS, Total Solar Irradiance Sensor—

Hon. BOLDEN. Sensor, yes, sir.

Mr. PERLMUTTER. —is what we met about at CU a couple years ago, built by CU students, and it's going to catch a ride to the

Space Station in 2018. And obviously very proud of the university and the kinds of things it does working with NASA and the things that it does in terms of getting students involved with outer space. So I don't know if you want to comment on any of those, but just thank you for your service again, General.

Hon. BOLDEN. Sir, my—I appreciate all the compliments. I'll try to make sure we get them out to everybody. I'll be with Scott next week when we go to Moscow for his post-flight.

But I would go back to Congresswoman Edwards' question about HBCUs and the like and say that's what we want to do with schools like Morgan and Howard and Hampton. We want them to have students who are working on spacecraft, and that's—that takes some effort. And, first of all, you have to convince them that they can. You've got to let them know that opportunities are there. You're not—we use the term inspire all the time. I had a young black engineer one time who told me if he heard me say inspire one more time he's going to puke. And I went, what do you mean? He said, we can't inspire anybody until we inform them. And so there are kids from my community back in South Carolina and all over this country that you all represent who don't have a clue what they can do. And so the first thing—and that's what NASA tries to do with the limited funds we do have in our education program.

And I actually have a \$19 billion education budget. I know you all think I'm being trite when I say that because everything we do in NASA is really focused on trying to inspire and inform young people about what they can do to be a part of the NASA family. And so I'm very, very thankful for the \$19.3 billion that you all appropriated for us out of the Congress last year. Thank you, sir.

Mr. PERLMUTTER. Thank you.

Chairman BABIN. Thank you. And this really concludes our hearing, and it's been an excellent hearing. And I want to thank the witness, General Charlie Bolden, for your long illustrious career and your leadership of NASA. And I want to thank you on behalf of the entire Committee. I'd also like to thank the Committee Members for their very informative and great questions.

So with that, this hearing is adjourned.

Hon. BOLDEN. Thank you, sir.

[Whereupon, at 12:09 p.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by the Hon. Charles F. Bolden, Jr.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY SUBCOMMITTEE ON SPACE**

*An Overview of the Budget Proposal for the National Aeronautics and Space
Administration for FY 2017*

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

Questions submitted by Rep. Brian Babin, Chairman,
Subcommittee on Space

QUESTION 1a:

A recent Op-Ed in Space News offered a potential warning about the commercial cargo program. Here is a brief quote from that Op-Ed:

"In early 2011, because the Commercial Orbital Transportation Services (COTS) program had spent to its contract ceiling of \$500M, and with neither of the two contractors, SpaceX or Orbital Sciences, within another two years of sending anything into ISS, NASA had no choice but to bail-out the COTS contractors with \$239M, nearly 50 percent over the original COTS contract. And today, with public records showing that the follow-on Commercial Resupply Services (CRS) program has been paid nearly up to the contract ceiling of \$3.5B, and with not even half the launches completed, it's looking increasingly as though a bailout of the CRS contractors will be needed at some point."

- a. Will the next Administration be blind-sided with a cost overrun and need to bail out this program?

ANSWER 1a:

This Op-Ed incorporated a fundamental misunderstanding about how the Commercial Resupply Services (CRS) program works. NASA is purchasing services under fixed-price contracts, and only pays its CRS contractors when they meet contractually-defined milestones. Commercial service providers must meet the terms of their contract for the agreed-to contract price.

QUESTION 2a:

The two contractors under the commercial crew program are facing two separate challenges that may require additional funding in order to ensure they can deliver by their agreed upon schedule to transport astronauts to the ISS. SpaceX is seeking approval to deviate from normal practice by fueling its vehicle with crew on-board. If NASA does not let them do that for safety reasons, it may be necessary to revisit their contract, which could impact cost. Boeing is currently planning to launch atop an Atlas 5 vehicle. While there is no prohibition on using RD-180 engines for civil or commercial purposes, if DOD stops buying Atlas 5's, NASA would presumably have to absorb the overhead costs associated with that

vehicle and suffer from decreasing economies of scale. If the price of an Atlas 5 goes up, or if Boeing has to certify launching on another vehicle, there could be a direct cost to NASA. Even though these are firm-fixed-price contracts, it is not unheard of for the government to have to bail-out contractors, as it had to do in 2011 with the commercial cargo program by "augmenting" the existing contract by roughly 50 percent more money.

- a. Will the next Administration be blind-sided with a cost over-run and need to bail out this program?

ANSWER 2a:

The basic contract details and structure will limit NASA's exposure to cost overruns. NASA's commercial crew and commercial cargo companies are required to provide all the hardware necessary to perform their missions, including engines, tanks, spacecraft, and ground systems. If some part of the transportation system should become unavailable for any reason, the companies are responsible for acquiring a replacement to meet the terms of their contract for the agreed to contract price of these fixed-cost contracts.

QUESTION 3:

You stated in your testimony before the committee that the White House did not consult you on the idea to fund NASA through mandatory spending accounts; however, you were assured by the OBM Director that NASA's FY 2017 budget would be \$19B. Could you define the difference between mandatory and discretionary spending accounts?

ANSWER 3:

Mandatory spending means spending controlled by laws other than appropriations acts (including spending for entitlement programs). Discretionary spending means budgetary resources (except those provided to fund mandatory spending programs) provided in appropriations acts.

QUESTION 4:

The constellation program benefitted from broad international support and participation derived from significant outreach and input. Our international partners seem to be uninterested in the Asteroid Retrieval Mission, as evidenced by the European Space Agency advocating for a cooperative lunar station. Please list all formal engagements with international partners where NASA sought input and participation on the Asteroid Retrieval Mission.

ANSWER 4:

The Asteroid Redirect Mission (ARM) is part of the Journey to Mars that has already begun on the International Space Station (ISS). ARM will advance the new technologies and spaceflight experience needed for a human mission to the Martian system in the 2030s. NASA is engaged in an ongoing dialogue with our space agency partners around the world, from agency leadership to technical and scientific working levels, regarding the phased approach for sustainable space exploration. These phases start with exploration systems testing on the ISS, transition to cislunar flight testing of exploration systems, then move to cislunar validation of exploration capability on the way to a one year crewed Mars-class shakedown cruise. The Asteroid Redirect Crewed Mission marks the move from the flight testing to validation phases. ARM and its critical exploration technologies constitute an integrated component of the exploration discussions in bilateral and multilateral engagements ranging from the ISS program to the International Space Exploration Coordination Group (ISECG). Several space agencies have expressed an interest in ARM, and bilateral discussions are actively occurring with the Japanese, Italian, and Canadian space agencies.

NASA has identified a number of areas where international collaboration on the ARM could provide mutual benefit. Examples could include:

- Data sharing and lessons learned analysis involving other asteroid/small body missions;
- Asteroid identification and characterization to support preparation for the selected asteroid boulder;
- Low gravity environment capture systems including both deployable structures and robotic manipulators;
- High speed relative navigation and autonomous close proximity operations including rendezvous and proximity operations sensor contributions that could be used for a wide range of mission applications;
- Secondary payload contributions to the Asteroid Retrieval Vehicle that could advance either science or future exploration capabilities; and
- Selection, extraction and containment of asteroidal samples of most benefit for scientific and resources interests.

We envision an important role for international participation in all aspects of the ARM and throughout the Journey to Mars.

QUESTION 5:

In last year's omnibus bill, Congress directed NASA to develop an Exploration Upper Stage for use on SLS' Exploration Mission 2, the first manned SLS mission. This new stage would replace the Interim Cryogenic Propulsion Stage, which, as the Aerospace Safety Advisory Panel pointed out, is not human-rated and would pose unnecessary risks to the astronauts aboard. NASA officials have said that this

year's request does not continue development of the Exploration Upper Stage. Why, after spending \$85M on developing a safer, more powerful second stage, is NASA proposing to abandon the effort?

ANSWER 5:

As with every budget submission, NASA must balance its priorities within the constraints of the budget. NASA plans to use the Exploration Upper Stage (EUS) on future Exploration Missions flown by the Space Launch System (SLS). Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would be planned for launch with Space Launch System (SLS) Block 1 using the Interim Cryogenic Propulsion Stage. The current (preliminary, early formulation) estimated range evolving SLS to Block 1B, including necessary work to ground systems, is between \$1.9 and \$2.6 billion over the next five years. It is not possible to accommodate these funding levels without risks to schedule or significant cuts to other work, including work needed to support the development of actual missions for SLS and Orion, and technologies needed to make deep space exploration missions affordable and achievable.

However, the FY 2016 Appropriations Act directs that no less than \$85M in FY 2016 be for development of the EUS. Consistent with this direction, the SLS Program will mature the EUS to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. NASA has issued a sole-source request for proposal (RFP) to Boeing to determine the development and hardware costs associated with design development, manufacturing, and test of the first flight EUS. NASA has also issued a sole-source request for proposal (RFP) to Aerojet Rocketdyne to support production of the RL10 upper stage engines, the associated integration, and required human rating information for the first flight EUS (four engines and two spares). Other contracting activity in support of EUS will likely follow later this year for the Universal Stage Adapter (USA). NASA will continue to assess implementation of EUS as we progress through the developmental cycle and available future year budgets.

QUESTION 6a & 6b:

The recent Appropriations bill directed NASA to use no less than \$85M of the \$2B appropriated for the Space Launch System for development of an enhanced upper stage.

- a. What is NASA's expected lifecycle development cost for the Exploration Upper Stage (EUS)?
- b. What are the costs associated with making modifications to Orion and Kennedy Space Center Ground Systems to support the EUS?

ANSWER 6a & 6b:

See table below. The range of estimates for SLS and Ground Systems Development and Operations (GSDO) for SLS Block 1B (which includes EUS) reflects the current uncertainty ahead of detailed designs and contracts. The estimates are based on the early design stage (prior to associated Preliminary Design Review [PDR] and other

assessments). These estimate ranges are subject to further maturation during ongoing contract negotiation, technical design reviews, and near-term budget formulation processes. SLS includes development and production of EUS, the upper-stage engines for EUS, the Universal Stage Adaptor to mate EUS to Orion, a Payload Attach Fitting to accommodate co-manifested payloads, and necessary vehicle-level systems engineering and integration. GSDO includes upgrades at the Kennedy Space Center to enable launch of an SLS Block 1B, including modifications to platforms in the Vehicle Assembly Building (VAB), increasing the height of the Mobile Launcher, and adding additional liquid hydrogen capability at the pad. Orion includes analysis to ensure adequate safety margin on the spacecraft structure to support EUS thrust loads.

	Estimates (FY16-21)
	TOTAL (\$M)
SLS (all elements)	~ 1,577 – 1,827
GSDO	~ 328 – 583
Orion	~ 7 – 20
TOTAL	~ 1,910 – 2,555

QUESTION 7:

There is a widespread view that human exploration of Mars should be the eventual goal of NASA's human exploration program, even if there are several intermediate, less challenging goals. Is it realistic to contemplate human exploration of Mars at the current level of NASA's exploration budget?

ANSWER 7:

NASA has a goal of sending a human mission to Mars in the 2030s. The President's 2017 Budget funds the development of systems and technologies that are critical for making future exploration activities affordable and sustainable. The achievability of sending astronauts to Mars will depend on the results of our system and technology developments between now and then. The President's Budget also funds development of systems for near-term human exploration of deep-space destinations, including to a redirected asteroid boulder in a distant retrograde orbit around the Moon, in the mid-2020s. The specific funding levels for future missions will depend on factors including the affordability of SLS and Orion operations and continued development, the benefit of those missions toward overall exploration objectives, as well as the development and operations costs of other assets to support humans in deep space, such as potential habitation capabilities. It will also depend on

partnering opportunities, the ability to leverage possible in-space resources, as well as learning about the human ability to live and work longer in deep space (including lessons learned from the International Space Station). As NASA learns from initial missions using SLS and Orion and develops new technologies and architectures to make exploration more affordable, the Agency will formulate cost and schedule details of future goals and hardware, and this analysis will be reflected in future budget requests.

QUESTION 7a:

If not, how much more funding would be needed to meet the ultimate goal of a human mission to Mars?

ANSWER 7a:

Please see response to Question #7, above.

QUESTION 7b:

Has NASA done an analysis of future Mars architectures and the budgets and schedules required to build that architecture? Can you provide that information to the Committee?

ANSWER 7b:

Please see response to Question #7, above.

QUESTION 8:

Please provide a "sand chart" that outlines the planned development funding profiles and schedules for each specific element of the Space Launch System (core stage, engines, boosters, upper stage, adapters and interstage elements, fairings, abort systems, avionics, and any other elements) for Block 1 (70t), Block 1B Crew (10St), Block 1B Cargo (10St), and Block 2 Cargo (130t).

ANSWER 8:

Please see table below, which displays the SLS portion of the President's FY 2017 Budget Request for NASA. This funding supports flights of a Block 1 SLS on EM-1 in 2018 and EM-2 in 2023.

(in \$M)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Space Launch System (SLS)	1,310.3	1,361.4	1,484.7	1,499.6	1,524.2
<i>Launch Vehicle Development</i>	<i>1,262.8</i>	<i>1,295.0</i>	<i>1,419.7</i>	<i>1,431.5</i>	<i>1,454.6</i>
<i>SLS Program Integration and Support</i>	<i>47.5</i>	<i>66.5</i>	<i>65.0</i>	<i>68.1</i>	<i>69.6</i>

NASA is presently developing as part of FY 2018 budget formulation a plan for

SLS that includes developmental costs for the various components listed. NASA is also working on production and operation costs for evaluation later this year. In all scenarios the costs will be consistent with FY 2016 appropriated funds.

QUESTION 9:

Please provide a "sand chart" that outlines the planned development funding profiles and schedules for each specific element of Orion (including the crew module, the European service module, the launch abort system, heat shield, avionics, environmental control and life support systems, radiation protection, parachutes, or any other primary components) for EM-1, EM-2, and any future additional mission-sets currently under consideration.

ANSWER 9:

Please see table below, which displays the Orion portion of the President's FY 2017 Budget Request for NASA. This funding supports flights of a Block 1 SLS on EM-1 in 2018 and EM-2 in 2023.

(in \$M)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Orion	1,119.8	1,119.9	1,123.9	1,135.1	1,153.3
<i>Crew Vehicle Development</i>	<i>1,109.3</i>	<i>1,109.4</i>	<i>1,113.4</i>	<i>1,124.6</i>	<i>1,142.7</i>
<i>Orion Program Integration and Support</i>	<i>10.5</i>	<i>10.5</i>	<i>10.5</i>	<i>10.5</i>	<i>10.7</i>

QUESTION 10:

Please provide a "sand chart" that outlines the planned development funding profiles for Exploration Ground Systems (EGS) elements for EM-1, EM-2, and any future additional mission-sets currently under consideration.

ANSWER 10:

Please see table below, which displays the Exploration Ground Systems (EGS) portion of the President's FY 2017 Budget Request for NASA. This funding supports flights of a Block 1 SLS on EM-1 in 2018 and EM-2 in 2023.

(in \$M)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Exploration Ground Systems (EGS)	429.4	441.2	453.0	457.5	464.7
<i>EGS Development</i>	<i>414.1</i>	<i>425.9</i>	<i>437.7</i>	<i>442.1</i>	<i>449.1</i>
<i>SLS Program Integration and Support</i>	<i>15.3</i>	<i>15.3</i>	<i>15.3</i>	<i>15.4</i>	<i>15.7</i>
TOTAL Exploration Systems Development	2,859.5	2,922.5	3,061.6	3,092.2	3,142.3

QUESTION 11:

Please provide a "sand chart" that outlines the integrated development of the SLS, Orion, and GSDO to support EM-1 and EM-2.

ANSWER 11:

Please see table below, which displays the Exploration Systems Development portion of the President's FY 2017 Budget Request for NASA, including the development funding lines for Orion, the Space Launch System (SLS), and Exploration Ground Systems (EGS). Funding for these programs supports a continuing, sustainable human deep-space exploration effort, rather than discrete, separable missions.

(in \$M)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Orion	1,119.8	1,119.9	1,123.9	1,135.1	1,153.3
<i>Crew Vehicle Development</i>	<i>1,109.3</i>	<i>1,109.4</i>	<i>1,113.4</i>	<i>1,124.6</i>	<i>1,142.7</i>
<i>Orion Program Integration and Support</i>	<i>10.5</i>	<i>10.5</i>	<i>10.5</i>	<i>10.5</i>	<i>10.7</i>
Space Launch System (SLS)	1,310.3	1,361.4	1,484.7	1,499.6	1,524.2
<i>Launch Vehicle Development</i>	<i>1,262.8</i>	<i>1,295.0</i>	<i>1,419.7</i>	<i>1,431.5</i>	<i>1,454.6</i>
<i>SLS Program Integration and Support</i>	<i>47.5</i>	<i>66.5</i>	<i>65.0</i>	<i>68.1</i>	<i>69.6</i>
Exploration Ground Systems (EGS)	429.4	441.2	453.0	457.5	464.7
<i>EGS Development</i>	<i>414.1</i>	<i>425.9</i>	<i>437.7</i>	<i>442.1</i>	<i>449.1</i>
<i>SLS Program Integration and Support</i>	<i>15.3</i>	<i>15.3</i>	<i>15.3</i>	<i>15.4</i>	<i>15.7</i>
TOTAL Exploration Systems Development	2,859.5	2,922.5	3,061.6	3,092.2	3,142.3

QUESTION 12:

Please provide a "sand chart" that outlines the notional development of a mission to Mars, including, but not limited to funding for SLS; Orion; EGS; in situ resource utilization and surface power; habitation and mobility; human/robotic and autonomous operations; exploration extravehicular activities; crew health technologies; environmental control and life support systems; radiation safety; ascent from planetary surfaces; entry, descent and landing; in-space power and propulsion; and communications and navigation.

ANSWER 12:

Please see response to Question #7, above, and table below, which displays the Exploration portion of the President's FY 2017 Budget Request for NASA. NASA is working to shape future architecture of human space exploration to be sustainable and pioneering approaches by progressively expanding capabilities and distance with

an objective of extending human presence into the solar system and to the surface of Mars. Human Exploration and Operations Mission Directorate (HEOMD) programs continue to develop a robust core set of evolving capabilities within the Exploration budget, intended to ensure flexibility, affordability, and sustainability in the Nation's human spaceflight program, while using the International Space Station (ISS) and Low Earth Orbit as a research testbed for long-duration spaceflight. This approach provides the Agency adequate adaptability to carry out increasingly complex missions to a range of destinations over time.

HEOMD's Exploration Systems Development programs are creating the first components of this architecture for human exploration beyond low Earth orbit, Orion, Space Launch System (SLS), and Exploration Ground Systems (EGS), will take us to the proving ground of cislunar space (the volume of space around the Moon) to conduct deep-space long-duration missions to test systems and concepts for further exploration.

Extending human presence into deep-space requires expansion of technical and scientific knowledge to tackle complex problems and devise creative new solutions to meet demands never before encountered by humans or crewed spacecraft. NASA must understand and mitigate the effects of long-term human exposure to space and the Human Research Program (HRP) is conducting research on the ISS toward this Exploration end. NASA's Advanced Exploration Systems (AES) is also developing the technologies and maturing the systems required for deep-space missions.

(in \$M)	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021
Orion	1,119.8	1,119.9	1,123.9	1,135.1	1,153.3
Space Launch System (SLS)	1,310.3	1,361.4	1,484.7	1,499.6	1,524.2
Exploration Ground Systems (EGS)	429.4	441.2	453.0	457.5	464.7
TOTAL Exploration Systems Development	2,859.5	2,922.5	3,061.6	3,092.2	3,142.3
Human Research Program	153.3	178.2	178.2	180.0	182.8
Advanced Exploration Systems	324.1	429.0	842.0	971.4	936.6
TOTAL Exploration Research and Development	477.3	607.2	1,020.1	1,151.4	1,119.5
TOTAL Exploration	3,336.9	3,529.7	4,081.7	4,243.6	4,261.7

QUESTION 13:

Please provide a "sand chart" that outlines the notional development of a mission to return to the Moon's surface, including, but not limited to funding for SLS; Orion; EGS; in situ resource utilization and surface power; habitation and mobility; human/robotic and autonomous operations; exploration extravehicular activities; crew health technologies; environmental control and life support systems; radiation safety; ascent from planetary surfaces; entry, descent and landing; in-space power and propulsion; and communications and navigation.

ANSWER 13:

Please see response to Question 7 – regarding NASA’s human exploration plans – and Question 12 – including table displaying Exploration budget runout – above. The Agency is not planning to return humans to the lunar surface, and does not have the component costs listed in the question.

QUESTION 14:

If NASA were to receive the \$1.3B it requested for the Space Launch System, which is \$700M less than was enacted in FY 2016, could we realistically expect Exploration Mission 1 to launch in 2018?

ANSWER 14:

Yes, the President’s FY 2017 Budget Request fully funds the agency baseline commitment for launch readiness for the Space Launch System and Ground Systems Development on Exploration Mission 1 (EM-1) no later than November 2018 and for launch readiness for crewed Orion on EM-2 on a Block 1 SLS no later than August 2023. This funding level, however, would not support development work now for activities beyond EM-2. The funds provided above the President’s Budget Request have gone to support risk reduction activities for EM-1, development of SLS Block 1B for EM-2 per direction in FY 2016 Consolidated Appropriations Act, and development of capabilities needed beyond EM-2.

QUESTION 15:

NASA’s FY 2017 budget request for the Commercial Crew Program includes funding for Boeing and SpaceX to conduct uncrewed and crewed test flights to the International Space Station and to ultimately be certified by the end of 2017. What is NASA’s confidence level that these service providers will meet the 2017 certification deadline?

ANSWER 15:

NASA continues to monitor the progress of both companies in completing their contract milestones to date. Updated schedules show SpaceX certification in 2017 and Boeing certification in 2018. It is important to note that both companies continue to work risk refinement and mitigation, into which NASA has insight, for their certification schedules to add margin for unseen problems. NASA believes the schedules will be challenging for the contractors to meet.

QUESTION 16a:

51 U.S.C. 50503 allows NASA to enter into multiyear anchor tenancy contracts for the purchase of a good or service under certain conditions. In order to do so, the Administrator has to determine that 1) existing or potential customers for the good or service other than the United States Government have been specifically identified; 2) the long-term viability of the venture is not dependent upon a

continued Government market or other non-reimbursable Government support; and 3) private capital is at risk in the venture.

- a. Please provide any documentation related to the determinations made under 51 U.S.C 50503 for the Commercial Crew and Cargo Programs.

ANSWER 16a:

While NASA is encouraging the development of a low Earth orbit (LEO) space economy through purchasing crew and cargo transportation services from U.S. companies, the Agency's commercial crew and cargo programs are not based on the anchor tenancy provisions in 51 U.S.C. 50503.

QUESTION 16b:

Does NASA intend to procure or develop habitation modules or space station services? If so, will the NASA Administrator make determinations under 51 U.S.C. 50503?

ANSWER 16b:

It is NASA's intention to transition from the current government-owned and -operated ISS to private platforms and capabilities enabled by commercial markets and Government agencies, including NASA, with interest in LEO research and activities. Meanwhile, NASA's emphasis in human spaceflight will shift toward deep space beyond LEO. The development or procurement of deep space habitation modules is also expected to be synergistic with commercial LEO activities. NASA is working to encourage the growth of a LEO space economy. Private enterprise and affordable commercial operations in LEO will enable a truly sustainable step in our expansion into space — a robust, vibrant, commercial enterprise with many providers and a wide range of private and public users will enable U.S. industry to support other Government and commercial users safely, reliably, and at a lower cost.

NASA is committed to determining the most appropriate procurement mechanism that stimulates maximum competition for future missions and increases affordability. Such determinations will be dependent on a number of factors and will be consistent with Federal laws and regulations as well as business case analysis.

QUESTION 17:

NASA has already procured additional seats from Russia for 2018 in the event that the Commercial Crew contractors are not prepared to take astronauts to the ISS. This contract is valued at \$490M. If the contractors are ready by 2017, what will NASA do with the additional seats? How does the process for bartering those services work under our agreements with the ISS partners?

ANSWER 17:

NASA plans to utilize the Soyuz seats purchased. The procurement will be used to ensure proper launch vehicle cadence or augment ISS operations and research capabilities, as required. Flight priority will go to the U.S. commercial crew capability providers. The Soyuz seats will allow for extra crew time, which is presently a constraint to research operations.

The top-level ISS agreements, the multilateral Intergovernmental Agreement (IGA) and bilateral Memoranda of Understanding (MOU) between NASA and each of the four other partners, provide a framework for cooperation on the ISS Program among these International Partners. Both the IGA and MOUs state that the ISS partners shall seek to minimize the exchange of funds in the implementation of the ISS Program, including, if they agree, through the use of barter (exchange of goods and services).

QUESTION 18:

One of the Commercial Crew providers intends to launch its crew capsule on an Atlas V rocket. The maker of the Atlas V, United Launch Alliance, recently announced plans to develop a new rocket known as Vulcan. Do you anticipate that Vulcan will eventually replace the Atlas V for Commercial Crew launches?

ANSWER 18:

NASA's contract for CCP is with Boeing and SpaceX. NASA is not in a position to comment on our prime contractors' choices of launch vehicles and future business decisions.

QUESTION 18a:

What additional testing and certification processes would be required to permit such a change?

ANSWER 18a:

If a commercial crew provider were to significantly change the launch vehicle that had successfully completed system certification, a new system certification would need to be conducted and completed. Should either partner – Boeing or SpaceX-- choose to change their commercial transportation system to include a newly developed rocket, they would be required to meet the same NASA human rating certification requirements currently on the contract for this new part of their system. The application of these requirements to Boeing's new rocket, for example, would be a complex process, and NASA's understanding of the required amount of testing would mature as the new rocket launcher design matured. The exact details of the testing program are impossible to specify as these would depend on the technical configuration of the new rocket, its flight heritage, and the company's certification strategy. But at a minimum, certain analyses and tests would have to be repeated for the new launch vehicle.

QUESTION 18b:

Would NASA or the contractor be responsible for the cost of additional testing and certification?

ANSWER 18b:

NASA's commercial crew and commercial cargo companies are required to provide all the hardware necessary to perform their missions, including engines, tanks, spacecraft, and ground systems. If some part of the transportation system should become unavailable for any reason, the companies are responsible for acquiring a replacement and to perform the necessary testing to meet the requirements of the terms of their contract for the agreed upon contract price for these fixed-cost contracts.

QUESTION 19:

One of the Commercial Crew contractors intends to have astronauts on-board the vehicle while it is being fueled for launch. I understand that there is significant concern among members of the astronaut corps about the safety of fueling a rocket while people are on it. In the event NASA decides that this risk is not acceptable, how would such a change to the proposed launch operations impact the schedule and cost risk for NASA?

ANSWER 19:

The current SpaceX design for loading of densified propellants while the flight crew is on board the vehicle is currently under review by the Commercial Crew Program. In the event NASA does not approve this as meeting our safety requirements, SpaceX will be obligated to make a design change to their system that does comply with contract safety requirements. In general, changes required because of a failure to meet requirements are the responsibility of the contractor, although circumstances are always unique and must be carefully examined. Cost and schedule impacts can be determined at a later date, when data is available, and has been carefully analyzed by NASA.

QUESTION 20a:

Under the original CRS-1 contracts SpaceX was awarded 12 flights for \$1.6B and Orbital Sciences was awarded 8 flights for \$1.9B. Under CRS-1 Orbital-ATK was awarded an additional 2 flights and SpaceX was awarded an additional 8 flights.

- a. How much have the contractors been paid to-date?

ANSWER 20a:

Through March 31, 2016, SpaceX has been paid \$1.7B and Orbital ATK has been

paid \$2.0B.

QUESTION 20b:

How many flights have they provided by each contractor?

ANSWER 20b:

As of April 15, 2016, Under the CRS contracts, SpaceX has had eight flights, including one mission that was lost due to an anomaly (SpX-7). Orbital ATK has had five flights, including one mission that was lost due to an anomaly (Orb-3).

QUESTION 20c:

How much mass has been delivered by each contractor?

ANSWER 20c:

Under CRS, SpaceX has delivered 10,187 kg of upmass and 8,803 kg of return cargo not including SpX-8. Final numbers for SpX-8 are still being worked. Orbital ATK has delivered 10,241 kg of upmass and 4,618 kg of disposal cargo.

QUESTION 20d:

Are there any other metrics that would be important to evaluate the status of the contracts? If so, please provide that information.

ANSWER 20d:

Uplift/downlift transported is the key metric for the evaluation of the status of the contracts.

QUESTION 20e:

Please provide update information that reflects the originally manifested launch dated for all commercial cargo missions, as well as the dates those missions actually launched (or the newly planned launch dates).

ANSWER 20e:

The following table provides the dates at Authority to Proceed (ATP) as well as the actual or currently planned launch date as of March 31, 2016.

Mission	ATP Launch Date/ Window	Actual Launch Date (A) or Current Launch Date/ Window	Mission	ATP Launch Date/ Window	Actual Launch Date (A) or Current Launch Date/ Window
SpX-1	Dec-10	10/07/2012 (A)	Orb-1	Oct-11	01/09/2014 (A)
SpX-2	Jul-11	03/01/2013 (A)	Orb-2	01/2012-03/2012	07/13/2014 (A)
SpX-3	03/2012-05/2012	04/18/2014 (A)	Orb-3	03/2013-05/2013	10/28/2014 (A)
SpX-4	Aug-12	09/21/2014 (A)	OA-4	11/2013-01/2014	12/06/2015 (A)
SpX-5	Apr-14	01/10/2015 (A)	OA-6	12/2014-02/2015	03/22/2016 (A)
SpX-6	Aug-14	04/27/2015 (A)	OA-5	Jul-15	*05/31/2016-06/30/2016
SpX-7	Dec-14	06/28/2015(A)	OA-7	Jun-16	*10/04/2016-11/03/2016
SpX-8	Jun-15	4/8/2016 (A)	OA-8	06/2017-08/2017	*06/01/2017-08/31/2017
SpX-9	Nov-15	*NET 6/24/16	OA-9	10/2017-12/2017	TBD
SpX-10	Feb-16	*NET 8/01/16	OA-10	01/2018-04/2018	TBD
SpX-11	May-16	*08/15/2016-9/13/2016			
SpX-12	Aug-16	*12/15/2016-1/13/2017			
SpX-13	01/2017 - 03/2017	*02/13/2017-3/14/2017			
SpX-14	04/2017-07/2017	*04/08/2017-07/06/2017			
SpX-15	08/2017-10/2017	*08/01/2017-10/29/2017			
SpX-16	02/2018 - 05/2018	*TBD			

* Under assessment

QUESTION 20f:

What is NASA's plan if more funding is needed by the contractors to fulfill their contracts?

ANSWER 20f:

For the ISS Commercial Resupply Services (CRS) contracts, NASA is purchasing services under fixed-price contracts. NASA makes fixed-price payments for the services, regardless of the actual costs the contractor incurs to ensure its system meets the requirements or to address failures to meet the requirements.

QUESTION 21a:

The two contractors under the commercial crew program are facing two separate challenges that may require additional funding in order to ensure they can deliver by their agreed upon schedule to transport astronauts to the ISS. SpaceX is seeking approval to deviate from normal practice by fueling its vehicle with crew on-board. If NASA objects for safety reasons, it may be necessary to revisit their contract, which could impact cost. Boeing is currently planning to launch atop an Atlas V vehicle. While there is no prohibition on using RD-180 engines for civil or commercial purposes, if DOD stops buying Atlas V's, NASA would presumably have to absorb the overhead costs associated with that vehicle and suffer from decreasing economies of scale. If the price of an Atlas V goes up, or if Boeing has to certify launching on another vehicle, there could be a direct cost to NASA. Even though these are firm-fixed-price contracts, it is not unheard of for the government to have to bail-out contractors, as it had to do in 2011 with the commercial cargo program by "augmenting" the existing contract by roughly 50 percent more money.

- a. Will the next Administration be blind-sided with a cost over-run and need to bail out this program?

ANSWER 21a:

Please see response to Question #2, above.

QUESTION 22:

The proposed FY 2017 budget includes funding for Restore-L, a mission in formulation that is intended to demonstrate the robotic servicing of a U.S. government satellite in low Earth orbit. The Landsat 7 satellite is reportedly under consideration as a potential target for Restore-L.

- a. What factors will NASA consider when determining which satellite to select as the target for Restore-L?

ANSWER 22a:

NASA will consider a potential client's ownership, orbit, health, and decommission date, benefit of extending the clients on-orbit lifetime, and effectiveness in advancing servicing technologies by servicing an active satellite.

QUESTION 22b:

What are the potential risks to the target satellite? What is NASA doing to mitigate those risks?

ANSWER 22b:

The Restore-L Mission is planned to be two-fault tolerant against collision with the client (target satellite). It will automatically abort the autonomous rendezvous and capture sequence if a failure occurs that leaves the system zero-fault tolerant for performing the collision avoidance maneuver. Restore-L is also planned to be two-fault tolerant against client satellite damage that degrades the client's operational capability.

QUESTION 22c:

How will NASA balance the opportunity to service a satellite and demonstrate a servicing capability against the risk of damage to the target satellite and the loss of the services it provides?

ANSWER 22c:

The Restore-L mission is implementing system redundancy to ensure that no harm is done to the client satellite. The project has a "do no harm" requirement for the client satellite that drives the system design with respect to reliability and robustness, as well as on-orbit operations. Restore-L is planned to be two-fault tolerant as described in paragraph b. above.

QUESTION 22d:

How does NASA plan to mitigate orbital debris on such a mission?

ANSWER 22d:

NASA plans to mitigate the generation of on-orbit debris through the "do no harm" requirement as described in c. above. This will insure the servicing satellite does not contact the client eliminating the possibility of debris generation.

QUESTION 22e:

How is Restore-L being coordinated with DARPA?

ANSWER 22e:

NASA has coordinated with DARPA to ensure that our respective programs are complementary to each other with each organization focusing on its respective mission requirements while transferring technology to industry as appropriate. Goddard Space Flight Center and the Naval Research Lab are also collaborating on

the technology development required for the demonstrations such as robotics, rendezvous and proximity operations. NASA and DARPA have proposed establishing a government-industry consortium that will be co-led by the two organizations, and include the FAA and industry, to establish standards and identify policy issues.

QUESTION 22f:

How is Restore-L being coordinated with the private sector to ensure that NASA activities do not duplicate or "crowd out" private sector research and development investment?

ANSWER 22f:

In engaging industry, NASA has released three Requests For Information (RFI), conducted two workshops, and given numerous presentations at national aerospace conferences. NASA plans to conduct a number of industry workshops coincident with the project's major milestones such as the Mission Design Review and Critical Design Review. These workshops will allow industry to follow the project's technology and systems development activities to most effectively develop plans for commercial servicing capabilities. The technologies that NASA is developing are the ones that industry has told us they will need as they establish a servicing industry. Much of what we are going to attempt on this mission is extremely difficult. Part of NASA's job is to tackle the tough technology problems first, then turn over possible solutions to U.S. industry. NASA's job is to continue to stay aware of private sector capabilities and interests through RFIs and conference participation, while developing new hardware and technologies that will accelerate the growth of this emerging American-led industry.

QUESTION 23:

When looking at the FY 2017 budget, the Earth science budget request is disproportionately large compared to the other science divisions. Why does NASA believe we should prioritize Earth science over planetary science, astrophysics, and heliophysics where NASA has unique requirements and missions? Please explain why NASA does not believe that a balanced portfolio of missions is in the best interest of the nation.

ANSWER 23:

NASA's science program recognizes and leverages the fact that the universe and all of its parts are inextricably linked. The FY 2017 President's budget request invests optimally across the full range of NASA science priorities, and achieves a balance that allows NASA to realize interdisciplinary scientific goals in an effective and efficient way. The FY 2017 President's request takes into account and makes progress on the range of science objectives identified in all of the Decadal Surveys; it results from a detailed evaluation of the technical and scientific maturities in each of

the disciplines' issues, as well as the near-, mid-, and long-term costs and benefits to the nation that result from advancements on those issues.

Each of NASA's science disciplines: Heliophysics, Earth Science, Planetary Science, and Astrophysics, connects and is relevant to the others, linking the overall, multi-faceted effort. The Sun-Earth connection — including the behavior of the solar cycle — is important for understanding life on Earth, the parameters of human space exploration, and effects throughout the solar system. The vantage point of space enables NASA's constellation of Earth-orbiting satellites to provide essential observations that are used daily not only for research, but also by a multitude of government and private sector stakeholders for planning, for allocating strategic investments, and for improving national and economic security. What NASA learns about Earth's complex system, as well as remote sensing technologies that NASA develops and tests for Earth observations from space, are often used on planetary missions to expand our understanding of other worlds and to identify target locations for finding life elsewhere in the universe — on Mars, on Europa, and on exoplanets orbiting other stars. Similarly, study of phenomena occurring in the universe and of the physical principles that govern them helps us achieve a better understanding of how all of the elements of our solar system originated and evolved.

QUESTION 24:

NASA's Earth Science budget has ballooned over 70 percent since 2007 while NASA's core mission of space exploration, both human and robotic, has been consistently cut. When 13 other federal agencies fund earth observation research and only one agency funds space exploration, why is NASA sacrificing space exploration to do other agencies' work?

ANSWER 24:

The Space Act [P.L. 85-568, 72 Stat., 426, as amended] states the first objective for NASA is to contribute to “The expansion of human knowledge of the Earth and of phenomena in the atmosphere and space.” Thus Earth Science is part of NASA's “core mission.” NASA advances understanding of the Earth system using observations that can be made only from the vantage point of space. NASA is the only civil Federal organization that can procure, develop, and launch Earth monitoring spacecraft that provide critical space-based observations to support research, and then conduct the scientific research they bring forward. NASA is mandated to provide sustained and experimental observations, and focus on space-based platforms to advance research, technology development, and national capabilities.

The budget request for Earth Science highlights the important role that NASA Earth Science plays in the Nation's science priorities — specifically including those recognized in the National Academy of Sciences (NAS) Decadal Survey. It also demonstrates the Administration's confidence in NASA's ability to effectively implement satellite, research, and applications development missions that are vital to our nation's national and economic security. NASA continues to lead the world in space through a balanced program of exploration, science, technology, and

aeronautics research. In the Congressionally-approved NASA response (Op Plan #1) to the FY 2009 appropriation, funding for Earth Science constituted 9.1 percent of the total Agency budget. In the President's FY 2017 budget request, funding for Earth Science similarly constitutes only 10.7 percent of the total Agency request – hardly a significant change in agency focus and emphasis since 2009, especially in light of the National Academy of Sciences 2005 and 2007 Decadal Survey findings that the nation's Earth-observing satellite system was in imminent danger of severe degradation.

NASA rapidly (often in near-real time) makes available to other agencies our highly calibrated, reliable data; the NASA products are widely and routinely used by other federal agencies to improve their operational products, such as weather predictions and disaster response planning and execution. This synergy is seen in the Sustainable Land Imaging program and in the suite of atmospheric and radiation measurements that NASA is providing for use by the governmental and private sectors. Also, NASA conducts and funds comprehensive, peer reviewed scientific research programs that ultimately incorporate these data into computational models that provide quantitative understanding of our dynamic planet. NASA-funded Earth science research improves our understanding of long- and short-term phenomena and processes, including those associated with droughts, floods, fires, air pollution, land cover/land use change, oceans, and polar ice. Importantly, the NASA-funded, broadly solicited, and competitively selected research and applications development programs support a wide range of university and private-sector scientists, engineers, and non-federal users of remotely sensed Earth observations and information products. And by deliberate design, the nation's investment in NASA's Earth- and ocean-observing research satellite systems is routinely and continuously leveraged to provide critical information that supports our fighting forces as well as civilians. NASA satellites make global, accurate, high-resolution, all-weather (clear sky and clouds, day and night) measurements of key environmental quantities in and over the vast global oceans. All of the data from NASA's ocean-observing satellites and instruments are transmitted to the ground in near-real-time, where the measurements are used routinely for improving the accuracies of tactical short- and medium-term weather forecasts by operational agencies such as the civilian NOAA/National Weather Service, the National Hurricane Center, the civil/DoD Joint Typhoon Warning Center, and the military Fleet Numerical Meteorology and Oceanography Center. (Over land, measurements of precipitation, soil moisture, dust, winds, aerosols, and clouds from NASA satellite instruments are similarly used operationally for tactical trafficability, visibility, and dust forecasts for ground troops and aviators, as well as contributing to more accurate regional and global weather forecasts.)

On a more strategic level, one of the greatest threats to national security is climate change, which impacts sea levels, coastal communities, the frequency and intensities of extreme weather events and storms (especially over the oceans), the arctic polar icecap, and shipping lanes to name a few examples directly tied to naval operations. Looking more inward, climate change has direct economic impacts driven by such factors as warmer temperatures, seasonal change, extreme weather and severe droughts. Studying the science behind climate change is essential to predicting future global issues and informing policy on national security. The President's

FY2017 budget request maintains a strong Earth Science program for the nation addressing some of the most critical questions we have about how and why Earth's climate and environment is changing. Whether obtained from a research agency like NASA or daily weather monitoring/forecasting agencies like the civilian NOAA or the military Fleet Numerical Meteorology and Oceanography Center, all branches of the US armed forces including the Navy and Coast Guard address national security by using climate data to aid in their planning, anticipation of, and response to changing situations across the world.

QUESTION 25:

Over the next few years, NASA plans to launch several missions using Atlas V rockets. These include the OSIRIS-ReX asteroid exploration mission, the GOES-R and GOES-S weather satellites, the TDRS-M tracking and data relay satellite, and the Solar Orbiter science mission. One of the two planned providers of Commercial Crew Transportation to the International Space Station also intends to use the Atlas V. Because the Atlas V has a Russian rocket engine, its use by the Department of Defense (DOD) has become contentious.

- a. What issues, if any, are there currently with the availability of Atlas V rockets for NASA launches or for commercial launches in support of NASA?

ANSWER 25a:

There are currently no issues with the availability of Atlas V rockets for NASA launches or for commercial launches in support of NASA.

QUESTION 25b:

How have restrictions on DOD use of the Atlas V affected NASA?

ANSWER 25b:

To date, NASA has not been adversely affected by the Department of Defense (DoD) restrictions.

QUESTION 25c:

If DOD stops utilizing Atlas V, will NASA absorb the overhead costs associated with keeping the production line open?

ANSWER 25c:

No, NASA will not "absorb the overhead costs" should DoD stop utilizing Atlas V. NASA expects its commercial providers to provide launch solutions that meet their contractual commitments. Any attempt to pass on "overhead costs" would not be welcome and NASA would negotiate to severely limit, if not eliminate, any such cost increases.

QUESTION 25d:

What is the estimated cost to keep the Atlas V line open without DOD support?

ANSWER 25d:

NASA does not typically contract for commercial launch services in a manner to keep a certain launch vehicle line open. NASA typically conducts a competition for its launch services and utilizes what U.S. industry is able to offer.

QUESTION 25e:

Is NASA working with DOD and U.S. industry to develop a replacement engine for the Atlas V and/or a replacement rocket? If so, please outline those efforts.

ANSWER 25e:

NASA is supportive of the U.S. Air Force (USAF) strategy to enable a transition to multiple all-U.S. built launch systems by the 2022 timeframe, and is providing the USAF with NASA expertise and access to NASA facilities.

QUESTION 26:

With rare exception, outer planet exploration requires radioisotope thermal generators (RTGs) to provide power. Today, when NASA plans a mission to the outer planets or sends out an announcement of opportunity that includes the outer planets as destination of exploration, the current generation of RTGs, also known as multi-mission RTGs, is available. However, this generation of RTGs may not be optimal for such missions. As a result, our national capability to explore the outer planets could be hindered. What is NASA doing to address this issue and how are these steps reflected in the budget request? When (year) does NASA plan to have a solution that allows for outer planet exploration facilitated by appropriate RTGs? What is the estimated cost to accomplish this?

ANSWER 26:

Currently, Multi-Mission Radioisotope Thermoelectric Generators (MMRTGs) are the only flight qualified Radioisotope Power System (RPS) for planetary science missions. The MMRTG has been successfully utilized in the Mars Science Laboratory (Curiosity) mission and has a flexible modular design capable of meeting the needs of a wide variety of missions. Given the current allotment and expected new production of Plutonium 238, NASA can continue to use the MMRTG for missions into the next decade.

In addition, NASA's Planetary Science Division continues its research and development into more efficient conversion technologies that would extend the

availability of Plutonium 238 as the heating source. For example, the Enhanced MMRTG concept (e-MMRTG) seeks to retrofit the current system with new thermoelectric couples and an added surface oxidation layer to increase performance. The focus of this enhancement is on power available at destination, which addresses shortcomings of the MMRTG when compared to the much older and no longer available General Purpose Heat Source RTG (GPHS-RTG) currently powering New Horizons and Cassini. NASA is also continuing to invest in Stirling technology for a possible flight system development in the next decade that would further improve the performance of available radioisotope power systems.

The FY 2017 budget request includes approximately \$18.7M for studying such concepts.

QUESTION 27a:

The 2010 Decadal Survey in Astronomy and Astrophysics, New Worlds, and New Horizons, advocated for launch the Wide-Field Infrared Survey Telescope (WFIRST) by 2020. NASA's FY2017 budget calls for a launch around 2025.

- a. Given that Congress has appropriated funding to WFIRST above the levels requested by NASA, is it possible to launch WFIRST before 2025? If so, what is technologically the earliest possible launch date and what level of funding would be required to support that launch date?

ANSWER 27a:

The FY 2017 request reflects a funding profile that provides a good balance to achieve NASA's science goals and supports a launch date for WFIRST in the mid-2020s. Technologically, the earliest that WFIRST could launch is mid-2024. WFIRST is currently scheduled to undergo its Key Decision Point B in October 2017, which will provide better insight to possible schedules and associated budget profiles.

QUESTION 27b:

Given the significant issues faced by the James Webb Space Telescope (JWST) project, please describe what steps NASA is taking to ensure that these types of issues are mitigated or avoided on the WFIRST project.

ANSWER 27b:

The root causes of the JWST overrun were managing costs on a year-to-year basis, which led to deferred work and life-cycle cost increases; an initial budget estimate that was too low; and reserves that were skewed to the out years providing inadequate resources in the early years when technical challenges arose. To ensure an accurate budget estimate, the WFIRST team has acquired seven independent cost

estimates over the past six years which validated NASA's estimates for cost, schedule, and risk each time. NASA will continue to receive and apply independent cost estimates throughout the formulation period. To provide management insight into the project's performance against commitments, we will utilize earned value management tools, tracking technical, schedule, and cost metrics during each monthly review. Finally, the WFIRST design incorporates only two new technologies, both of which are on schedule to complete laboratory demonstrations one full year prior to the date required by NASA standards; one of the new technologies, the coronagraph instrument, is classified as a "technology demonstration," i.e. its performance does not affect our overall mission success criteria. This reduces the technical risk of the WFIRST mission compared to JWST.

QUESTION 28a:

The Mars 2020 rover designs state that it will dig up samples and leave them on the ground to be collected and returned to Earth by a future mission. Yet, NASA recently hinted that that the agency's next Mars-bound spacecraft may be an orbiter.

- a. Is it wise for the follow-up mission to the Mars 2020 rover to be unable to obtain the Martian samples dug up by Mars 2020?

ANSWER 28a:

While no decision has been made yet regarding a Mars mission beyond 2020, a Mars orbiter would help the Science Mission Directorate to maintain the Mars communications relay infrastructure for current landed assets as well as support the expected full operational life of the Mars 2020 rover. Current surface operations at Mars are dependent upon the support of orbiters. Orbital assets at Mars provide support capabilities that would be needed for any surface mission intended to retrieve the samples cached by Mars 2020, and therefore would likely need to be pre-positioned ahead of any sample retrieval mission.

QUESTION 28b:

When can we expect a mission to retrieve the samples Mars 2020 digs up?

ANSWER 28b:

At this time, return of any particular samples is beyond the current budget horizon and will be evaluated as part of future planning for NASA's integrated approach to the exploration of Mars. And while no specific timeframe for return has been established yet, the Mars 2020 mission design team is working to ensure that its systems can cache samples that would remain scientifically viable for a potential future mission.

QUESTION 29:

It was announced earlier this year that the InSight mission was not going to launch

on time in March 2016 because of problems with its seismometer. In addition, the FY 2017 budget request states that if NASA launches InSight in May 2018, it will exceed its cost and schedule commitments. It was recently announced that NASA has decided to continue with InSight and launch in May 2018 at an estimated cost of \$150M. What are the potential impacts of this overrun to the Mars program or the broader Science portfolio?

ANSWER 29:

At this time, the impacts to current Planetary Science programs or projects, including the Mars program, are not clear. While budget details for InSight will not be finalized until later this year, NASA will assess the potential impacts to other planetary projects within specific programs.

QUESTION 30:

NASA recently made the case for an orbiter follow-up to the Mars 2020 rover. At a recent meeting of the NASA Advisory Council's planetary science subcommittee, some members questioned why an orbiter is the "next logical step" in the Mars sample-return campaign. Do you believe an orbiter follow-up is a good use of NASA's funds and if so, why?

ANSWER 30:

While no decision has been made yet regarding a Mars mission beyond 2020, a Mars orbiter would help the Science Mission Directorate to maintain the Mars communications relay infrastructure for current landed assets as well as support the expected full operational life of the Mars 2020 rover. Although specific instruments and design of a Mars orbiter has not been defined, there is potential to refresh and maintain our high-resolution orbital imaging capability (currently provided by the 2005 Mars Reconnaissance Orbiter) to support landing site characterization and hazard assessments for future landed missions, as well as implement technologies necessary for sample return and future human exploration. Orbital assets at Mars provide support capabilities that would be essential for any surface mission intended to retrieve the samples cached by Mars 2020, and therefore will likely need to be pre-positioned ahead of any sample retrieval mission.

QUESTION 30a:

Under NASA's FY 2017 budget request, will any funds be spent on planning for, or development of, a follow-up orbiter?

ANSWER 30a:

In the FY 2017 budget request, NASA has allocated approximately \$10M to support future Mars mission concept studies and analyses.

QUESTION 31:

There have been multiple delays and setbacks for several key components of the

James Web Space Telescope (JWST). JWST is now entering the critical phase of system integration, typically a time when programs experience delays and technical challenges. Is JWST on schedule and on budget and what are you personally doing to ensure the telescope stays on schedule and budget as it moves closer to launch?

ANSWER 31:

The James Webb Space Telescope (JWST) is one of the most complex spacecraft ever developed by NASA. The JWST Project has made excellent progress in developing the difficult technologies required for its successful operation, and no technical constraints to successful completion have been identified. JWST is more complex, and significantly more capable, than the Hubble Space Telescope that it will follow in the NASA line of Great Observatories. While Hubble operates in low Earth orbit only 560 km above the Earth, and uses a single 2.4-meter diameter primary mirror, JWST will operate at 1.5 million km from Earth with a telescope designed to function at temperatures colder than liquid nitrogen, using an 18-segment primary mirror that is 6.5 meters in diameter.

JWST is currently on schedule, holding 7.5 months of funded schedule reserve to its October 2018 launch readiness date, and performing within its 2011 replan budget. This amount of schedule reserve matches that planned five years ago for this period of the program. The NASA JWST team, both at NASA Headquarters and the Goddard Space Flight Center, is closely monitoring the space telescope's progress to ensure adherence to the project's budget and schedule, and has done a consistent job of maintaining schedule reserve.

The NASA Administrator and JWST Program Director conduct bimonthly teleconferences with the Northrop-Grumman CEO to ensure that any problems that arise are quickly addressed. Additionally, Program Office personnel regularly attend Northrop-Grumman and Space Telescope Institute monthly meetings to hear technical, cost and schedule issues discussed in detail. Finally, we have begun regular discussions on the status of launch preparation activities between the Project Office and the European Space Agency's JWST management as efforts increase in that area of the program.

To reduce the possibility of problems during system integration and test, JWST components have been thoroughly tested at small levels of assembly, and a number of risk reduction tests have been completed on ground support equipment to further reduce schedule and budget risks during system integration. NASA remains confident that JWST will launch on time.

QUESTION 32:

Funding for the James Webb Space Telescope has created a significant wedge that will be drawn down in the run up to the launch of the telescope. This is funding that will be re-apportioned in the near future, either within the Astrophysics program or elsewhere within NASA. Does NASA have a plan in place to decide how and to what purpose this money will be budgeted in the future? If so, please provide the principles that will guide how that funding "wedge" is repatriated.

ANSWER 32:

NASA's notional plan is reflected in the FY 2017 Request and its notional outyears, where the funding for Astrophysics (including James Webb) is held roughly flat through FY 2021. This supports the decision to proceed with the Wide-Field Infrared Survey Telescope (WFIRST) mission, which entered Phase A study in February 2016.

QUESTION 33a:

For several years, Congress has appropriated more than NASA has requested for formulation of a mission to Jupiter's moon Europa. As directed by the Consolidated Appropriations Act, 2016 (P.L. 114-113), the FY 2017 budget justification includes a five year estimate of the funding required for a Europa mission, based on the assumption of a 2022 launch. The justification states, however, that the budget request supports a launch in the late 2020s, and that "acceleration of the launch to 2022 is not recommended, given potential impacts to the rest of the Science portfolio."

- a. Considering the explicit statutory direction to plan for a launch no later than 2022, together with the fact that a mission to Europa was a high priority of the most recent National Research Council decadal survey, what steps is NASA taking to ensure a 2022 launch schedule for a Europa mission?

ANSWER 33a:

NASA's FY 2017 budget request continues formulation for a future multiple flyby mission to Jupiter's moon, Europa, under the newly established Outer Planets and Ocean Worlds Program. The multiple flyby mission entered Phase A formulation in June 2015 and is anticipated to enter Phase B in early 2017. Costs and schedule for the current Europa mission design are not firm, as the mission is still in formulation and NASA does not commit to costs and schedules until Key Decision Point-C (KDP-C). At this time, the multi-year budget request supports a launch in the late 2020s and NASA will continue to evaluate launch options as mission development progresses. At the same time, the Europa project, in executing the FY 2016 appropriation, remains on a schedule consistent with the statutory direction.

QUESTION 34:

How much is NASA planning on spending in FY 2016 on nuclear thermal propulsion?

ANSWER 34:

Consistent with the FY 2016 Initial Op Plan, NASA's FY 2016 plan for nuclear thermal propulsion (NTP) is \$6.9M.

QUESTION 35a:

In FY2016, Congress appropriated more funding than requested by NASA for a Europa orbiter and included a requirement to add a lander. In a recent House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies hearing on the Ocean Worlds program, Dr. Elachi, the head of the Jet Propulsion Laboratory, said that NASA plans to develop the orbiter and lander concurrently.

- a. Who is the current program lead for the Europa mission?

ANSWER 35a:

The Planetary Missions Program Office (PMPO) at the Marshall Space Flight Center (MSFC) manages all of the Planetary Science flight projects for the NASA Science Mission Directorate excluding the Mars Exploration Program. Including Europa, the PMPO also manages the Discovery and New Frontiers programs, which include some noteworthy missions such as OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, Security-Regolith Explorer) and Juno. NASA's Jet Propulsion Laboratory (JPL) has been assigned as the project lead for the Europa flyby mission and the potential lander mission. Scientific mission priorities for all planetary missions reside within SMD's Planetary Science Division.

QUESTION 35b:

NASA is only requesting \$16M in discretionary funding in FY 2017 for Europa, how does NASA plan to budget and execute the project(s)?

ANSWER 35b:

NASA's FY 2017 budget request includes sufficient funds for continuing formulation of the flyby mission as well as ongoing lander studies. The Europa Mission has been generously funded at levels higher than expected for Pre-Phase A and Phase A, and currently has enough funding to proceed into Phase B.

QUESTION 35c:

How will NASA ensure this mission is accomplished within 7 years?

ANSWER 35c:

As mentioned in question #33, NASA's FY 2017 budget request continues formulation for a future multiple flyby mission to Jupiter's moon, Europa, which entered Phase A formulation in June 2015 and is anticipated to enter Phase B in early 2017. Costs and schedule for the current Europa mission design are not firm, as the mission is still in formulation and NASA does not commit to costs and schedules until KDP-C. At this time, the budget request supports a launch in the late 2020's and NASA will continue to evaluate launch options as mission development

progresses.

QUESTION 36:

NASA's Jet Propulsion Laboratory's preliminary mission studies indicate that the Europa Clipper will cost approximately \$2B and the spacecraft itself will likely be rendered non-functional in only a few months due to radiation, in part because NASA chose to use solar power as opposed to a radio-isotope thermal generator. How will NASA ensure that useful scientific information capable of justifying the expense of the mission can be obtained during such a brief operational window?

ANSWER 36:

The multiple flyby mission design, which has been referred to as the Clipper mission, would operate for three years in Jupiter orbit (after launch, cruise and Jupiter orbit insertion). It has been designed to achieve more than 90 percent of the science envisioned in the previously studied Europa Orbiter concept at approximately 50 percent of the estimated costs. The multiple flyby design builds on technologies and techniques developed for Cassini and Juno. The multiple flyby mission dips into the highest radiation environment only for a short duration close flyby (≈ 6 hours) to collect science data, and then gets out of the intense radiation environment to downlink the data and recharge the batteries over the next two weeks. The mission achieves near global coverage through approximately 45 flybys without sustained, life-limiting radiation exposure. The decision to use solar power was made by the Europa project based upon technical trades between solar and radioisotope power sources. Based upon test and analysis, JPL was able to show that solar power capabilities would last longer than RPS capabilities for this specific mission design. In addition, the solar power does not limit the life of the mission; there would be remaining power for an extended mission beyond the three-year prime mission, if warranted and approved.

QUESTION 37:

Private companies have clear incentives to develop faster and more fuel-efficient vehicles. Yet, NASA's FY 2017 budget request prioritizes the Aeronautics Research Mission Directorate's Advanced Air Vehicles Program (AAVP), which seeks to develop technologies that, among other benefits, enable faster and more fuel-efficient vehicles. Why is NASA requesting that more money go toward AAVP than anything else in the Aeronautics Research Mission Directorate? Does NASA believe that airlines are not sufficiently incentivizing aircraft manufacturers to produce efficient aircraft? How does NASA ensure it doesn't duplicate or crowd-out private sector research in these areas?

ANSWER 37:

NASA Aeronautics has a strong set of core competencies and facilities that support a principal mission of aeronautics vehicle related research. NASA's goal is to never compete with, crowd-out, or duplicate industry-based research,

but rather complement that research in coordination with U.S. industry. Government-funded aeronautics research focuses on the development of future capabilities that benefit the broad aeronautics community and accepts more risk than is acceptable to industry. NASA's focus is on long-term, high-risk technology research from foundational concepts through initial capability demonstration of individual technologies (largely in the Advanced Air Vehicle Program, AAVP) and systems (largely in the Integrated Aviation Systems Program, IASP). Industry research is focused on commercialization of those technologies and systems for near-term product development. While manufacturers are incentivized to deliver efficient and fast aircraft, they will only do so if they are sufficiently confident that the return on their investment will be acceptable to shareholders. Over the long run, NASA research enables significant improvements in performance that would not occur if left solely to industry by bringing a larger number of more advanced technologies to the point where they can be commercialized.

NASA establishes the long-term vision for capability improvements based on input from the broad stakeholder community, then coordinates closely with industry in development of NASA's aeronautics research portfolio. In 2007, NASA initiated a set of studies to identify aircraft technologies which could meet very stringent performance targets by 2030. Working together, NASA and our partners subsequently researched the combination of novel configurations (beyond today's "tube and wing") and other very advanced technologies which would meet these targets. Since then, NASA, industry, and academia have been analyzing and ground-testing the configurations and technologies and have laid the groundwork for the New Aviation Horizons initiative that is part of the 2017 ARMD budget. New Aviation Horizons will fund a series X-Planes to flight demonstrate and validate integrated configurations, technologies and benefits. By 2026, when the flight demonstrations are completed, and the configurations, technologies, and physics-based analysis codes are validated; industry will have the capability to design and develop the transformative products that will keep U.S. industry at the leading edge of aviation. Clearly, this would not be possible without a sustained long-term government-industry partnership.

QUESTION 38:

How does NASA envision the UAS Traffic Management system, or UTM, will be used post-2019 when NASA's work on this project should be completed?

ANSWER 38:

NASA will transition the UTM Research Transition Products to the FAA as well as to the broader UAS community. The transition products will include experiment simulations and flight results, operational concepts, and system capabilities. In line with prior research transitions, the FAA will decide whether to further invest into operational implementation of these concepts or technologies and select their own production contracts. A large contingent of partners have

contributed to development of UTM concepts and ideas to date and are able to continue to develop their own complementary technologies as they go along.

QUESTION 38a:

When UTM is completed, who will own the intellectual property rights to the system?

ANSWER 38a:

NASA has filed patent applications on a UTM concept. If patents are granted on NASA's concept, the U.S. government will own the rights to these UTM patents. NASA is developing a version of its UTM research platform and will conduct field tests and simulation studies to finalize the performance requirements at various levels of technical capability. The research platform and requirements to safely manage the UAS in the low altitude airspace and associated capabilities will be provided to the FAA under a FAA-NASA Research Transition Team (RTT). The FAA has the responsibility and authority to certify any system(s) for deployment as it meets agency requirements, or otherwise establish certification requirements for low altitude UAS operations. Although the FAA may choose to serve as the air navigation service provider (ANSP) for UTM installations, other entities may also serve as ANSPs for UTM including federal entities managing national forests or wildlife, local law enforcement, regional communication providers, rail transportation companies, etc.

QUESTION 38b:

Will everyone be able to use the technology that is developed through UTM, or is this something that only companies who worked with NASA to develop UTM will be able to use?

ANSWER 38b:

As stated above, NASA has filed a patent application on a UTM concept. All of our work will be freely available to FAA. The external organizations that participate in the UTM collaborations have largely participated in flight testing and to develop early insight into common service needs (e.g., weather, vehicle to vehicle coordination, etc). Active participation in the flight tests or service system prototype development are not prerequisites for other industry organizations or the public from getting licenses to NASA's intellectual property (IP) resulting from those joint flight tests and service system prototypes.

QUESTION 39:

How much of the Aeronautics Research Mission Directorate will go toward NextGen- related activities in FY 2017?

ANSWER 39:

NASA Aeronautics estimates that 72 percent of the FY 2017 Aeronautics Budget Request (including mandatory funding) will contribute to NextGen goals and objectives through research in next generation air traffic management, air vehicle and engine concepts and technologies. Activities conducted by the Airspace Operations and Safety Program directly relate to NextGen needs in the near term, whereas the activities conducted by all four ARMD programs will contribute to NextGen goals over a longer time horizon. See table below.

NASA NextGen Contribution – Aeronautics (SMs)				
Agency	Directorate	Program	FY16	FY17 PB
NASA	ARMD	Airspace Operations and Safety Program	\$147	\$159
NASA	ARMD	Advanced Air Vehicles Program	128	171
NASA	ARMD	Integrated Aviation Systems Program	102	184
NASA	ARMD	Transformative Aero Concepts Program	41	53
Total NextGen Contribution			\$418	\$568
Aeronautics Budget			\$633	\$790
NextGen % of Budget			66%	72%

* FY17 PB includes mandatory funding for 21st Century Clean Transportation Plan and R&D initiatives.

QUESTION 39a:

What NextGen-related work will NASA perform in FY 2017?

ANSWER 39a:

NASA Aeronautics NextGen-related work is in each of the four Aeronautics programs described below:

The Airspace Operations and Safety Program's (AOSP) NextGen contribution is from activities that improve air traffic management and maintain safety. AOSP develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Air Space (NAS) safely. The program works in close partnership with the FAA and the aviation community to

enable and extend the benefits of NextGen. AOSP conducts integrated demonstrations of these advanced technologies that will lead to clean air transportation systems and gate-to-gate efficient flight trajectories. The program conducts leading edge research into increasingly autonomous aviation systems, including innovation in the management of Unmanned Aircraft System (UAS) traffic. The program is also pioneering the real-time integration and analysis of data to support system-wide safety assurance, enabling proactive and prognostic aviation safety assurance.

The Advanced Air Vehicle Program's (AAVP) NextGen contribution is from research into new aircraft, vertical lift vehicles, and propulsion systems which contribute to reducing emissions, fuel consumption, and noise. AAVP develops tools, technologies, and concepts that enable new generations of civil aircraft that are more highly energy efficient and have a smaller environmental footprint. AAVP's contribution also includes low-boom supersonic flight research which will lead to new levels of global mobility.

The Integrated Aviation System Program's (IASP) NextGen contribution is from investments in experimental aircraft development and flight testing of new technologies which reduce emissions, fuel consumption, and noise. IASP's contribution also includes the UAS integration in the National Airspace System (NAS) Project which develops technologies to enable routine civil operations for UAS of all sizes and capabilities in the NAS.

The Transformative Aviation Concepts Program's (TACP) NextGen contribution is from investments in fundamental disciplinary advancements and physics based methods that enable next generation aviation systems. TACP also cultivates multi-disciplinary, revolutionary concepts to enable aviation transformation and harnesses convergence in aeronautics and non-aeronautics technologies to create new opportunities in aviation.

QUESTION 39b:

What will this work cost in FY 2017?

ANSWER 39b:

NASA Aeronautics estimates that \$568M of the FY 2017 Aeronautics Budget Request (including mandatory funding) will contribute to NextGen goals and objectives. See table above in #39.

QUESTION 39c:

How does this compare to previous years' spending on NextGen programs?

ANSWER 39c:

NASA Aeronautics estimates the NextGen contribution will increase by approximately \$150M from FY 2016 to FY 2017. The increase is mainly funding for

X-plane development in AAVP and IASP. The AAVP increase includes additional funding for X-plane risk reduction activities such as ground testing of new technologies. IASP's increase is for funding to establish New Aviation Horizons (NAH) X-plane flight demonstrator projects. In FY 2017, IASP begins two subsonic flight demonstrator projects and one supersonic demonstrator project. The subsonic flight demonstrator projects will test technologies that achieve a 50 percent reduction in fuel use while also dramatically reducing noise. The supersonic demonstrator project demonstrates quiet overland supersonic flight which will open new markets for the U.S.

QUESTION 40 & 40a:

GAO published a report which found that FAA lags in addressing new cyber-threats created by its transition to NextGen. NASA helped to develop, and continues to work with FAA on the NextGen system. Does NASA have any role in assuring that cyber vulnerabilities within NextGen are minimized? If so, what is NASA's role?

- a. How does NASA ensure that the technology it develops for NextGen doesn't create additional cyber-threats?

ANSWER 40 & 40a:

NASA's current focus in this area is to ensure that the technology developed by NASA for NextGen doesn't create additional cyber-threats. NASA does this through coordination with FAA, DoD, and DHS through the Interagency Core Cyber Team (ICCT) of the FAA Interagency Planning Office (IPO). The ICCT facilitates coordination of the activities of IPO member agencies, and leveraging of DoD and DHS capabilities in Cyber Security for NextGen application. NASA also coordinates directly with the FAA NextGen Chief Scientist for Software, and has initiated discussions with the Air Force Research Laboratory to leverage their capabilities towards Cyber Security. NASA will continue to consider cyber security aspects and associated requirements as NASA conducts research for "beyond NextGen" air traffic management concepts, algorithms, technologies, and architectures.

QUESTION 41:

NASA is working on the Asteroid Retrieval and Redirect Mission, which would allow the Space Technology Mission Directorate to demonstrate solar electric propulsion, or SEP. NASA officials have stated that this technology is needed whether NASA moves forward with the Asteroid mission or not. If Space Technology was not investing in this mission to meet certain technical specifications, how might the investment in SEP change? Would the Space Technology Mission Directorate still develop the same type of propulsion or would they invest in other types such as VASMIR?

ANSWER 41:

Solar Electric Propulsion (SEP) technology has been a priority technology

investment by the Space Technology Mission Directorate (STMD) since its inception, and SEP has been of great interest to NASA and other government organizations and industry for many years. NASA has been planning for a spaceflight demonstration to advance higher power SEP technology since before the Asteroid Redirect Mission (ARM) concept existed. ARM requires the unique capabilities offered by SEP and therefore is an excellent mission to demonstrate the SEP technologies. This demonstration will then support the further development of SEP applications for support to human exploration missions to Mars in which SEP vehicles would, very efficiently, deliver large cargo to Mars, and possibly crew to Mars on a vehicle that also uses chemical propulsion. Additionally, SEP has many other applications, including science missions with greatly increased capabilities, transport of large vehicles and payload from low Earth orbit to higher orbits and throughout cis-lunar space, missions for other government agencies requiring greater maneuverability in Earth orbit, and finally more efficient delivery and operation of commercial satellites. If STMD were not supporting the ARM project, SEP would still remain a priority for NASA and STMD would continue to further develop the technology that will lead to a flight demonstration of SEP.

The focus of the SEP technology project has been on lighter and more efficient solar array structures and on electric thrusters that are about 2.5 times the power level of existing thrusters of that type. The advanced solar arrays developed by NASA are two times lighter and use four times less stowed volume for the amount of electricity produced than commercially available arrays. These are significant steps forward toward systems that can be utilized in the next few years for the types of missions noted above including science missions, Mars exploration, and widespread use on vehicles in Earth orbit and in cis-lunar space. The solar array technology is already being utilized in commercial spacecraft and satellites, and similar adoption of the new electric thrusters is also expected because the performance levels for both the arrays and thrusters were designed with commercial space industry. As such, NASA could potentially become a marginal buyer of the technology in the future, thus lowering overall mission cost.

In addition to these SEP investments, NASA is also evaluating the next generation of extremely high-power electric propulsion technologies that offer the potential for substantially reduced transit times to Mars and other deep space destinations. These technologies are in the early development stage with several significant system development challenges that need to be addressed prior to being implemented on a NASA mission. The technologies being evaluated include the Variable Specific Impulse Magnetoplasma Rocket (VASIMR), a nested Hall thruster, and a Lorentz force thruster that are funded as part of the Next Space Technologies for Exploration Partnerships (NextSTEP). Given the substantial development risks associated with these extremely high-power electric propulsion systems, and the many potential SEP applications, NASA would retain the SEP investment regardless of whether the

ARM mission plans are changed.

QUESTION 42:

On April 15, 2010, the President directed NASA to conduct a crewed mission to an asteroid by 2025. With the 2014 Budget Request, The Administration changed course and directed NASA to "redirect" an asteroid to orbit the Moon and then visit that asteroid in lunar orbit. The mission continued to evolve even after that. Last year NASA decided to only remove and redirect a boulder from a larger asteroid. Originally scheduled for 2017, then 2020, this budget request now slips the first robotic launch to 2021. The crewed encounter will also slip to 2026 – and more likely later based on SLS mission requirements. In practical terms, the President's own budget request delays the ARM beyond the next Administration's potential second term. All of NASA's advisory bodies have roundly criticized the project. International interest is absent. The scientific community is unimpressed. Planetary defense investments would be better spent elsewhere. Congress has deferred to NASA too much on this mission-appropriating hundreds of millions of dollars. NASA is still on course to approve continued development of the mission this summer in an attempt to tie the hands of the next Administration. Rather than developing unique, one-off technologies and dead-end missions that do not logically feed-forward to future exploration, will NASA instead "redirect" this funding to other more worthy endeavors such as advancing deep space habitats and starting work on a lander?

ANSWER 42:

The overall plan for human exploration and pioneering includes the Asteroid Redirect Mission (ARM) as a critical part of early cislunar flight testing. The Mission serves as an integrated demonstration of several ongoing technology developments for future human exploration and pioneering purposes, including large-scale solar electric propulsion technologies, low-gravity environment capture systems including robotic manipulators, and deep-space life support systems and other technologies for complex extra-vehicular activities. ARM is the earliest possible mission that tests these critically needed capabilities for human exploration in the proving ground of cislunar space while also providing highly desired opportunities for testing the extraction of in-space resources, demonstrating a unique asteroid deflection technique for planetary defense, and collecting asteroid science data of high interest to planetary scientists.

The ARM complements ISS, on which exploration technologies and systems will also be tested, such as long-term closed-loop life support for deep-space missions. ARM develops operational techniques in the proving ground of cislunar space, prepares the way to support potential lunar surface activities of commercial or international partners, and builds the skills and hardware needed for Mars-class missions. The ARM will affordably support and leverage multiple efforts across the Agency as it paves the way for journeys to other destinations by helping NASA prove out its crewed heavy-lift launch vehicle and exploration spacecraft in a near-term mission.

NASA will expand the duration of early beyond-LEO crewed missions toward crewed missions to Mars. Part of this expansion is understanding how humans perform in the microgravity environment and ISS plays a key role, enabling longer stays on orbit, such as the recently completed one-year mission with Scott Kelly. The early cislunar crewed mission to the redirected asteroid boulder is planned as almost one-month-long proving ground mission utilizing only Orion with a capability to sustain two crew members and perform EVAs in a very cost-effective manner. This will be the longest human mission ever performed beyond LEO, and farther than humans have travelled before. This reference mission plan can be enhanced and lengthened through partner-provided systems and/or vehicles.

The changes made to the mission have been in response to input from external communities such as the Planetary Defense community and planetary science Small Bodies Assessment Group which has resulted in recent findings from both communities showing strong support for the re-formulated mission.

QUESTION 43:

The constellation program benefitted from broad international support and participation derived from significant outreach and input. Our international partners seem to be uninterested in the Asteroid Retrieval Mission, as evidenced by the European Space Agency advocating for a cooperative lunar station. Why is NASA ignoring the interests of our international partners?

ANSWER 43:

Building on the response to #4 above, international cooperation and coordination are essential as we move forward into the exploration era. No one nation can afford to do this alone. NASA is working to refine a set of strategic principles for sustainable space exploration. Foremost among these is that of "Continuity of Human Spaceflight." By this we mean the uninterrupted expansion of human presence into the solar system by establishing a regular cadence of crewed missions to cislunar space during the International Space Station (ISS) lifetime. Building on our partnership on the ISS, we will continue to expand our reach beyond low-Earth orbit, undertaking missions of increasing distance and complexity in the proving ground of cislunar space, asteroids, and on to Mars.

NASA's ultimate goal is humans on Mars. The journey can accommodate the individual plans and priorities of the partners that join with us. Though some nations may consider Mars as too hard to be realistic in the near term, today we are performing the human research and technology demonstrations onboard the ISS to validate human mission performance to Mars. We are building the initial version of the rocket, SLS, and crew module, Orion, for early missions in cislunar space and also investigating concepts for long duration habitation. Among the key technologies demonstrated on the Asteroid Redirect Mission, large scale solar electric propulsion will provide the capability to move large masses such as habitats and landers through space.

Within these activities, there are many opportunities for cooperation and collaboration. For example, as we move into the proving ground of cislunar space, we expect agencies to cooperate with us on the cislunar ARM and we expect to cooperate with agencies planning lunar surface excursions and habitation, such as the lunar village espoused by ESA Director General Wörner. Together, we will also begin to learn to utilize in-situ resources from the available natural bodies such as the Moon, asteroids and Mars to improve both cost effectiveness and human mission resilience. NASA sees the next step on the Journey to Mars to be longer duration habitation and in-space transit capability in cislunar space as a means to achieve further readiness for human exploration beyond the Earth-Moon system, and we envision this as an international collaboration. This is a journey we are embarking on together, as advancing humanity's reach will be a truly global endeavor.

QUESTION 44a:

In an October 26, 2015 memo, NASA's Associate Administrator, Robert Lightfoot, promoted the dissolution of the Independent Program Assessment Office (IPAO) and its umbrella organization, the Office of Evaluation. In the memo Mr. Lightfoot wrote, "the executing Mission Directorates and Center Directors will own the accountability of establishing independent assessment of their programs and projects". NASA terminated the IPAO in December of last year. In March, 2016, the Government Accountability Office published a report: "NASA: Assessments of Major Projects." The report noted that such reorganization could impact project oversight. Also, the robustness of program reviews could vary from center to center, as the GAO as previously found.

- a. How can NASA maintain independent assessments of its programs when those responsible for the programs are closely related to those conducting the reviews?

ANSWER 44a:

Robust independent assessment of NASA Flight Programs and projects is essential for long-term mission success and will continue under the new model. NASA is in the process of developing a new independent assessment model to provide Missions and Centers the responsibility for managing independent assessments. The new model also decentralizes participation in independent assessment by increasingly relying on talent from across the Agency who will primarily be doing in-line programmatic work in other projects or mission areas. This broader participation will enhance sharing of best practices between mission areas and increase learning and synergy between them.

NASA's intent is to maintain robust independent assessment of its programs and projects under the new model as described in the following.

- Requirements for independent assessment of spaceflight Programs and projects at life-cycle reviews, including required

assessment products, are specified in NASA Procedural Requirements (NPR) documentation and these requirements have not changed under the new model.

- Standing Review Boards (SRBs) will continue performing independent assessments at life-cycle reviews.
- The following important characteristics of SRBs are maintained under the new model.
 - o SRBs are composed of technical and programmatic experts who have relevant and current experience, are independent from the Program and projects under review, and are free from organizational and personal conflicts of interest.
 - o SRBs engage with the Programs and projects through their life cycles to provide continuity.
 - o SRBs perform their assessments in accordance with the charter issued by the Convening Authorities for the review and report their results and recommendations to the Decision Authority independent of the Program and project under review.
- The staffing, chartering, and reporting processes for SRBs contain built-in checks and balances. This process was originally maintained by the IPAO. It will now be provided by separate organizations: the Office of the Chief Engineer for technical matters, the Office of the Chief Financial Officer for programmatic (cost and schedule) matters, and with the Office of the Chief Engineer continuing to maintain oversight of the flight program and project management NPRs and assuming the book manager role for the Standing Review Handbook. These organizations are part of the Convening Authorities for the reviews but are separate from the Mission Directorates and Centers.

QUESTION 44b:

How does NASA define "independent"?

ANSWER 44b:

SRB independence is defined as selecting SRB members who (1) are not in the chain of command of the Program or project under review and with the SRB chair being independent of the performing Center or institution; (2) funded by a source that is separate from the Program or project under review; and (3) free from any personal or organizational conflict of interest such that they have no stake or involvement in the design, build, or operation of the work being reviewed. These parameters have not changed with the new model. Vetting of SRB civil servants and non-civil servant members or consultants to ensure their independence will continue per guidance provided in the NASA SRB Handbook by the NASA Office of the General Counsel. The SRB Handbook will be updated by the end of FY 2016, to account for new

changes to the process.

QUESTION 44c:

How does NASA plan to retain the institutional knowledge associated with the IPAO?

ANSWER 44c:

Preservation of the lessons learned and recommended best practices from many years of experience conducting independent assessment of NASA flight Programs and projects by IPAO is a key part of the new model. We are focusing our efforts in the following key areas.

- Review Guidance. IPAO has captured guidelines based on best practices and lessons learned for the conduct of independent assessments in the SRB Handbook. The Office of the Chief Engineer (OCE) will assume management of the SRB handbook. The SRB handbook will be updated as needed to reflect the changes implemented as part of the new model and to capture best practices from lessons learned going forward.
- Cost and Schedule Analysis Methods and Standards. IPAO has developed methods and standards for the performance of cost and schedule analyses in support of independent reviews performed by SRBs. As part of this change, the NASA Office of the Chief Financial Officer (OCFO) is assuming the role as the programmatic analysis capability leader for the agency including assuming ownership over cost and schedule analyses methods and standards. OCFO will work with the Mission Directorates and Centers to examine, adjust, and broaden the applicability of these methods and standards to address both in-line and independent assessment work. The CFO is increasing staffing to handle these additional requirements.
- Competency stewardship. Consideration has been given to preserve the competencies previously maintained by IPAO in: cost and schedule analysis; review management; and for preparing new SRB members for service. New organizational stewards have been designated for maintaining these competencies, leveraging on IPAO developed training, tools, processes and other infrastructure. These organizational stewards are the OCFO for cost and schedule analysis and the Mission Directorates with support from the Centers for review management and for preparing SRBs members for service.
- Involvement from experienced personnel. Direct transfer of corporate knowledge has taken place assisted by former IPAO personnel that have transferred to Mission Directorates and Centers and from personnel already in those organizations that have participated in SRBs as members or Chairs. These

individuals are helping guide the implementation of the new model.

- Training Activities. Planning is underway to conduct pause-and-learn activities led by the Mission Directorates and involving former IPAO personnel to discuss lessons learned and best practices that apply to the new model.

QUESTION 44d:

Will the standards and practices developed by the IPAO remain in place for other entities, such as the Mission Directorates and Centers, to follow?

ANSWER 44d:

Yes. IPAO standards and practices are continuing to be used in the performance of independent assessment by SRBs and have been captured and documented for transfer to the organizations assuming responsibility for independent assessment. Additional information is provided under #44c above.

QUESTION 44e:

How will NASA ensure that the practices followed by individual Mission Directorates and Centers follow agency best practices?

ANSWER 44e:

As mentioned under item c above, IPAO has captured guidelines based on best practices and lessons learned for the conduct of independent assessments in the SRB Handbook. The former IPAO Director will support the NASA Associate Administrator during the initial implementation to help oversee the implementation of the new model and to ensure consistency. Additionally, personnel within the OCE and OCFO will help oversee that best practices are being followed by the Mission Directorates with support from the Centers.

QUESTION 44f:

Please outline the training and qualifications required for IPAO staff.

ANSWER 44f:

IPAO personnel performed two primary functions: review management and cost and schedule programmatic analyses in support of SRBs.

- Review management was performed by Review Managers (RM) who worked very closely with the SRB chair to plan, organize, and manage the review. RMs came to IPAO with a project management or systems engineering background. To perform as

RMs, individuals needed to have good organizational, interpersonal, and communication skills. They also needed to have knowledge of the Agency flight projects requirement documentation, and knowledge of agency review processes and expectations for the life cycle reviews (SRB handbook and operating procedures for SRBs). IPAO provided new RMs with initial training (IPAO boot camp) followed by an assignment to assist an experienced RM with an ongoing review prior to assignment to an SRB.

- Programmatic Analysis was performed by cost and schedule analysts that were assigned by IPAO to support SRBs. Programmatic analysts came to the IPAO with an applied mathematics or operations research background. These individuals had experience performing statistical risk analyses of cost and schedule for projects. Once in IPAO, they participated in the IPAO boot camp training and were mentored by other experienced IPAO programmatic analysts on the particulars of cost and schedule analyses as performed by NASA before assignment to an SRB. As part of initial or recurrent training, the analysts participated in training for the statistical tools they used.

QUESTION 44g:

Please outline the training and qualifications required for Mission Directorate and Center staff that are now accountable for "independent" assessments?

ANSWER 44g:

The qualifications for Review Managers and Programmatic Analyst will remain largely the same, however, personnel will be assigned ad-hoc, rather than as full time responsibilities. Review Managers will be assigned by the Mission Directorates or their supporting Centers. As part of the transition to the new model, the training infrastructure developed by IPAO is being transferred to the Mission Directorates for training new Review Managers. Under the new model experienced personnel with the pre-requisite qualifications performing in-line programmatic work in other projects or mission areas will be assigned to SRBs by the Mission Directorates and their supporting Centers in consultation with the OCFO. As part of their new role as programmatic analysis capability lead, OCFO is leveraging on IPAO training products to create training materials specifically for programmatic SRB support as well as developing a programmatic training curriculum. OCFO already has an established infrastructure for training: The OCFO University. All training will be available to Center and Mission Directorate personnel through the OCFO University.

QUESTION 44h:

Did NASA consult with the ASAP or NAC prior to implementing this change?

ANSWER 44h:

No consultation took place with ASAP or NAC prior to this change.

**HOUSE 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*

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

Questions submitted by Rep. Dana Rohrabacher

QUESTION 1:

I would note the tremendous success of the NeoWise mission after the spacecraft was shut down at the completion of the Wise mission. This is obviously not first time, or only time, that a useful spacecraft has been turned off. The "repurposing" of NASA spacecraft including Kepler, WIRE, ISEE-3, IRAS, Deep Impact and other missions displays excellent creativity and speaks incredibly highly of the hardware, the design, and the construction of these missions. But it also points out that we have significant assets with great capabilities that are no longer being used. How do you determine when to turn off an asset?

ANSWER 1:

Per statute, NASA's Science Mission Directorate (SMD) conducts Senior Reviews for each mission every two years after completion of the primary mission. The Senior Review panel is composed of roughly a dozen leading scientists not employed by NASA. These reviews assess the spacecraft's health and value of the science return. The Heliophysics Senior Reviews include a voting member from NOAA's Space Weather Prediction Center to ensure that data needed for NOAA's operations are considered. For Earth Science missions, NASA also forms an interagency panel to assess the utility and value of the NASA science mission for operational purposes.

If the Senior Review panel determines that the proposed science, either repurposed or a continuation, is not sufficiently compelling to warrant the cost, and NASA agrees that there is insufficient scientific merit or operational utility to continue the mission, then NASA decides to terminate the mission. Once the termination decision is made, NASA also notifies external parties that the mission is planned for termination, and waits for 90 days before executing the actual termination, to allow for any other entity to take over the mission for a re-purposed, non-NASA objective.

QUESTION 2:

How do you determine if hardware can be repurposed? Do you only do so if you receive a specific proposal, or are you actively seeking to use assets that are already in space to accomplish other important and interesting goals?

ANSWER 2:

NASA actively encourages principal investigators to propose new science during the Senior Review, and often the type of science that is proposed is different from that which was conducted during the primary mission. We also repurpose missions after hardware failures change the capability of the spacecraft, as we did with the Kepler telescope when we repurposed the telescope after the loss of two reaction wheels. Once the spacecraft was stabilized, it was approved to continue as K2 on the strength of new science that was proposed in keeping with the spacecraft's reduced pointing capability.

If NASA decides to terminate a mission, we notify the relevant science advisory councils, with which we meet quarterly, and encourage the councils to notify us if they have repurposing ideas. These councils have deep ties to the scientific community and communicate extensively throughout the community. We also notify Congress and other federal agencies, and post our intent to terminate on the science.nasa.gov website. In some cases we would still like continued access to the data collected by the spacecraft and so we issue solicitations for repurposing the mission. The EPOXI mission was created by combining two Mission of Opportunity proposals that came to us as part of the Discovery 2006 Announcement of Opportunity for repurposing the Deep Impact spacecraft. In other cases the community finds independent funding and enters into a Space Act Agreement with NASA; this is how the GALEX mission continued for almost an extra year.

QUESTION 3:

Can you please provide a complete list of NASA spacecraft and instruments that still have useful life left in them that are currently not being used? Please include information on why they aren't being used: lack of funding, mission complete, etc.?

ANSWER 3:

NASA does not have any spacecraft or instruments that still have useful life but are not being used. Once the determination has been made to terminate a mission and no entity has stepped forward to take over, we are required by international treaty and NASA regulations to passivate the spacecraft if possible. Passivation includes emptying all remaining fuel and disconnecting power supplies to remove all chances of explosion that could result in orbital debris. This is required for spacecraft in Earth, lunar, and Mars orbit, and also for spacecraft in the L1 and L2 Earth-Sun Lagrange points to protect other assets in those locations. Deep space missions are terminated only when they are no longer usable. Instruments on the International Space Station that have been terminated are removed and destroyed upon reentry to make room for new instruments.

QUESTION 4:

ISEE-3 was repurposed using "crowd funding" by a private group. Is this a good model for NASA to use moving forward for space-based assets that it has no intention of using further? Are there other methods that might be just as good, or even better?

ANSWER 4:

NASA supported the ISEE-3 repurposing, and could support similar private efforts in the future, should they arise. NASA has also, in the past, transferred operations responsibility of some spacecraft to educational institutions that were interested in using them for education and training. We are open to discussions with interested parties when opportunities for repurposing arise.

QUESTION 5:

Could the possibility of repurposing be an evaluation criteria for scientific missions?

ANSWER 5:

Strategic decisions for future missions and scientific pursuits within NASA's Science Mission Directorate (SMD) are driven by priorities recommended in the National Academy of Sciences (NAS) decadal surveys, national needs, and guided by a commitment to preserve a balanced program across the four major science disciplines (Astrophysics, Earth Science, Heliophysics and Planetary Science). NASA evaluates each proposal for a new mission on the basis of the following criteria:

- Scientific merit of the proposed investigation;
- Scientific implementation merit and feasibility of the proposed investigation; and
- Technical, management, and cost (TMC) feasibility of the proposed mission implementation, including cost risk.

As explained in #1-3 above, NASA's Science Mission Directorate (SMD) already reviews Senior Review proposals to repurpose a science mission after the completion of its primary mission. In some circumstances, repurposed assets from a completed primary mission can prove very valuable (see examples above). However, it is neither possible nor appropriate to evaluate possible repurposing options when initially selecting science missions. It is not practical to develop realistic proposals for a future repurposing before designing and developing the primary mission, realizing the period between initial design of the primary mission and its completion often is about a decade or more. In addition, on-orbit performance needs to be well understood before repurposing options can realistically be explored. That is why it makes sense to evaluate repurposing a science mission after its primary mission is complete, not before it is begun.

QUESTION 6:

I have heard that among experimenters there is a saying "Millions for hardware and pennies for operations and data analysis." The programs we have in place to continue to collect and analyze data from older space-based assets may be insufficient for the opportunities that we have. Clearly, it would be useful to have a dedicated fund that would enable that type of activity. If Congress created such a fund, would NASA prefer to manage that fund and that activity, or to transfer control of these assets elsewhere?

ANSWER 6:

A dedicated fund is not needed, and would not be helpful. NASA's four Science Themes (Earth Science, Planetary Science, Astrophysics and Heliophysics) all support the collection and analysis of data from older spacecraft. We currently have about 60 spacecraft in extended operations. All of the data from these missions are freely available, and analysis is broadly funded. Total funding for extended Science mission operations and data analysis is approximately 1/5 of the Science budget. The existing funding arrangement enables NASA, with the advice of its scientific communities and the National Academies, to balance the funding for older assets and data analysis with other activities. No other entity is in a position to properly manage, and balance the funding for, these assets.

QUESTION 7:

What are the next steps in moving towards establishing a planetary protection capability for near-Earth asteroids that pose an impact threat? Have you had conversations with your international counterparts on this question? And do you have an estimate of how much such a capability would cost?

ANSWER 7:

The most important step forward for establishing a planetary defense capability is to deploy a sufficiently robust Near Earth Object (NEOs) observation capacity that will detect, track and characterize any significant object on an impact path with Earth early enough to allow action to prevent or otherwise mitigate the effects. NASA, under its Planetary Defense Coordination Office (PDCO), is working with partners across the space science spectrum including private and international entities. We have already established an impressive network of observatories and data analysis facilities that since 1998 have found over 13,500 NEOs, including just under 1,700 objects whose orbits may become hazardous to Earth in the future. None are on course to impact Earth for the next 100 years, but this impressive total includes only about 25 percent of the objects predicted to exist that could do extensive damage at the Earth's surface should one impact (i.e., asteroids larger than 140 meters in size as called for in the 2005 George E. Brown NEO Survey Act). Currently, almost all

observatories that can be used for this mission are ground-based and therefore only operate on a part-time basis. It is estimated that it will take several decades to meet the goal of the George E Brown NEO Survey Act at the rate that can be achieved with the ground-based observation network. Space-based survey assets would shorten this time frame.

NASA has very active and fruitful partnerships with our international counterparts at the European Space Agency (ESA) and other space institutions in Russia, Japan, Korea, Mexico and other nations acting as part of an International Asteroid Warning Network (IAWN) for detection of impact threats, and within the Space Mission Planning Advisory Group (SMPAG) for planning and development of in-space asteroid threat deflection capabilities.

Since a significant impact of Earth is so rare, the most cost effective solution to acquiring the needed capabilities is to leverage efforts already being accomplished and planned by other space programs both within and outside of NASA. The PDCO is therefore utilizing the capabilities existing with the US Air Force (e.g. Space Surveillance Telescope), the National Science Foundation (e.g. Arecibo Observatory and the planned Large Synoptic Survey Telescope) and others, in addition to efforts within NASA in the Near Earth Object Observation and Discovery Programs. But there will also need to be capability demonstration of asteroid deflection techniques to be assured they will be effective if and when needed. The Asteroid Redirect Mission (ARM) is being leveraged to demonstrate the "Enhanced Gravity Tractor" technique to slowly tug an asteroid off a hazardous trajectory. We are also working in partnership with ESA to study a "kinetic impactor" deflection technique under a mission concept call the Asteroid Impact Deflection Assessment (AIDA), in which NASA would develop and deploy the Double Asteroid Redirection Test (DART).

**HOUSE 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*

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

Questions submitted by Rep. Jim Bridenstine

QUESTION 1a:

In the FY 2016 Omnibus, Congress directed NASA to spend at least \$55M on a "habitation augmentation module" to support NASA's exploration initiatives, and directed the agency to develop a prototype by 2018. It is my understanding that NASA's Operations Plan for FY 2016 only provided \$25M for the Next Space Technologies for Exploration Partnerships initiative.

- a. Can you explain how NASA intends to comply with Congress' directive to produce a habitat by 2018?

ANSWER 1a:

NASA's transition of its primary focus for human spaceflight from low Earth orbit (LEO) to deep space will include key partnerships with commercial industry for the development of advanced exploration systems. In an effort to stimulate deep-space capability development across the aerospace industry, NASA released the Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement (BAA) and selected 12 projects to advance the development of necessary exploration capabilities. Through these public-private partnerships, NextSTEP partners will provide advance concept studies and technology development projects in multiple areas including habitation systems. Four of the awards are addressing habitat concept development, and three are addressing Environmental Control and Life Support Systems (ECLSS).

In April 2016, the Agency issued a Next Space Technologies for Exploration Partnerships -2 (NextSTEP-2) Broad Agency Announcement (BAA) to solicit proposals for additional habitation development activities. NASA plans to integrate functional systems into a prototype habitat for ground testing in 2018.

It is important to note that a deep-space long-duration habitation capability, critical for extended missions in cislunar space and human transit to and from Mars, includes an array of complex systems and components that will need to be installed in the pressure vessel itself. These technologies are important for operations and crew safety, and they include docking capability, environmental control and life support systems, logistics reduction efforts, radiation sensors, fire safety technologies, and

crew health capabilities. Long-duration system demonstrations of these critical habitation systems are being planned on the ISS. The sum of FY 2016 expenditures on habitation systems comprising both these activities and the NextSTEP agreements exceeds the \$55M level directed by Congress.

QUESTION 2a:

Last year Congress extended the life of the International Space Station to 2024. There are no guarantees that the United States, or our international partners, will extend the life of the ISS beyond that date, which in aerospace development terms is right around the corner. The United States should maintain a permanent human presence in low earth orbit, need to make sure we have a plan in place so that we do not cede LEO to other nations and create a dependence on foreign space stations similar to how we currently rely on Russia to launch our astronauts.

- a. Has NASA begun to think about transition strategies for post-ISS, and if so, do they involve partnering with private companies? NASA could either serve as an anchor tenant on a private space station, or the agency could purchase space as needed depending on the missions NASA is undertaking.

ANSWER 2a:

Yes, NASA is actively working transition strategies for the post-International-Space-Station (ISS) era and is engaged with the private sector to foster both commercial demand and supply for LEO services. One of NASA's goals is to expand human presence into the solar system and to Mars, consistent with Presidential and Congressional direction. ISS operations in LEO constitute a foundation for such expansion. It is NASA's intention to transition from the Government-owned and operated ISS to private platforms and capabilities enabled by commercial markets and Government agencies with interest in LEO research and activities, while NASA's primary focus for human space exploration shifts toward deep space. NASA has already taken large steps to stimulate the development of a LEO space economy through its procurement of commercial cargo services and welcomes input from other stakeholders on how best to enable future commercial LEO platforms.

QUESTION 2b:

Can you commit that NASA will thoroughly exhaust these options before committing to building a new space station in house?

ANSWER 2b:

Please see response to Question #2a, above. NASA has no plans for a Government-led LEO space station beyond ISS.

QUESTION 3a:

I have asked many NASA officials who have testified before this committee how we can increase the launch frequency of the SLS and Orion. As a pilot, I know practice and repetition are key parts of preparation and success. This is not only true for the teams that fly on and operate the system, but also for those who contribute to building it - a steady flight rate will keep the industrial base preserved and viable, and ensure no critical components suffer setbacks due to lack of production.

- a. Have you had discussions with other agencies such as the DoD, NRO, or NOAA about their potential needs for this kind of heavy lift capability?

ANSWER 3a:

NASA has had discussions with the Department of Defense, National Intelligence agencies, and the National Oceanic and Atmospheric Administration; to date those agencies have not identified a need for the SLS.

QUESTION 3b:

When can we expect a schedule for launches after EM-2?

ANSWER 3b:

NASA has defined its top-level objectives for proving ground missions in cislunar space in the decade of the 2020s that will validate our readiness for human expeditions beyond the Earth-Moon system in the 2030s. NASA is currently in the process of detailing those objectives into flight test and mission objectives that can then be allocated to specific flights of SLS and Orion. These specific missions beyond Exploration Mission-2 (EM-2) will depend on factors including the incremental evolution of SLS and Orion, as well as the development of other assets, like those to support humans in deep space such as potential habitation capabilities. These missions will be informed by potential partnering opportunities; the ability to leverage technology developments; the ability to leverage possible *in situ* resources as well as learning about the human ability to live and work longer in deep space (including lessons learned from the ISS). As NASA learns from initial missions using SLS and Orion, the Agency will formulate details of future goals, missions, and hardware, and this analysis will be reflected in future budget requests. NASA's exploration strategy, progress to date, and forward plans have been articulated in "NASA's Journey to Mars – Pioneering Next Steps in Space Exploration," which can be found at the link below:

http://www.nasa.gov/sites/default/files/atoms/files/journey-to-mars-next-steps-20151008_508.pdf

**HOUSE 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*

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

Questions submitted by Rep. Donna Edwards, Ranking Member,
Space Subcommittee

QUESTION 1:

In light of the clear Congressional direction on an Enhanced Upper Stage (EUS) in the FY 2016 consolidated appropriations, what was the rationale for not requesting the necessary EUS funding in the FY 2017 request to continue the work being done in FY 2016?

ANSWER 1:

As with every budget submission, NASA must balance its priorities with the constraints of the budget. Under the President's Budget Request for FY 2017, Exploration Mission-2 (EM-2) would launch with SLS Block 1 using the Interim Cryogenic Propulsion Stage. Under the President's Budget Request (PBR) for FY 2017, Exploration Mission-2 (EM-2) would be planned for launch with Space Launch System (SLS) Block 1 using the Interim Cryogenic Propulsion Stage. The current (preliminary, early formulation) estimated range evolving SLS to Block 1B, including necessary work to ground systems, is between \$1.9 and 2.6 billion over the next five years. Under the PBR, it is not possible to accommodate these funding levels without risks to schedule or significant cuts to other work, including work needed to support the development of actual missions for SLS and Orion, and technologies needed to make deep space exploration missions affordable and achievable.

The FY 2016 Appropriations Act directs NASA to develop the EUS for the second joint mission of the Agency's Space Launch System and Orion spacecraft. The SLS Program will mature the EUS to the level of Preliminary Design Review (PDR), to be held near the end of calendar year 2016. After the PDR, NASA will have a better understanding of EUS cost and schedule projections and will continue to assess implementation of EUS as we progress through the developmental cycle.

QUESTION 1a:

Did you consider including the EUS as a "mandatory investment"? If not, why not?

ANSWER 1a:

See response to question 1.

QUESTION 2:

Our European partners are currently building the Service Module for the Orion spacecraft and are doing so as part of the barter agreement associated with ISS operations. The existing agreement is limited to the Service Module to be used on EM-1. When will NASA make a decision on who will build the Service Module for EM-2?

ANSWER 2:

The Implementing Arrangement between NASA and the European Space Agency (ESA), which was signed in 2012, provided for the design, development and delivery of the European Service Module (ESM) for the Orion spacecraft for Exploration Mission-1 (EM-1) as well as the long-lead items associated with the production of the service module for Exploration Mission-2 (EM-2). An Annex to the Implementing Arrangement also afforded NASA the opportunity to exercise an option for ESA to provide the service module for EM-2. On March 26, 2016, NASA notified ESA of its intent to exercise that option, and ESA has agreed to manufacture and assemble the Service Module for EM-2.

QUESTION 2a:

How is NASA planning for EM-2 given the uncertainty regarding who will build follow-on Service Modules?

ANSWER 2a:

NASA values its partnership with ESA and intends to continue that partnership on EM-2. In accordance with the Annex to the Implementing Agreement between ESA and NASA, NASA notified ESA of its intent to exercise the option for ESA to provide a second ESM for EM-2. As a result, we have eliminated any uncertainty regarding the provision of the EM-2 service module. At the technical level, the NASA and ESA teams are coordinating on configuration details to be incorporated into the EM-2 flight unit.

QUESTION 3:

Your prepared statement referred to public-private partnerships, called NextSTEP, to advance exploration capabilities such as the development of concepts for a deep space habitation system. What is the nature of these public-private partnerships?

ANSWER 3:

Next Space Technologies for Exploration Partnerships (NextSTEP) is a public-private partnership model that seeks commercial development of deep space exploration capabilities to support more extensive human space flight missions in the Proving Ground around and beyond cislunar space—the space near Earth that extends just beyond the Moon.

NASA issued the original NextSTEP Broad Agency Announcement (BAA) to U.S. industry in late 2014. In March 2015, NASA selected 12 awardees – seven in habitation (four integrated habitation concepts and three advanced life support systems and integrated concepts), three in propulsion, and two in small satellites. The Agency issued the second NextSTEP BAA in April 2016. The second NextSTEP BAA is an omnibus announcement with appendices that solicit proposals in specific research areas.

An important part of NASA's strategy is to stimulate the commercial space industry to help the agency achieve its strategic goals and objectives for expanding the frontiers of knowledge, capability, and opportunities in space. A key component of the NextSTEP partnership model is that it provides an opportunity for NASA and industry to partner to develop capabilities that meet NASA human space exploration objectives while also supporting industry commercialization plans.

QUESTION 3a:

Is industry putting "skin in the game" and if so, how much?

ANSWER 3a:

Offerors were required to show a minimum of 50 percent corporate contribution for Phase 1, made within the five years prior to the release of the NextSTEP BAA or during the duration of the proposed period of performance that was directly relevant to the proposed effort, and 30 percent for Phase 2 made within one year prior to the release of the NextSTEP BAA or during the period of the contract performance. Corporate contribution could be in the form of direct labor, travel, consumables or other in-kind contributions. Also, other reasonable forms of corporate contribution could include investments in special facilities or equipment, tooling or other prior private investment, including Independent Research and Development (IRAD). For this BAA, state and local government contributions could be included with private corporate resources.

QUESTION 3b:

Who will retain the intellectual property derived from the government's investment?

ANSWER 3b:

Please see below regarding to intellectual property in the NextSTEP BAA.

- Data Rights: The objective of a contract awarded under this [NextSTEP] BAA is to provide recipients with the incentive to develop commercial applications of technologies developed through the partnership. Data exchanged between NASA and a recipient will generally be freely exchanged without restriction as to its disclosure, use or duplication. However, a recipient's proprietary data that is exchanged or developed will be protected from disclosure provided it is clearly marked as such. Further, data produced by NASA that would be a trade secret or commercial or financial information that would be privileged or confidential had the data been obtained from the nongovernmental partner, may be protected from disclosure for up to 5 years.
- Invention Rights: Recipients that are Small Businesses or nonprofit organizations may elect to retain title to their inventions pursuant to the Bayh-Dole Act (35 U.S.C. § 202). Large business recipients are subject to section 20135 of the National Aeronautics and Space Act (51 U.S.C. § 20135) relating to property rights in inventions. Title to inventions made under an agreement by a large business recipient initially vests with NASA. However, these recipients may request a waiver to obtain title to inventions made under the agreement. Such a request may be made in advance of the agreement or within 30 days thereafter. Even if a waiver request is not made, or denied, a large business recipient may request a waiver on individual inventions made during the course of the agreement.

QUESTION 3c:

When could NASA expect to have a system that can be tested in space?

ANSWER 3c:

To obtain innovative habitat concepts from outside NASA, four habitation concept study contracts were awarded from the original NextSTEP BAA. As these studies near completion, NASA intends to select some of these concepts for continued development and validation of prototypes. Any additional companies that are selected under NextSTEP-2, Appendix A will "on-ramp" with the currently awarded NextSTEP habitat contractors and work toward the same objectives for developing and validating prototype systems.

Appendix A, released in April 2016, focuses on developing deep space long-duration habitation concepts, engineering design and development, and risk reduction efforts leading to a habitation capability in cislunar space. The objective is

to identify habitation concepts that can support extensive human spaceflight missions in the Proving Ground (around and beyond cislunar space) while encouraging application to commercial LEO habitation capabilities.

It is important to note that a deep-space habitation capability, critical for extended missions in cislunar space and human transit to and from Mars, includes an array of complex systems and components that will need to be installed in the pressure vessel itself. These technologies are important for operations and crew safety, and they include docking capability, environmental control and life support systems, logistics reduction efforts, radiation sensors, fire safety technologies, and crew health capabilities. Long-duration system demonstrations of these critical habitation systems are being planned on the International Space Station (ISS).

QUESTION 4:

What is the timeline for finalizing the requirements and goals of the Restore-L satellite servicing technology demonstration mission? What future NASA applications do you envision for this technology?

ANSWER 4:

The Restore-L objectives and requirements will be completed by the project System Requirements Review (SRR), currently scheduled for no later than early FY 2017.

NASA is directly applying the Restore-L technologies to support the Asteroid Redirect Mission, including the autonomous rendezvous capability, robotic capture, tool drive system, and servicing avionics. These technologies and capabilities will also enable more capable systems for future robotic and human exploration of the solar system. Additional candidate applications include on-orbit manufacturing and assembly, propellant depots, orbital debris management, and observatory servicing.

QUESTION 5a:

NASA is proceeding with the formulation of a Europa fly-by mission. In the FY 2016 Consolidated Appropriations, NASA was directed to develop an orbiter and a lander to meet the science goals of a Jupiter Europa mission as laid out in the National Academies planetary science decadal survey.

- a. What is the estimated cost of adding a lander to the Europa mission and what scope of lander is assumed in that estimate?

ANSWER 5a:

NASA has initiated a study of lander concepts by JPL, which is still ongoing. However, preliminary results show that a lander would add significant cost, schedule risk and complexity if integrated directly into the flyby mission.

QUESTION 5b:

What planned planetary science activities might be affected if NASA were to add a lander?

ANSWER 5b:

Until the studies are complete, and a decision is made regarding mission scope, cost, and schedule, there will not be a definitive answer to this question. Developing multiple flagship missions (e.g., Mars 2020, a Europa orbiter, a Europa lander) within the Planetary Science budget in the same timeframe could put significant pressure on other programs, such as the smaller competed missions.

QUESTION 5c:

Do you intend to seek advice either from the National Academies or other external body to inform decisions regarding the scope of and timeframe for a Europa mission and the potential impacts on the overall planetary science program? If not, why not?

ANSWER 5c:

While no plans currently exist to get feedback specific to the Europa mission and potential impacts to other parts of the Planetary Science program from external groups, NASA could seek such feedback in the future. NASA considers several inputs in developing its science program, including recommendations from the National Academies and from advisory committees such as the NASA Advisory Council Planetary Science Subcommittee.

QUESTION 6:

With regards to NASA's consolidation of its network operations, IT network transformation, and voice services under the Agency Chief Information Officer, what prompted this effort?

ANSWER 6:

Beginning in 2014, the NASA Mission Support Council (MSC) directed a Business Services Assessment (BSA) team to perform a detailed analysis of several key IT service areas, including networks/communications. The resulting analysis, approved by the MSC on 31 March 2016, reinforced the strategy that transforming NASA's disparate networks into an end-to-end integrated NASA network will reduce cost, improve operational efficiencies, increase collaboration, and improve IT Security. The BSA team also recommended consolidation of funding to enable the efficient operations of an

end-to-end network. These steps will also strengthen NASA's compliance with the Federal IT Acquisition Reform Act.

QUESTION 6a:

How do you plan to assure Congress that this consolidation will not negatively impact IT security for the networks and systems that support NASA's critical aeronautics, science, and human exploration missions?

ANSWER 6a:

The consolidation will positively impact NASA's security posture. Projects are underway to create an Agency perimeter with next generation security devices deployed at NASA's Trusted Internet Connection (TIC) locations as well as the deployment of Network Access Control across NASA's internal network. The consolidation of funding gives the OCIO additional capability to prioritize and mitigate risk at an agency level. Both the budget consolidation and the network consolidation also provide tighter integration with IT security programs external to NASA, such as the Department of Homeland Security's (DHS') Continuous Diagnostics and Mitigation (CDM) program and DHS' National Cyber Protection System (NCPS or 'Einstein').

QUESTION 7:

Further to my question during the hearing, please provide a list of actions that you are taking to ensure that NASA is not making near-term trades in trying to meet a 2021 schedule for EM-2 that could inadvertently lead to perceived schedule pressure and that could negatively affect safety.

ANSWER 7:

NASA conducted a comprehensive review of the Orion Program to develop a deep-space crew capability, taking into consideration an integrated look at cost, schedule, technical performance, risk, and safety. At the conclusion of this integrated review, in September 2015, NASA established the Agency Baseline Commitment for the Orion program as part of the Agency's Key Decision Point C (KDP-C). Since that time, NASA has further conducted a comprehensive Critical Design Review (CDR) to further assess the progress of the design, testing, and verification plans. The comprehensive and integrated nature of these reviews is the primary tool by which NASA ensures programs like Orion are making trades that are cognizant of schedule without negatively affecting safety.

The Agency Baseline Commitment was for a launch readiness date no later than April 2023 at a 70 percent confidence level, as calculated using Joint Confidence Level (JCL) methodology at that point in time. NASA also assessed an internal Management Agreement against a launch readiness date of August 2021 which resulted in a 40 percent confidence. NASA continues to hold the Orion program to a schedule consistent with an EM-2 launch readiness date of August 2021.

NASA is implementing a distributed system test and verification plan that ensures the safety and success of Orion and SLS and our crews who will fly with them. For Orion, this plan combines comprehensive ground testing using a proto-qual approach with further validation through flight testing (including critical systems operating today on ISS) to ensure that the spacecraft will support the successful first flight of humans into deep space in 2021. This test plan is thorough, logically laid out, draws heavily on the prior heritage of integrated testing for crew certification, and reflects a very-high level of engineering rigor, allowing for the discovery of problems early in the design and development process. The test plan was affirmed as part of the Orion CDR, reviewed by the independent NASA Standing Review Board, presented to the Agency Management Council, and delineated to the NASA Aerospace Safety Advisory Panel. As NASA now executes this system test and verification plan, per NASA procedures, it will continue to work with these organizations to ensure the safety of the Orion spacecraft.

**HOUSE 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*

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

Questions submitted by Representative Ami Bera

QUESTION 1:

Administrator Bolden, several times you and others at NASA have discussed innovation through the use of Space Act Agreements (SAAs) with new companies. Can you describe other ways that NASA has supported innovation through collaboration with other companies? For example, are there any other companies innovating in the area of the booster engine development for capabilities that U.S. currently doesn't have? Is it fair to say that NASA has indirectly played a role in innovation by using contract mechanisms other than Space Act Agreements?

ANSWER 1:

Space Act Agreements are one of many mechanisms used by the Agency to support and encourage innovation. For example, Small Business Innovation Research (SBIR) contracts are awarded to hundreds of small businesses each year, and Small business Technology Transfer Research (STTR) contracts encourage innovation partnerships between small businesses and universities. NASA also fosters innovation with incentive prize competitions through the Centennial Challenges Program. Further, there are numerous competitive technology development procurements across many NASA program areas aimed at driving innovation to meet the Agency's mission needs. Finally, NASA also supports innovation through licensing NASA technology.

In the area of spaceflight and human exploration, for example, NASA has played a role in supporting innovation in a variety of ways, including the following.

- NASA's launch services contracts are currently supporting the development of new U.S. commercial launch capabilities. Through the Venture Class Launch Services (VCLS) contracts, NASA is provided an avenue for "mentoring" of emerging launch providers.
- NASA uses Broad Agency Announcements (BAAs) to create cost-sharing relationships. Examples include the Next Space Technologies for Exploration Partnerships (NextSTEP) – through which NASA selected 12 projects to advance the development of advanced propulsion, habitation, and small satellites.

- The Sabatier fixed price contract for systems to recover water from carbon dioxide and the Universal Waste Management System to develop a space toilet represent contracts where NASA provided success payments for the design, engineering, and manufacturing of the first unit, sharing the risk, and now leases the equipment, buying water on a per liter basis ensuring performance.
- As of April 2016, the Orion program has provided over 800 data products to Commercial Crew program providers, a transfer of knowledge and experience which has significantly augmented the providers' capabilities and accelerated their development. These products include data results from parachute and other tests; trade studies and analyses; software models; and interface definition, design data, and operations document. In addition, Orion engineering experts are routinely utilized in Commercial Crew program design and anomaly reviews.
- Under the Advanced Booster Engineering Demonstration and Risk Reduction (ABEDRR) from FY 2013 through FY 2015, NASA's Space Launch System (SLS) program invested over \$75M with companies to advance boost-phase technology in the areas of high-energy solid propellants and composite cases, kerosene main stage engines, and advanced composite cryogenic tanks.
- NASA's SLS and Orion programs have made extensive investments in advanced manufacturing techniques like reaction friction stir welding and additive manufacturing, investments which have helped to position the U.S. and U.S. companies as world leaders in this critical technological area.
- Innovative partnerships for the reutilization and revitalization of NASA infrastructure have enabled the transition of the Kennedy Space Center's Space Shuttle-era facilities to a multi-user spaceport of the future.

These are just a few examples of many NASA activities supporting innovation through collaboration. For more examples, please see the NASA-related activities on the Federal Government's SBIR/STTR portal site at <https://www.sbir.gov/news/success-stories>.

