

**AN OVERVIEW OF THE BUDGET PROPOSAL
FOR THE NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION FOR FISCAL YEAR 2016**

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

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**AN OVERVIEW OF THE BUDGET PROPOSAL
FOR THE NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION FOR FISCAL YEAR
2016**

THURSDAY, APRIL 16, 2015

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

The Subcommittee met, pursuant to call, at 9:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Steven Palazzo [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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Subcommittee on Space

***An Overview of the Budget Proposal for the National
Aeronautics and Space Administration for Fiscal Year 2016***

Thursday, April 16, 2015
9:00 a.m. to 11:00 a.m.
2318 Rayburn House Office Building

Witnesses

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

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

***An Overview of the Budget Proposal for the National Aeronautics and Space
Administration for Fiscal Year 2016***

Thursday, April 16, 2015
9:00 a.m. – 11:00 a.m.
2318 Rayburn House Office Building

Purpose

The Space Subcommittee will hold a hearing entitled *An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2016* on Thursday, April 16, 2015 in Room 2318 of the Rayburn House Office Building. The purpose of the hearing is to review the Administration's fiscal year 2016 (FY16) budget request for the National Aeronautics and Space Administration (NASA) and examine its priorities and challenges.

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 17,400 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 FY16 budget request was released on Monday, February 2, 2015. NASA is requesting \$18.53 billion, an increase of \$519 million over what was appropriated for the agency in FY15. For each of the fiscal years 2016 – 2019, 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."

Budget Request

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	FY16	FY16	2017	2018	2019	2020
NASA Total	17,646.5	18,010.2	18,529.1	518.9	18,807.0	19,089.2	19,375.5	19,666.1
Science	5,148.2	5,244.7	5,288.6	43.9	5,367.9	5,488.4	5,530.2	5,613.1
Earth Science	1,824.9	-	1,947.3	-	1,966.7	1,988.0	2,009.3	2,027.4
Planetary Science	1,345.7	-	1,361.2	-	1,420.2	1,458.1	1,502.4	1,527.8
Astrophysics	678.3	-	709.1	-	726.5	769.5	1,005.5	1,138.3
James Webb Space Telescope	658.2	645.4	620.0	(25.4)	569.4	534.9	305.0	197.5
Heliophysics	641.0	-	651.0	-	685.2	697.9	708.1	722.1
-	-	-	-	-	-	-	-	-
Aeronautics	566.0	651.0	571.4	(79.6)	580.0	588.7	597.5	606.4
Space Technology	576.0	596.0	724.8	128.8	735.7	746.7	757.9	769.3
Exploration	4,113.2	4,356.7	4,505.9	149.2	4,482.2	4,298.7	4,264.7	4,205.4
Exploration Systems Development	3,115.2	3,245.3	2,862.9	(382.4)	2,895.7	2,971.7	3,096.2	3,127.1
Commercial Spaceflight	696.0	805.0	1,243.8	438.8	1,184.8	731.9	173.1	1.1
Exploration Research and Dev	302.0	306.4	399.2	92.8	401.7	595.1	995.4	1,077.2
Space Operations	3,774.0	3,827.8	4,003.7	175.9	4,191.2	4,504.9	4,670.8	4,864.3
International Space Station	2,964.1	-	3,105.6	-	3,273.9	3,641.0	3,826.0	4,038.3
Space & Flight Support	809.9	-	898.1	-	917.3	863.8	844.8	826.1
Education	116.6	119.0	88.9	(30.1)	90.2	91.6	93.0	94.4
Safety, Security, and Mission Services	2,793.0	2,758.9	2,843.1	84.2	2,885.7	2,929.1	2,973.0	3,017.5
Center Management and Ops	2,041.5	-	2,075.2	-	2,105.0	2,136.6	2,168.6	2,201.0
Agency Management and Ops	751.5	-	767.9	-	780.7	792.5	804.4	816.5
Construction & Environmental Compliance & Restoration	522.0	419.1	465.3	46.2	436.1	442.6	449.3	456.0
Construction of Facilities	455.9	-	374.8	-	344.3	349.3	354.6	359.9
Environmental Compliance and Restor	66.1	-	90.5	-	91.8	93.3	94.7	96.1
Office of Inspector General	37.5	37.0	37.4	0.4	38.0	38.5	39.1	39.7
NASA Total	17,646.5	18,010.2	18,529.1	518.9	18,807.0	19,089.2	19,375.5	19,666.1

This year's request contains several items of note:

1. While Congress has consistently appropriated roughly \$1.2 billion each year for the past three years on the development of the Orion crew vehicle to ensure Orion remains on schedule, NASA has requested approximately \$100 million less for the third year in a row.
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 fourth year in a row, the Administration has reduced the budget request for this vital national asset. The FY16 budget request seeks a reduction of \$343.5 million for launch vehicle development compared with the FY15 appropriation.
3. Although widely critiqued by its own advisory committees, NASA is requesting \$220 million to continue work on the Asteroid Robotic Redirect Mission.

4. The budget request proposes funding the formulation of a Europa mission at \$30 million. This is only the second year that the Administration has requested funding for this mission despite guidance from the Decadal Surveys and Congressional direction that it be included in the agency's planetary science program. Congress added \$75 million in FY13, \$80 million in FY14, and \$100 million in FY15 for Europa studies and pre-formulation activities.
5. NASA requested \$1.243 billion for the Commercial Crew program to procure crew access to the International Space Station (ISS). NASA's current contract with Russia to purchase seats for astronauts for roughly \$75 million expires on 2017. NASA recently started negotiating a follow-on contract to procure services after 2017 in the event that the Commercial Crew contractors are unable develop domestic capabilities by that target date.

Asteroid Redirect/Retrieval Mission

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 an 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 the Orion crew vehicle. This is in contrast to the original proposal to capture an asteroid in its native orbit to be "tugged" to lunar orbit. NASA has never attempted this type of sample capture and return. The OSIRIS-REx mission, to be launched next year, will attempt to capture approximately 60 grams of regolith from the asteroid, Benu, and return it to Earth robotically for less than one billion dollars.

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. This will largely be tasked to the Human Exploration and Operations Mission Directorate. Finally, the development of high-power solar electric propulsion (SEP) will be necessary for travel to the asteroid and then transfer it to lunar orbit. This effort would be conducted by the Space Technology Mission Directorate.

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 Propulsion Laboratory. NASA Associate Administrator Robert Lightfoot recently stated the robotic part of ARM would fit within a cost cap of \$1.25 billion, excluding the launch vehicle and other

leveraged costs.¹ When the Administration released last year's budget request, NASA planned to provide a more detailed budget profile for this mission by the summer of 2014. NASA completed the mission formulation review last February, but still has not provided a detailed budget profile and full development plan for the mission to Congress. Despite recommendations from NASA Advisory Committees that call for an independent cost estimate of the mission options, NASA has refused to conduct such an assessment. Additionally, the NAC recently proposed a finding that NASA would be better served by utilizing an SEP demonstration for a Mars mission rather than ARM.

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."² The NASA Authorization Act of 2010 required NASA to contract with the National Academies of Science to review the future of human spaceflight.³ 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.⁴

The Small Bodies Assessment Group, 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."⁵ 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."⁶

The Administration's FY 2016 request for the Asteroid Redirect Mission totals \$220 million, and includes funds dispersed throughout the mission directorates. The request includes \$94 million (\$56 million of which would be leveraged) in the Human Exploration and Operations Mission Directorate for ARM formulation and in-space robotic servicing and EVA suits; \$69 million in the Space Technology Mission Directorate (all of which would be leveraged) for high-powered solar electric propulsion development; \$50 million in the Science Mission Directorate (all of

¹ 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/>.

² 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

³ NASA Authorization Act of 2010 (P.L. 111-267): <http://www.gpo.gov/fdsys/pkg/PLAW-111publ267/pdf/PLAW-111publ267.pdf>

⁴ Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration, http://www.nap.edu/catalog.php?record_id=18801

⁵ 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/>.

⁶ NASA Advisory Council Recommendation, Asteroid Redirect Mission, 2014-02-02 (Council-02) http://www.nasa.gov/sites/default/files/files/SquvresLetterToBolden_tagged.pdf

which would be leveraged) for planetary science research and near-Earth object observations; and \$7 million for the Chief Technologist for Asteroid Grand Challenge prizes.

Human Exploration and Operations Mission Directorate

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Exploration	4,113.2	4,356.7	4,505.9	149.2	4,482.2	4,298.7	4,264.7	4,205.4
Exploration Systems Development	3,115.2	3,245.3	2,862.9	(382.4)	2,895.7	2,971.7	3,096.2	3,127.1
Commercial Spaceflight	696.0	805.0	1,243.8	438.8	1,184.8	731.9	173.1	1.1
Exploration Research & Development	302.0	306.4	399.2	92.8	401.7	595.1	955.4	1,077.2
Space Operations	3,774.0	3,827.8	4,003.7	175.9	4,191.2	4,504.9	4,670.8	4,864.3
International Space Station	2,964.1	-	3,105.6	-	3,273.9	3,641.0	3,826.0	4,038.3
Space and Flight Support	809.9	-	898.1	-	917.3	863.8	844.8	826.1

The Human Exploration and Operations Mission Directorate is responsible for five broad human spaceflight areas at NASA; Exploration Systems Development, Commercial Spaceflight, Exploration Research and Development, International Space Station, and Space & Flight Support. NASA is requesting an increase of \$149.2 million (3.4 percent) in the Exploration account and an increase of \$175.9 (4.6 percent) in the Space Operations Account.

Exploration Systems Development

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Exploration	4,113.2	4,356.7	4,505.9	149.2	4,482.2	4,298.7	4,670.8	4,864.3
Exploration Systems Development	3,115.2	3,245.3	2,862.9	(382.4)	2,895.7	2,971.7	3,096.2	3,127.1
Orion Multipurpose Crew Vehicle	1,197.0	1,194.0	1,096.3	(97.7)	1,119.8	1,122.9	1,126.7	1,138.0
Space Launch System	1,600.0	1,700.0	1,356.5	(343.5)	1,343.6	1,407.6	1,516.5	1,531.6
Exploration Ground Systems	318.2	351.3	410.1	58.8	432.3	441.2	453.0	457.5

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; the Space Launch System (SLS) heavy lift rocket, the Orion crew vehicle (Orion), and Exploration Ground Systems (EGS). The total request for Exploration Systems Development is \$2.86 billion, an 11.7 percent reduction from the FY15 appropriation. In August of 2014, NASA completed a key decision point (KDP-C) in the SLS program that included a cost and schedule commitment. The Administration slipped the launch readiness date for Exploration Mission 1 (EM-1) to November 2018 despite numerous assertions from the Administration that no additional funds beyond previous requests would be needed to keep the SLS and Orion on schedule.

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 fourth year in a row. The request of \$1.096 billion is a reduction of approximately eight percent from the FY2015 enacted levels. Last December, NASA completed Exploration Flight Test 1 (EFT-1),

which is the first in a series of flight tests for the SLS/Orion systems. EFT-1 was a major success and was the subject of a Subcommittee hearing last December.⁷

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. This year’s request includes a reduction of approximately \$343.5 million (20 percent) relative to the enacted fiscal year 2015 levels, despite insistence from Congress that SLS be a top priority.

Exploration Ground Systems - The Exploration Ground Systems program received an increase in the President’s budget request of \$58.8 million as a result of 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.^{8,9}

Commercial Spaceflight

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Exploration	4,113.2	4,356.7	4,505.9	149.2	4,482.2	4,298.7	4,670.8	4,864.3
Commercial Crew	696.0	-	1,243.8	-	1,184.8	731.9	173.1	1.1
Subtotal, Commercial Spaceflight	696.0	805.0	1,243.8	438.8	1,184.8	731.9	173.1	1.1

With the transition of commercial cargo from development to an operational contract, the Commercial Crew Development Program is the only development effort in the Commercial Spaceflight line.

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.¹⁰

In September of last year, NASA 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,

⁷ See: <http://science.house.gov/hearing/subcommittee-space-hearing-update-space-launch-system-and-orion-monitoring-development>

⁸ Testimony of Cristina T. Chaplain, Director, Acquisition and Sourcing Management, before the House Committee on Science, Space and Technology, December 10, 2014. <http://gao.gov/assets/670/667350.pdf>

⁹ NASA’s Launch Support and Infrastructure Modernization: Assessment of the Ground Systems Needed to Launch SLS and Orion. NASA Office of Inspector General. <http://oig.nasa.gov/audits/reports/FY15/IG-15-012.pdf>

¹⁰ 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>.

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.

This year's request includes a significant increase for the program. The request of \$1.24 billion is an increase of \$438.8 million (55 percent) over FY15. The Administration contends that this increase is required to support two contracts through the certification phase. The Administration has not offered any alternative acquisition model (such as selecting a single contractor) that would fall within historical funding levels for this program. NASA also has not conducted an independent cost estimate for the program.¹¹

Exploration Research and Development

Budget Authority (\$ in millions)	Actual 2014	Enacted 2015	Request 2016	FY15 vs FY16	Notional			
					2017	2018	2019	2020
Exploration	4,113.2	4,356.7	4,505.9	149.2	4,482.2	4,298.7	4,670.8	4,864.3
Exploration Research and Dev	302.0	306.4	399.2	92.8	401.7	595.1	995.4	1,077.2
Human Research Program	149.4	-	167.8	-	170.3	178.2	178.2	180.0
Advanced Exploration Systems	152.7	-	231.4	-	231.4	416.9	817.2	897.2

The President's FY16 request for Exploration Research and Development is \$399.2 million, an increase of \$92.8 million (30 percent) above FY15. 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, as well as robotic precursor missions to gather critical knowledge about potential destinations in advance of crewed missions.

¹¹ NASA contracted with BoozAllenHamilton 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. 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.

Space Operations

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Space Operations	3,774.0	3,827.8	4,003.7	175.9	4,191.2	4,504.9	4,670.8	4,364.3
International Space Station	2,964.1	-	3,105.6	-	3,273.9	3,641.0	3,826.0	4,038.3
Space and Flight Support (SFS)	809.9	-	898.1	-	917.3	863.8	844.8	826.1

The Space Operations Account funds activities for the International Space Station, 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 FY16 is \$4.003 billion, which represents an increase of \$175.9 million (4.6 percent).

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. In FY14, the Station hosted 368 experiments (28 percent increase). These included 64 in biology and biotechnology, 91 in Earth and space science, 50 educational activities, 36 in human research, 43 in physical science, and 84 in technology.¹²

The ISS Program contains three major projects: Systems Operations and Maintenance (O&M), Research, and Crew and Cargo Transportation. Funding to procure commercial crew or cargo transportation is in the ISS Crew and Cargo Transportation program within the ISS budget. The President's FY16 budget request for the International Space Station is \$3.106 billion, an increase of \$131.2 million over FY15.

Commercial 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 SpaceX contract is valued at \$1.6 billion for 12 missions and Orbital contract is valued at \$1.9 billion for 8 missions.

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,

¹² President's Budget Request for Fiscal Year 2016 for the National Aeronautics and Space Administration, Congressional Justification, P. SO-14. Retrieved at http://www.nasa.gov/sites/default/files/files/FY2016_Budget_Book_508_TAGGED.pdf

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)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Science	5,148.2	5,244.7	5,288.6	43.9	5,367.9	5,488.4	5,530.2	5,613.1
Earth Science	1,824.9	NA	1,947.3	-	1,966.7	1,988.0	2,009.3	2,027.4
Planetary Science	1,345.7	NA	1,361.2	-	1,420.2	1,458.1	1,502.4	1,527.8
Astrophysics	678.3	NA	709.1	-	726.5	769.5	1,005.5	1,138.3
James Webb Space Telescope	658.2	645.4	620.0	(25.4)	569.4	534.9	305.0	197.5
Heliophysics	641.0	NA	651.0	-	685.2	697.9	708.1	722.1

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. NASA is requesting \$5.288 billion for SMD this year, which is an increase of less than one percent (\$43.9 million) above the FY15 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. NASA launched five Earth Science missions in 2014 and the beginning of 2015. The Global Precipitation Measurement (GPM) Core Observatory was launched in early 2014. The mission measures rain and snowfall around the world every three hours. The International Space Station is hosting two Earth Science missions on station: RapidScat replaces QuickScat and gathers data on ocean winds, while the Cloud-Aerosol Transport System (CATS) instrument measures small particle in the atmosphere. The Orbiting Carbon Observatory-2 (OCO-2) was launched in July 2014 and measures carbon dioxide levels in Earth's atmosphere, and replaces the satellite (OCO-1) that was destroyed in a launch failure in 2009. The Soil Moisture Active/Passive (SMAP) mission was launched later than scheduled in January of 2015 and measures soil moisture, contributing to climate research and knowledge of the global water cycle. The NOAA mission

Deep Space Observatory (DSCOVR) (an Earth observation and space weather satellite developed by NASA) was launched in February 2015.

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 \$1.947 billion for Earth Science, an increase of approximately ten percent (\$175 million) from FY 2015. This represents a 62.5 percent increase from 2007.

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 FY16 President's Budget Request for Planetary Science is \$1.361 billion, down over five percent (\$77 million) from the FY15 appropriation.

In 2014, Planetary Science mission highlights included the New Horizons mission "waking up" to be ready for its approach to Pluto. The mission will reach its mission destination in July 2015, and is expected to provide scientists with the first detailed look at dwarf planet Pluto in human history. In the summer of 2014 the ESA/NASA Rosetta comet rendezvous mission reached the Comet Churyumov-Gerasimenko (Comet C-S), and successfully placed the lander, Philae, on the surface. While mainly an ESA mission, NASA scientists contributed to the mission, and will participate in analyzing its data. The historic Dawn spacecraft has successfully been inserted into orbit around the dwarf planet Ceres, after successfully studying the giant asteroid, Vesta. Ceres is the largest object in the asteroid belt between Mars and Jupiter, and this is the first time a mission has successfully orbited two celestial targets. Cassini continues to orbit Saturn, studying its rings and moons, including Titan and Enceladus. This past year, the Curiosity rover on Mars determined Mars was once habitable. In October 2014, NASA's 2001 Mars Odyssey, Mars Reconnaissance Orbiter (MRO), Mars Atmospheric EVolutioN Mission (MAVEN), the Mars rovers, the European Space Agency's orbiter Mars Express, and the Indian Space Research Organization's (ISRO) satellite, and the Mars Orbiter Mission all collected data as Comet Siding Spring made a very close pass by Mars.

Although highly recommended for extended missions by the 2014 Planetary Science Senior Review, the Lunar Reconnaissance Orbiter (LRO) and the Mars Opportunity Rover were not funded in the President's FY16 budget request.

Work continues on the Origins-Spectral-Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-Rex) mission to obtain a sample of near-Earth asteroid Benu, and the Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission to

Mars, both of which are expected to launch in 2016. Work also continues on the Mars 2020 rover, NASA's next flagship mission to Mars.

The President's FY16 budget request includes a line item of \$30 million to continue designing a mission to Europa. Congress has long supported the National Academies' recommendation of this mission. The funding request is a decrease of 70 percent (\$70 million) of the \$100 million Congress appropriated for a Europa mission in FY2015. NASA expects to select instruments for a possible Europa mission in FY15.

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. In 2014 scientists researching data provided from the Kepler space telescope mission confirmed over 1,000 planets outside the Solar System – with over 4,000 awaiting confirmation. NASA approved extending Kepler's mission in 2014, albeit with a modified scientific purpose, following the failure of the reactor wheels used for positioning the space telescope.

The President's FY16 budget request funds the SOFIA mission at \$85 million. Last year, the President's budget request significantly under-funded SOFIA, leading the scientific community to believe the mission would be cancelled. Congress appropriated funds to maintain the mission. However, as a caveat to the President's budget request, SOFIA will undergo a senior review this year, which may recommend its cancellation. 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 was expected to operate for 20 years. Annual operation costs for SOFIA are roughly \$85 million.

The FY16 President's budget request includes \$14 million for continued formulation of an AFTA-WFIRST telescope, the follow-on telescope to the James Webb Space Telescope (JWST). This is a decrease of \$25.4 million from NASA's FY15 Operation Plan.

The Transiting Exoplanet Survey Satellite (TESS) is given an \$8 million increase in the FY16 budget request. 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 budget request for FY16 for \$620 million is in line with projected development costs. In FY15 and FY16 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 goal of the program is to understand the Sun, heliosphere, and planetary environments as a single connected system. The Magnetospheric MultiScale (MMS) mission, designed to investigate how the Earth and Sun's magnetic fields interact, launched in March 2015. In FY16 the Heliophysics Research Program will collect science from 20 active space missions, including IRIS, MMS, and the Voyager 2 spacecraft, among others. Solar Probe Plus, the flagship mission to explore the Sun's outer atmosphere and get closer to the Sun than any previous mission, will conduct its System Integration Review in FY16.

Aeronautics Research Mission Directorate

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Aeronautics	566.0	651.0	571.4	79.6	580.0	588.7	597.5	606.4
Airspace Operations and Safety Program	-	-	142.4	-	153.2	159.6	160.0	163.0
Advanced Air Vehicles Program	-	-	240.9	-	243.2	243.2	231.0	232.8
Integrated Aviation Systems Program	-	-	96.0	-	85.6	89.0	101.6	104.8
Transformative Aeronautics Concepts Prog	-	-	92.1	-	98.0	98.9	104.9	105.8
Aviation Safety	80.0	-	-	-	-	-	-	-
Airspace Systems	91.8	-	-	-	-	-	-	-
Fundamental Aeronautics	168.0	-	-	-	-	-	-	-
Aeronautics Test	77.0	-	-	-	-	-	-	-
Integrated Systems Research	126.5	-	-	-	-	-	-	-
Aeronautics Strategy & Management	22.7	-	-	-	-	-	-	-

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 FY16 budget request for ARMD is \$571.4 million, a 12 percent decrease (\$79.6 million) from the \$651 million included in the FY15 appropriations act.

In FY16, NASA will focus on four major goals. First, developing and demonstrating air traffic controller-managed spacing of arriving flights (Thrust 1). This will improve the efficiency of aircraft flows into airports. Second, validating the truss-braced wing (TBW) aircraft design that should reduce transport aircraft fuel consumption (Thrust 2). Third, developing and refining data analytics to provide information about precursors to safety risks (Thrust 5). This advancement in data analytics will also support development of a system that can predict and mitigate emerging risks. Lastly, NASA will test unmanned aircraft systems (UAS) and use data from those tests to deliver UAS recommendations to the Radio Technical Commission for Aeronautics (Thrust 6).

NASA will also continue work on a UAS Traffic Management (UTM) system. These efforts will contribute to the development of the standards necessary to achieve UAS integration into the NAS.

Among the goals highlighted in the request is also the development, transfer, and implementation of new technologies as part of the Next Generation (NextGen) Air Transportation System.

Major changes in the FY16 budget include increasing investment in UAS research (particularly in UTM), increasing funding for low-carbon propulsion-related research, increasing funding for hypersonics research, and transitioning knowledge from the Environmentally Responsible Aviation (ERA) Project to stakeholders after the Project ends in FY15.

Space Technology Mission Directorate

Budget Authority (\$ in millions)	Actual 2014	Enacted 2015	Request 2016	FY15 vs FY16	Notional			
					2017	2018	2019	2020
Space Technology	576.0	596.0	724.8	128.8	735.7	746.7	757.9	769.3
SBIR & STTR	175.0	-	200.9	-	213.0	213.2	213.5	213.8
Agency Technology and Innovation	30.6	-	33.0	-	33.0	33.2	33.2	33.2
Space Technology Research and Development	370.4	-	491.0	-	489.7	500.3	511.2	522.4

The request for the Space Technology Mission Directorate was realigned in this request to include three main programs rather than four. The three programs include Agency Technology and Innovation; Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR); and Space Technology Research and Development. NASA requested \$724.8 million this year for Space Technology which is an increase of \$128.8 million (21.6 percent) relative to the FY15 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, administer prizes and challenges, and 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 nine major projects identified by NASA as critical within their various program offices. They are referred to as “the big nine”, and include: 1) Laser communications; 2) Cryogenic Propellant Storage & Transfer; 3) Deep Space Atomic Clock; 4) Large-Scale Solar Sail; 5) Low Density Supersonic Decelerators; 6) Green Propellants; 7) Human Exploration Telerobotics and Human-Robotics Systems; 8) Solar Electric Propulsion; and 9) Composite Cryotank.

Education

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Education	116.6	119.0	88.9	(30.1)	90.2	91.6	93.0	94.4
Aerospace Rsch & Career Dev	58.0	58.0	33.0	(25.0)	33.0	33.0	33.0	33.0
STEM Education & Accountability	58.6	-	55.9	-	57.2	58.6	60.0	61.4

The President’s FY15 request for NASA’s Education program is \$88.9 million, a 25.3 percent (\$30.1 million) decrease from the FY15 enacted levels. The FY16 request is structured to implement the Administration’s initiative to reorganize Science, Technology, Engineering and Mathematics (STEM) education programs and activities across the federal government. In FY14 NASA’s STEM education activities were unified under the Office of Education. However, an additional \$20 million is requested for the Science Mission Directorate to competitively fund the best application of science assets to STEM education goals, in addition to funding the Global Learning and Observations to Benefit the Environment (GLOBE) program at \$6 million per year.

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 FY15. 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 FY15.

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 FY16 the President's budget requests \$55.9 million.

Safety, Security, and Mission Services (SSMS)

Budget Authority (\$ in millions)	Actual	Enacted	FY15 vs	Request	Notional			
	2014	2015	FY16	2016	2017	2018	2019	2020
Safety, Security, and Mission Services	2,793.0	2,758.9	84.2	2,843.1	2,385.7	2,929.1	2,973.0	3,017.5
Center Management and Operations	2,041.5	-	-	2,075.2	2,105.0	2,136.6	2,168.6	2,201.0
Agency Management and Operations	751.5	-	-	767.9	780.7	792.5	804.4	816.5

Formerly called 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 \$2.843 billion for SSMS in FY16, an increase of \$84.2 million or 3.1 percent.

Construction & Environmental Compliance and Restoration (CECR)

Budget Authority (\$ in millions)	Actual	Enacted	Request	FY15 vs	Notional			
	2014	2015	2016	FY16	2017	2018	2019	2020
Construction and Enviro Comp and Rest	522.0	419.1	465.3	46.2	436.1	442.6	449.3	456.0
Construction of Facilities	455.9	-	374.8	-	344.3	349.3	354.6	359.9
Environmental Compliance and Restoration	66.1	-	91.8	-	91.8	93.3	94.7	96.1

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 82 percent of NASA's infrastructure is beyond its constructed design life. ECR is responsible for cleaning up pollutants released into the environment during past activities.

The President's request for FY16 provides an increase to the CECR account of \$46.2 million or 11 percent.

Inspector General

Budget Authority (\$ in millions)	Actual	Enacted	FY15 vs	Request	Notional			
	2014	2015	FY16	2016	2017	2018	2019	2020
Inspector General	37.5	37.0	0.4	37.4	38.0	38.5	39.1	39.7

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 \$37.4 million in FY16, which represents a 1.1 percent increase from previous year funding.

Chairman PALAZZO. The Subcommittee on Space will come to order. Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Welcome to today's hearing titled "An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2016." I recognize myself for five minutes for an opening statement.

The first and perhaps most important point I want to make today is that I believe the taxpayers' investment in NASA is generally well spent, and that I support increasing NASA's budget if we're assured American access to space. Discretionary spending such as research and development investments at NASA is the seed corn of future economic growth. In order to preserve these activities, we must address the larger economic problems we face as a nation. This involves either complying with the President's Budget Control Act, which caps discretionary spending, or figuring out how to repeal, replace, or amend it. Unfortunately, this proposal does not do that.

Because this request does not provide any constructive or workable guidance, Congress must now bear that burden. 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. At NASA alone, the President's request exceeds the budget caps by \$519 million. This isn't to say that this is an unreasonable request. After all, the increase simply reflects the rate of inflation. The concern that I have is that the Administration did not propose offsets to account for the increase; did not propose a workable solution to repeal, replace, or amend the President's Budget Control Act; and once again reorganizes priorities in previous bipartisan NASA funding bills that the President signed. For example, the budget proposes cutting the Space Launch System by \$344 million, the Orion crew capsule by \$98 million, the Planetary Science Division by \$77 million, the Heliophysics Division by \$11 million, the Aeronautics Mission Directorate by \$80 million, and NASA education by \$30 million.

SLS and Orion are national assets. They are the tip of the spear in our nation's deep space exploration efforts. Cuts to the Planetary Science Division will empty the pipeline for outer-planet missions and force scientists and engineers into other fields and to foreign projects. Cuts to Heliophysics are weakening our ability to understand and predict solar storms that could threaten astronauts in space, and impact communication, financial, and energy systems here on Earth. Cuts to NASA education hurt NASA's ability to engage and inspire the next generation of explorers.

These harmful cuts accompany increased requests for other activities at NASA. The President's proposal seeks to increase the Earth Science budget by \$175 million this year. This amounts to a 63 percent increase since 2007. The budget also seeks to dilute NASA's existing earth science research portfolio by conducting other agencies' work. It seeks to develop 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. If NASA is tasked to do other agencies' 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.

The budget request also seeks an increase of \$129 million for the Space Technology Mission Directorate and \$439 million for the Commercial Crew Program. I fully support developing the capabilities necessary to launch American astronauts on American rockets from American soil as soon as possible.

I also believe that NASA should be investing in the technologies necessary to enable future exploration. Congress will have to evaluate these proposals to ensure that they are the most efficient uses of taxpayer resources in a challenging budget environment. For example, NASA has argued that it is necessary to fund two contractors in the Commercial Crew Program to provide a redundant capability and enable competition to drive down costs. That is why NASA selected two contractors last fall. Congress will have to decide whether a redundant capability is best provided by two contractors in the Commercial Crew Program, or by external capabilities such as the Orion crew vehicle on an existing launch vehicle. The NASA Authorization Act of 2010 requires NASA to ensure that Orion can serve as an emergency backup to the Commercial Crew Program. NASA has not devoted any effort to complying with this requirement.

The benefits of cost competition also need to be weighed considering the government now has fixed-price contracts. Ultimately, Congress will have to decide whether the nation should develop a capability or should stand up a market.

One thing that would assist Congress in evaluating this proposal is an independent cost estimate for the Commercial Crew Program. NASA previously contracted for an independent cost assessment, which only evaluated contractor-provided data. Now that we have fixed-price contracts from the contractors, NASA should initiate a more thorough independent cost estimate to determine whether the contractors can be reasonably expected to execute within cost and schedule.

Another NASA activity that would benefit from an independent cost estimate is the Asteroid Redirect Mission. Unfortunately, NASA indicated that it was unnecessary to conduct an independent cost estimate prior to selecting optional mission concepts, despite a recommendation from the NASA Advisory Council. The ARM mission still hasn't garnered any support in academic, scientific, exploration, or international communities. NASA's own advisory bodies have heavily criticized the mission. Without consensus, without a realistic cost, and without a clear explanation of how it fits into a broader exploration architecture, it is tough to see how this proposal gains traction in the remaining 18 months of the President's term.

NASA is at a crossroads. Unfortunately, the last six years featured drastic change with the cancellation of Constellation and uncertain direction with the President's ever-changing asteroid initiative. Congress has been consistent in its guidance to NASA that it

develop a long-term sustainable exploration strategy that is evolvable and flexible based on an uncertain budget environment. Recent announcements from NASA indicate that the agency is heading that direction by working towards an architecture that can weather the storms of change that accompany new Administrations. Administrator Bolden and his leadership team have a tough job. General Bolden, I am glad you are at the reins.

[The prepared statement of Chairman Palazzo follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
CHAIRMAN STEVEN PALAZZO

The first and perhaps most important point I want to make today is that I believe the taxpayer's investment in NASA is generally well spent, and that I support increasing NASA's budget. Discretionary spending such as research and development investments at NASA are the seed corn of future economic growth. In order to preserve these activities, we must address the larger economic problems we face as a Nation. This involves either complying with the President's Budget Control Act which caps discretionary spending, or figuring out how to repeal, replace, or amend it.

Unfortunately, the President's budget proposal does not comply with his own Budget Control Act. Because the President failed to provide any constructive or workable guidance, Congress must now bear that burden. I had hoped that the Administration would have demonstrated leadership by proposing a realistic budget, but instead we were presented with a list of unfunded priorities.

At NASA alone, the President's request exceeds the budget caps by \$519 million. This isn't to say that this is an unreasonable request. After all, the increase just keeps up with inflation. The concern that I have is that the Administration did not propose off-sets to account for the increase; did not propose a workable solution to repeal, replace, or amend the President's Budget Control Act; and once again reorganizes priorities in previous bipartisan NASA funding bills that the President signed.

For instance, the budget proposes cutting the Space Launch System (SLS) by \$344 million; the Orion crew capsule by \$98 million; the Planetary Science Division by \$77 million; the Heliophysics Division by \$11 million; the Aeronautics Mission Directorate by \$80 million; and NASA education by \$30 million.

SLS and Orion are national assets. They are the tip of the spear in our nation's deep space exploration efforts. Cuts to the Planetary Science Division are emptying the pipeline for outer-planet missions and forcing scientists and engineers into other fields and to foreign projects. Cuts to Heliophysics are weakening our ability to understand and predict solar storms that could threaten astronauts in space, and impact communication, financial, and energy systems here on Earth. Cuts to NASA education hurt NASA's ability to engage and inspire the next generation of explorers.

These harmful cuts accompany increased requests for other activities at NASA. The President's proposal seeks to increase the Earth Science budget by \$175 million this year. This amounts to a 63 percent increase since 2007. The budget also seeks to dilute NASA's existing earth science research portfolio by conducting other agencies' work. It seeks to develop 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. 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.

The budget request also seeks an increase of \$129 million for the Space Technology Mission Directorate and \$439 million for the Commercial Crew Program. I fully support developing the capabilities necessary to once again launch American astronauts on American rockets from American soil as soon as possible. I also believe that NASA should be investing in the technologies necessary to enable future exploration. Congress will have to evaluate these proposals to ensure they are the most efficient uses of taxpayer resources in a challenging budget environment. For instance, NASA has argued that it is necessary to fund two contractors in the Commercial Crew program to provide a redundant capability and enable competition to drive down costs. That is why NASA selected two contractors last fall.

Congress will have to decide whether a redundant capability is best provided by two contractors in the Commercial Crew program, or by external capabilities such as the Orion crew capsule on an existing launch vehicle. Existing law requires NASA to ensure that Orion can serve as an emergency backup to the Commercial Crew program. NASA has not devoted any effort to complying with this requirement. NASA could also resort to relying on the Soyuz as well. This is certainly not an ideal option, but it does provide a capability in the event that domestic contractors are late or experience setbacks.

The benefits of cost competition also need to be weighed considering the government now has fixed-price contracts. Ultimately, Congress will have to decide whether the nation should develop a capability or should stand-up a market. One thing that would assist Congress in evaluating this proposal is an Independent Cost Estimate (ICE) for the Commercial Crew program. NASA previously contracted for an independent cost assessment which only evaluated contractor-provided data. Now that we have fixed-price contracts from the contractors, NASA should initiate a more thorough (ICE) to determine whether the contractors can be reasonably expected to execute within cost and schedule.

Another NASA activity that would benefit from an independent cost estimate is the Asteroid Retrieval and Redirect Mission. Unfortunately, NASA indicated that it was unnecessary to conduct an (ICE) prior to selecting optional mission concepts, despite a recommendation from the NASA Advisory Council. The ARM mission still hasn't garnered any support in academic, scientific, exploration, or international communities. NASA's own advisory bodies have heavily criticized the mission. Without consensus, without a realistic cost, and without a clear explanation of how it fits into a broader exploration architecture, it is tough to see how this proposal gains traction in the remaining 18 months of the President's term.

NASA is at a crossroads. Unfortunately, the last six years featured drastic change with the cancellation of Constellation and uncertain direction with the President's ever-changing Asteroid initiative. Congress has been consistent in its guidance to NASA that it develop a long-term sustainable exploration strategy that is evolvable and flexible based on an uncertain budget environment. Recent announcements from NASA indicate that the agency is heeding that direction by working towards an architecture that can weather the storms of change that accompany new Administrations. Administrator Bolden and his leadership team have a tough job. General Bolden, I am glad you have the reins.

Chairman PALAZZO. At this time I recognize our Ranking Member, Ms. Edwards.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and good morning and welcome to Administrator Bolden at today's hearing.

Mr. Chairman, I want to thank you for calling this hearing on an overview of the budget proposal for the National Aeronautics and Space Administration fiscal year 2016 budget.

The President is requesting 18.5 billion dollars for NASA's programs and plans for fiscal year 2016. That's about a 2.8 percent increase over the FY 2015 enacted appropriation. It's a significant topline increase given the current fiscal environment, but the question is whether it's a proposal that's sufficient to enable NASA to do all that we have asked and expect it to accomplish. I want NASA to succeed, and I want to provide it with the tools and resources needed to continue to achieve great things for this nation and our citizens, like the winglets we now see on commercial aircraft that improve fuel efficiency and which were invented through NASA's aeronautics research program, the scientific exploration of uncharted corners of our solar system, such as Pluto, where the New Horizons probe will provide our first close-up examination of this remote body when it arrives there this summer, the successful Orion Exploration Flight Test-1 that helps us prepare to once again send humans beyond low-Earth orbit, and being the source of inspiration that lights up children's faces as they hear from astronauts and researchers, watch a launch, and realize that they too can be our next space scientists, engineers, and explorers.

Mr. Chairman, accomplishments such as these would not have been possible without the ingenuity, knowhow, commitment, and dedication demonstrated by the NASA federal workforce and its partners in industry and academia. So they deserve our thanks for all they do. They and the public also deserve to know what lies ahead for NASA.

Over the past few years, we have heard from many witnesses that stability is a critical enabler for NASA's progress. That is why in my statement on the House Floor for passage of the now House-passed, bipartisan NASA Authorization Act of 2015, I said that NASA needs our constancy of purpose and direction now so that we might provide some stability to the agency while we work on multi-year reauthorization, once the current bill is enacted into law. So I hope to hear today about whether or not the Fiscal Year 2016 budget request provides NASA with the clear goals that maintain a constancy of purpose. And one area where the need for constancy of purpose has been widely discussed is human exploration, perhaps because of the commitment of resources and goals that must span multiple Congresses and Presidential Administrations if we are to be successful in that undertaking.

To that end, I'm pleased that NASA and the community have embraced Mars as the long-term goal for human exploration. And indeed our bipartisan Authorization Act establishes such a goal and directs the development of a roadmap to get us there. I hope Congress has the foresight to commit the necessary resources to fund a humans-to-Mars plan, because it is a worthy goal that among other things will do much to advance our nation's technological capabilities. But as the National Academies stressed just a year ago, if Mars is a worthy goal, and they think it is and if we think it is, we need to provide the resources to achieve it. If Congress is unwilling to commit the required resources, we must not let the enthusiasm for a goal of sending humans to Mars divert resources from NASA's other important mission areas, because our House-passed bipartisan NASA Authorization Act reflects an enduring commitment to NASA's multi-mission role. This is true.

I look forward to hearing from Administrator Bolden and to working with him and my colleagues on maintaining a constancy of purpose for NASA going forward, and I thank you and I yield back.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
RANKING MEMBER DONNA F. EDWARDS

Good Morning, and welcome Administrator Bolden to today's hearing. Mr. Chairman, thank you for calling this hearing on "An Overview of the Budget Proposal for the National Aeronautics and Space Administration for Fiscal Year 2016."

The President is requesting \$18.5 billion for NASA's programs and plans for Fiscal Year 2016, about a 2.8 percent increase over the Fiscal Year 2015 enacted appropriation. That is a significant topline increase given the current fiscal environment. But is it a proposal that is sufficient to enable NASA to do all that we have asked and expect it to accomplish?

I want NASA to succeed, and I want to provide it with the tools and resources needed to continue to achieve great things for this nation and our citizens. Like the winglets we now see on commercial aircraft that improve fuel efficiency and which were invented through NASA's aeronautics research program; the scientific exploration of uncharted corners of our Solar System, such as Pluto, where the New Hori-

zons probe will provide our first close-up examination of this remote body when it arrives there this summer; the successful Orion Exploration Flight Test -1, that helps us prepare to once again send humans beyond low-Earth orbit; and being the source of inspiration that lights up children's faces as they hear from astronauts and researchers, watch a launch, and realize that they too can be our next space scientists, engineers, and explorers.

Mr. Chairman, accomplishments such as these would not have been possible without the ingenuity, know-how, commitment, and dedication demonstrated by the NASA federal workforce and its partners in industry and academia. So, they deserve our thanks for all that they do. They and the public also deserve to know what lies ahead for NASA.

Over the past few years, we have heard from many witnesses that "stability" is a critical enabler for NASA's progress. That is why in my statement on the House Floor for passage of the now House-passed, bipartisan NASA Authorization Act of 2015, I said that "NASA needs our constancy of purpose and direction now" so that we might provide some stability to the agency while we work on a multi-year reauthorization, once the current bill is enacted into law.

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I look forward to hearing from Administrator Bolden and to working with him and my colleagues on maintaining a "constancy of purpose" for NASA going forward.

Thank you and I yield back.

Chairman PALAZZO. Thank you, Ms. Edwards. I now recognize the Chairman of the full Committee, Mr. Smith.

Chairman SMITH. Thank you, Mr. Chairman, and I, like you, appreciate Administrator Bolden's testifying today.

While there are some areas of agreement between the Committee and the Administration in this budget, the President's request regrettably changes agreed-upon national priorities. The President's request puts NASA in a tough position because it ignores his own sequestration levels and fails to identify offsets for increases of \$500 million. It is hard for Congress to consider this a serious proposal when it does not comply with the law and is not grounded in reality.

I also disagree with the Administration's continued attempt to redistribute funding within NASA. For example, Europa is one of the best destinations we have in our own solar system for finding life beyond our planet. Yet this year's request of \$30 million for the Europa mission is disappointing considering the mission's potential. In contrast, Congress has funded a Europa mission at \$75 million, \$80 million, and \$100 million over the last three years.

Missions like this, as well as the search for exoplanets and signs of life in other areas of our universe, captivate the American people. I appreciate the progress, on the other hand, that has been made with other priorities such as the James Webb Space Tele-

scope, the Transitioning Exoplanet Survey Satellite, and the Wide Field Infrared Space Telescope. Overall, though, there is a lack of balance in the overall science account request.

Congressional guidance and the decadal surveys advocate for a balanced portfolio of science activities. Unfortunately, the President's request does not adhere to that recommendation by the space experts. One of the most glaring examples is the disproportionate increase in the Earth Science Division that it receives at the expense of other science divisions and human and robotic space exploration. There are 13 other agencies involved in climate change research, but only one that is responsible for space exploration. In the last eight years, the Earth Science Division funding has increased by more than 63 percent. This year, the Administration requested another increase of \$175 million over last year's levels for a total increase of nearly \$2 billion. The Administration doesn't even come close to funding other science divisions at this level.

The Planetary Science budget request is 43 percent lower than the Earth Science budget request. Also, the Earth Science request is almost as much as the Astrophysics division, the James Webb Space Telescope, and the Heliophysics Division combined. This is anything but a balanced portfolio.

These increases come at the expense of NASA's high-priority exploration programs, which the White House has once again attempted to raid to fund the Administration's environmental agenda. The budget underfunds the Space Launch System and Orion programs and it cuts human spaceflight programs by almost \$400 million. The Obama Administration seems to have forgotten NASA's priorities—and the main one is space exploration.

This budget also continues to request funding for the uninspiring Asteroid Redirect Mission (ARM), which was recently rebranded the Asteroid Redirect Mission. 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 even NASA's own advisory committees. This is an uninspiring mission without a realistic budget or destination. It has no certain launch date or ties to existing exploration goals. It is a mission that is without the consensus necessary to make it a reality in the 18 months remaining in the Obama Administration.

The Administration continues to starve NASA's exploration programs to fund a partisan environmental agenda. NASA simply deserves better.

Thank you, Mr. Chairman, and I'll yield back.

[The prepared statement of Chairman Smith follows:]

PREPARED STATEMENT OF FULL COMMITTEE
CHAIRMAN LAMAR S. SMITH

Thank you, Mr. Chairman. And I appreciate Administrator Bolden's testifying today. While there are some areas of agreement between the Committee and the Administration in this budget, the president's request regrettably changes agreed-upon national priorities.

The President's request puts NASA in a tough position because it ignores his own sequestration levels and fails to identify offsets for increases of \$500 million. It is hard for Congress to consider this a serious proposal when it does not comply with the law and is not grounded in reality.

I also disagree with the Administration's continued attempt to redistribute funding within NASA. For example, Europa is one of the best destinations we have in our own solar system for finding life beyond our planet. Yet this year's request of \$30 million for the Europa mission is disappointing considering the mission's potential.

In contrast, Congress has funded a Europa mission at \$75 million, \$80 million, and \$100 million over the last three years. Missions like this, as well as the search for exoplanets and signs of life in other areas of our universe, captivate the American people.

I appreciate the progress, on the other hand, that has been made with other priorities such as the James Webb Space Telescope, the Transitioning Exoplanet Survey Satellite, and the Wide Field Infrared Space Telescope.

Overall, though, there is a lack of balance in the overall science account request. Congressional guidance and the decadal surveys advocate for a balanced portfolio of science activities. Unfortunately, the President's request does not adhere to that recommendation by the space experts.

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This year, the Administration requested another increase of \$175 million over last year's levels for a total increase of nearly \$2 billion. The administration doesn't even come close to funding other science divisions at this level.

The planetary science budget request is 43 percent lower than the earth science budget request. Also, the Earth Science request is almost as much as the Astrophysics division, the James Webb Space Telescope, and the Heliophysics Division combined. This is anything but a balanced portfolio. These increases come at the expense of NASA's high-priority exploration systems, which the White House has once again attempted to raid to fund the Administration's environmental agenda.

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The Administration continues to starve NASA's exploration programs to fund a partisan environmental agenda. NASA simply deserves better.

Thank you, Mr. Chairman, and I yield back.

Chairman PALAZZO. Thank you, Chairman Smith.

Let me introduce our—today's witness. Our first and only witness today is the Hon. Charles F. Bolden, Jr. General Bolden has been the Administrator of NASA since 2009. 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 United States Naval Academy.

In order to allow time for discussion, please limit your testimony to five minutes. Your entire written statement will be made part of the record.

I now recognize General Bolden for five minutes to present his testimony.

**TESTIMONY OF THE HONORABLE CHARLES F. BOLDEN, JR.,
ADMINISTRATOR, NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION (NASA)**

General BOLDEN. Thank you very much, Mr. Chairman, and Mr. Chairman and Members of the Subcommittee, five years ago yesterday, President Obama came to the Kennedy Space Center and laid out what I consider to be a bold, transformative agenda for NASA. He challenged us to embark on a journey to Mars. He challenged us to extend the life of the International Space Station and increase Earth-based observations. He called for investments in new, advanced technologies that will not only take Americans farther into space than ever before but also will provide spinoff benefits and create high-paying jobs here at home. Five years later, we've made landmark progress toward these goals. SpaceX's successful launch just this week is a shining example.

The budget proposed by the President furthers the goals we share of extending our reach into space while strengthening American leadership here at home. It is an \$18.5 billion investment that represents a leap into a future greater of discovery, job creation and economic growth as well as a healthier planet.

Thanks to the hard work of our NASA team and partners all across America, we've made a lot of progress on our journey to Mars. In fact, we have now progressed farther on this path to sending humans to Mars than at any point in NASA's history, and this budget will keep us marching forward.

The support of this Subcommittee and the Congress are essential to this journey. The International Space Station is the crucial first step in this work. It is our springboard to the rest of the solar system, and we are committed to extending space station operations to at least 2024. Thanks to grit, determination, and American ingenuity, we've returned ISS cargo resupply missions to the United States in-sourcing these jobs and creating a new private market in low-Earth orbit.

Under a plan outlined by the Administration earlier in its term, we have also awarded two American companies, SpaceX and Boeing, fixed-price contracts to safely and cost-effectively transport our astronauts to the space station from U.S. soil. This will end our sole reliance on Russia. It is critical that we receive the funding requested for 2016 so that we can meet our 2017 target date and stop writing checks to the Russian space agency.

Our newest, most powerful rocket ever developed, the Space Launch System, or SLS, has moved from formulation to development, something no other exploration-class vehicle has achieved since the agency built the space shuttle. The Orion spacecraft performed flawlessly on its first trip to space this past December. The SLS and exploration ground systems are on track for launch capability readiness by November of 2018, and the teams are hard at work on completing technical and design reviews for Orion.

Our budget also funds a robust science program with dozens of operating missions studying our solar system and the universe. New Horizons is preparing for its arrival at Pluto in July and Dawn has entered into orbit around the dwarf planet Ceres.

Before we send humans to Mars, robots are paving the way. We are at work on a Mars rover for 2020 and have begun planning a mission to explore Jupiter's fascinating moon Europa.

NASA is a leader in Earth science and our constantly expanding view of our planet from space is helping us better understand and prepare for these changes. NASA has 21 research missions studying Earth, and in the last year alone, we launched an unprecedented five more. We also are at work on Humanity's first voyage to our home star, a mission that will repeatedly pass through the sun's outer atmosphere.

NASA's Hubble, Chandra and Kepler Space Telescopes explore the universe beyond our solar system. Hubble's successor, the James Webb Space Telescope, is taking shape right now out in Maryland, and a new mission is in development to extend Kepler's pioneering work in finding planets.

Technology drives science exploration and our journey to Mars. With the President's request, NASA will continue to maintain a steady pipeline of technology to ensure that we continue to lead the world in space exploration and scientific discovery.

NASA is also with you when you fly, and we are committed to transforming aviation by dramatically reducing its environmental impact, maintaining safety in more crowded skies, and paving the way toward revolutionary aircraft shapes and propulsion systems.

Mr. Chairman, America's space program is not just alive; it is thriving. The strong support we receive from this Subcommittee is making that happen, and I particularly appreciate the generous FY 2015 appropriation. As the President said at the Kennedy Space Center, and I quote, "For pennies on the dollar, the space program has improved our lives, advanced our society, strengthened our economy, and inspired generations of Americans." NASA looks forward to working with the Congress to continue making this vision a reality.

I would be pleased to respond to your questions.

[The prepared statement of General Bolden follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
April 16 2015

Statement of
The Honorable Charles F. Bolden, Jr.
Administrator
National Aeronautics and Space Administration
before the
Subcommittee on Space
Committee on Science, Space and Technology
U.S House of Representatives

Mr. Chairman and Members of the Subcommittee, I am pleased to have this opportunity to discuss NASA's FY 2016 budget request. The President is proposing an FY 2016 budget of \$18.5 billion for NASA, building on the significant investments the Administration has made in America's space program over the past six years, enabled through the strong and consistent support by this Committee and the Congress. This request will allow NASA to continue to lead the world in space through a balanced program of exploration, science, technology, and aeronautics research. NASA is an outstanding investment for our nation not only because we uncover new knowledge, but because we raise the bar of human achievement, inspiring the next generation of scientists, engineers and astronauts.

The FY 2016 request includes \$4,505.9 million for Exploration with \$2,862.9 million for Exploration Systems Development, \$1,243.8 million for Commercial Space Flight, and \$399.2 million for Exploration Research and Development. This funding, with critical investment from each of NASA's mission directorates, supports NASA's plans to, as the President said in his State of the Union speech, continue our journey to Mars and push "out into the solar system not just to visit, but to stay[.]" NASA has made tremendous progress on this journey, and we will continue to progress, with building momentum, through the years to come.

As part of our strategic, stepping stone approach to deep-space explorations, NASA is facilitating the development of a U.S. commercial crew transportation capability with the goal of launching NASA astronauts from American soil in the next couple of years. This initiative to facilitate the success of U.S. industry to provide crew transportation to low Earth orbit will end our sole reliance on Russia and ensure that we have safe, reliable and cost-effective access to the ISS and low-Earth orbit. The Commercial Products Contracts allowed potential providers to better understand and align with NASA human spaceflight requirements and gave NASA early insight into vehicle designs and approaches. NASA has now entered the development and certification phase with the award of two FAR-based, fixed-price Commercial Crew Transportation Capability (CCiCap) contracts to American companies to transport our Astronauts to and from the ISS. SpaceX and Boeing have laid out milestones with the goal of certified commercial crew capability in 2017. The contractors are committed and at work. Our approach has emphasized competition and redundancy to ensure that NASA's human safety and certification requirements are met, we achieve the best value for the American taxpayer, and we end our sole reliance on Russia for transportation services. Now, we need the funding necessary to execute this plan to

completion. With continued support from the Congress, crews will again launch to the ISS from American soil by the end of 2017.

Technology drives science, exploration and economic opportunity. NASA will continue to maintain a steady pipeline of technology to ensure that we continue to lead the world in space capabilities. NASA's FY 2016 request includes \$724.8 million for Space Technology, to conduct rapid development and infusion of transformative space technologies that enable NASA's missions and advance our country's dynamic aerospace industry. Over the next two years, NASA will execute several in-space demonstrations including: a deep space atomic clock for advanced navigation, green propellant, and four small spacecraft demonstrating pioneering new technologies. This summer, NASA plans to again test our Low Density Supersonic Decelerator off the coast of Hawaii to continue proving in flight the new technologies critical for landing larger payloads on the surface of the Red Planet. Informed by the results of FY 2014 testing of solar array and thruster designs, NASA continues development of a high-powered solar electric propulsion capability to enable future exploration missions and meet needs of U.S. aerospace industry. This capability will be demonstrated on the Asteroid Redirect Mission. We will continue to progress toward a 2019 demonstration of space-to-ground laser communications, a capability that both American industry and NASA mission teams are eager to explore and harness. But the most exciting piece of our technology investments is the broad portfolio of research grants and other early stage investments, where the new technologies that will change the way we operate in space have a chance to move from ideas to components, to demonstrations of new systems and capabilities. These early stage investments are building stronger links between NASA and academia, and providing unique opportunities for the NASA workforce to innovate.

In December, NASA completed the first orbital test flight of the *Orion* crew vehicle, including a successful high speed reentry through the atmosphere. The Exploration Flight Test 1 (EFT-1) mission of *Orion* was nearly flawless. For the first time in a generation, a deep-space U.S. exploration vehicle has splashed down in the Pacific, and what we are learning from this test gives us increasing confidence in the systems we are designing.

Just as we have recently tested *Orion* by sending it on a shorter version of its future missions, we are continuously testing and experimenting on the International Space Station (ISS) in preparation for long-term missions in deep space. The Administration has committed to extending operation of the International Space Station to at least 2024. The FY 2016 request includes \$4,003.7 million for Space Operations, including \$3,105.6 million for ISS. Two commercial providers are now under contract to supply cargo to this critical asset, making the extension possible and giving us increasing confidence in our long-term strategy. On March 27, astronaut Scott Kelly began a one-year mission aboard the ISS to learn more about how to live and work in space for the long term. We will compare his vital signs to those of his twin brother, Mark, here on Earth in a first-ever experiment using identical twins to learn more about the effects of living in space. This is just one example of the vital knowledge and technology that our outpost in space will provide over the coming decade. The Space Station 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.

For the next step on the journey, NASA is developing the required deep-space exploration infrastructure while we plan for the earliest missions. NASA has established Agency Baseline Commitments for the Space Launch System (SLS) and Exploration Ground Systems (EGS), each of which supports a launch capability readiness date for Exploration Mission 1 (EM-1) of November 2018. EM-1 is the first mission for SLS and Orion. NASA remains on schedule for this EM-1 launch readiness date for SLS and EGS. Baseline cost and schedule for *Orion* are now being developed. NASA's budget request provides the funding needed to keep SLS, *Orion*, and EGS on track. NASA will determine the integrated launch date for the EM-1 mission after all critical design reviews are complete, later this year. SLS and *Orion* are

critical to human spaceflight beyond low-Earth orbit as part of an evolvable, sustainable, and affordable exploration program.

The journey to Mars runs through cis-lunar space. NASA's initial deep-space mission, EM-1, will launch to a "Distant Retrograde Orbit" around the Moon. 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. In this 'proving ground' of cis-lunar space, we will prepare for future deep space missions that will lead us to Mars. In late 2020, NASA plans to launch an advanced solar electric propulsion (SEP) based robotic spacecraft to approach an asteroid and remove a multi-ton boulder. After removing the boulder, the SEP spacecraft will redirect the asteroid in a demonstration of slow push deflection, a technique relevant to potential future planetary defense missions, and take the asteroid boulder to a stable Distant Retrograde Orbit around the moon. In 2025, launched by SLS, *Orion* will carry a two person crew on a 24-25 day mission to rendezvous and dock with the robotic SEP spacecraft in cis-lunar space. NASA will maneuver the integrated Orion and robotic vehicle stack in lunar orbit for about five days. The crew can then conduct Extra Vehicular Activities (EVA) to examine the asteroid boulder and collect samples before returning to Earth. NASA's plan leverages development efforts from existing programs across NASA mission directorates, and provides a critical opportunity to exercise our emerging deep space exploration capabilities.

As NASA strives to achieve the goal of sending humans to Mars, it is important to remember we are already there. For 40 years, increasingly advanced robotic explorers have studied the Red Planet. This has dramatically increased our scientific knowledge and helped pave the way for astronauts to travel there. Our latest Mars spacecraft, MAVEN (Mars Atmosphere and Volatile EvolutioN), arrived last September to study the upper atmosphere and joined a fleet of orbiters and rovers on the surface. Next year, we will send the InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) lander to study the planet's deep interior. In 2020, a new rover, building on the incredible success of Curiosity, will help us prepare for the arrival of humans at Mars. The Mars 2020 rover will address the highest priority Mars science objectives recommended by the Planetary Decadal Survey and will carry exploration technology investigations focused on capabilities such as in-situ resource utilization that will help in our planning for future human missions.

Mars is a key destination, but only one point on humanity's journey of discovery. Ours is a journey of understanding reaching through our Earth system, across our solar system, and beyond, deep into the universe. The FY 2016 budget request includes \$5,288.6 million for Science to continue that mission, with \$1,947.3 million for Earth Science, \$1,361.2 million for Planetary Science, \$709.1 million for Astrophysics, \$620.0 million for the James Webb Space Telescope, and \$651.0 million for Heliophysics.

NASA's Planetary Science program continues to expand our knowledge of the solar system, with spacecraft in place from the innermost planet to the very edge of our sun's influence. After nine years and three billion miles of travel, the New Horizons spacecraft awakened and began to prepare for its arrival in the Pluto system in July. Right now, Dawn has entered into orbit around the dwarf planet Ceres. Juno is speeding toward Jupiter where it will not only send back unprecedented data from a first ever polar orbit of our giant neighbor, but will also demonstrate how solar power can work at great distances from the sun. With the FY 2016 request, NASA will continue development of a robotic asteroid rendezvous and sample return mission, dubbed OSIRIS-REx, planned for launch in 2016. OSIRIS-REx will approach the near-Earth Asteroid Bennu, map the asteroid, and collect a sample for return to Earth in 2023. Looking further to the future, NASA is planning a mission to explore Jupiter's fascinating moon Europa, selecting instruments this spring and moving toward the next phase of our work.

The most important planet we study is the one on which we live -- Earth. Today, 21 NASA-developed research missions orbit Earth and provide a quantitative understanding of our complex planet, its origins and its future. In the last year, we have launched an unprecedented five Earth science missions, starting with the Global Precipitation Measurement Core Observatory (GPM) that already has observed Hurricane Arthur's brush of the East Coast last July. The Soil Moisture Active Passive (SMAP) mission, launched in January, will give us for the first time ever, a picture of soil moisture on a global scale, allowing scientists to monitor droughts and predict flooding caused by severe rainfall or snowmelt. New research missions in formulation include PACE, the Pre-Aerosol, Clouds and ocean Ecosystem continuity mission, that observes ocean color, aerosols, and clouds; NISAR, the NASA-ISRO Synthetic Aperture Radar mission, being developed in partnership with the Indian Space Research Organization to measure complex processes such as ecosystem disturbances and ice-sheet collapse; and CLARREO, the Climate Absolute Radiance and Refractivity Observatory Pathfinder that will begin pre-formulation this fiscal year.

The Landsat series of satellites is a cornerstone of our Earth observing capability. The world relies on Landsat data to detect and measure land cover/land use change, the health of ecosystems, and water availability. The President's FY 2016 request recognizes Landsat's critical importance and sets out a multi-decadal plan for an Earth-observing architecture that ensures data continuity and reliability. The Sustainable Land Imaging program partnership with the Department of the Interior's U.S. Geological Survey will include flight of a thermal-infrared free flyer and an upgraded Landsat-9 mission, while infusing new technological developments for future missions and ensuring consistency with the existing 42-year Landsat data record.

Twenty-five years ago this April NASA deployed the Hubble Space Telescope. Hubble is still doing amazing science, and the last textbook that will have to be revised because of its discoveries has not yet been written. In just slightly over three years, NASA plans to launch the James Webb Space Telescope (JWST), Hubble's successor, and continue to reveal the unknown with the largest observatory ever put into space. This amazing telescope is taking shape right now in suburban Maryland, where this year the mirrors will be installed on the telescope backplane. The "heart" of the telescope that holds its instruments successfully completed a nearly four-month test in a cryogenic thermal vacuum chamber. NASA's Astrophysics program operating missions include the Hubble, Chandra, Spitzer, and Kepler 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. With the FY 2016 request, NASA will continue development of the Transiting Exoplanet Survey Satellite (TESS). TESS will extend the pioneering work of the Kepler Space Telescope, which showed us that virtually every star in the sky has a planetary system. TESS launches in 2018 and will discover rocky exoplanets orbiting the nearest and brightest stars in the sky in time for Webb to conduct follow-up observations. NASA will also continue pre-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.

Just as the most important planet that we study is the Earth, the most important star that we study is our own. NASA's Heliophysics Program is monitoring the Sun, near-Earth space, and the space environment throughout our solar system, with 29 spacecraft making up 18 missions. These missions work toward one goal: to better understand the sun and its interactions with the Earth and solar system, including space weather. The FY 2016 request supports development of NASA's Solar Probe Plus (SPP) mission, planned for launch in 2018. SPP will be humanity's first voyage to our home star and will repeatedly pass through the Sun's hot outer atmosphere. NASA will also begin science operations of the Magnetospheric Multiscale (MMS) mission to investigate how magnetic fields around Earth connect and disconnect, explosively releasing tremendous amounts of energy in a process called magnetic reconnection.

NASA's Aeronautics research is making air travel cleaner, safer, and more efficient. Every U.S. aircraft and U.S. air traffic control tower has NASA-developed-technology on board. NASA's FY 2016 budget request includes \$571.4 million for Aeronautics to fulfill the Agency's strategic research agenda, addressing the most critical challenges facing the aviation sector. NASA is improving safety and reducing development costs of new aviation technologies, developing integrated air traffic management tools to expand airspace capacity with more fuel-efficient flight planning and diminish delays, and researching next generation aircraft configurations, efficient engines, and low carbon propulsion systems such as hybrid electric technology systems. NASA is enabling the future of unmanned and autonomous flight by providing technical data and analysis to directly inform FAA rulemaking related to Unmanned Aircraft Systems (UAS), funding technology development to address emerging needs for UAS integration, and initiating fundamental research in autonomous systems for aviation. Also in FY 16, NASA is initiating a series of flight demonstrations focused on environmental performance, and expanding our portfolio of rapid-turnover feasibility demonstrations to infuse new ideas into our research program. NASA's aeronautics research continues to play a vital leadership role to air travel and commerce by enabling game-changing technologies and innovation that allow the U.S. aviation industry to continue to grow and maintain its global leadership role. NASA is truly with you when you fly.

NASA's spacecraft are voyaging beyond the solar system, we are developing a mission to pass right through the Sun's atmosphere, and our spacecraft are exploring the planets in between. The venerable Hubble Space Telescope is looking back into deep time, Kepler is demonstrating the prevalence of planets around other stars, and the James Webb Space Telescope is on the way. An early version of Orion splashed down in the Pacific, Astronaut Mark Kelly is preparing for a one-year mission in space, and the Space Launch System is on track for a November 2018 launch capability. NASA is embracing its mission as never before. NASA looks forward to working with the Committee and the Congress to make this vision a reality.

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

Maj. Gen. Charles Frank Bolden, Jr., (USMC-Ret.) was nominated by President Barack Obama and confirmed by the U.S. Senate as the 12th Administrator of the National Aeronautics and Space Administration. He began his duties as head of the agency on July 17, 2009. As Administrator, Bolden leads a nationwide NASA team to advance the missions and goals of the U.S. space program.



At NASA, Bolden has overseen the safe transition from 30 years of space shuttle missions to a new era of exploration focused on full utilization of the International Space Station and space and aeronautics technology development. He has led the agency in developing a Space Launch System rocket and Orion spacecraft that will carry astronauts to deep space destinations, such as an asteroid and Mars. He also established a new Space Technology Mission Directorate to develop cutting-edge technologies for the missions of tomorrow. During Bolden's tenure, the agency's support of commercial space transportation systems for reaching low-Earth orbit have enabled successful commercial cargo resupply of the space station and significant progress toward returning the capability for American companies to launch astronauts from American soil by 2017. Bolden has also supported NASA's contributions toward development of developing cleaner, faster, and quieter airplanes. The agency's dynamic science activities under Bolden include an unprecedented landing on Mars with the Curiosity rover, launch of a spacecraft to Jupiter, enhancing the nation's fleet of Earth-observing satellites, and continued progress toward the 2018 launch of the James Webb Space Telescope, the successor to the Hubble Space Telescope.

Bolden's 34-year career with the Marine Corps also 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 and piloting two others. 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 his nomination as NASA administrator, Bolden was Chief Executive Officer of JACKandPANTHER LLC, a small business enterprise providing leadership, military, and aerospace consulting, as well as motivational speaking.

Born Aug. 19, 1946, in Columbia, S.C., Bolden graduated from C. A. Johnson High School in 1964 and received an appointment to the U.S. Naval Academy. He 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 between 1972 - 1973.

Bolden earned a Master of Science degree in systems management from the University of Southern California in 1977. In 1978, 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 in Houston; Chief of the Safety Division at Johnson (where he oversaw efforts to return the shuttle to flight safely after the 1986 Challenger accident); lead astronaut for vehicle test and checkout at the Kennedy Space Center in Florida; and Assistant Deputy Administrator at NASA Headquarters. After his final shuttle flight in 1994, he left NASA and returned to active duty with Marine Corps operating forces as the Deputy Commandant of Midshipmen at the U.S. Naval Academy.

In 1997, Bolden was assigned as the Deputy Commanding General of the 1st Marine Expeditionary Force in the Pacific. 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. He 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 - 2002. He retired 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 Chè, a lieutenant colonel in the Marine Corps, who is married to the former Penelope McDougal of Sydney, Australia, and Kelly Michelle, a plastic surgeon at the Howard University Hospital in Washington.

Material requested for the record on page 46, line 1044, by Chairman Smith during the April 16, 2015, hearing at which Administrator Charles Bolden testified.

NASA is planning for an Independent Cost Estimate (ICE) on the ARM robotic mission in support of Key Decision Point-B. We anticipate that the ICE will be available in the first quarter of calendar 2016.

Chairman PALAZZO. Thank you, Administrator Bolden, for your testimony. The Chair recognizes himself for five minutes for questions.

The NASA Authorization Act of 2010 directed NASA to develop the Orion crew vehicle and the Space Launch System, or the SLS rocket. The development of these systems is managed by NASA's Exploration Systems Development program. Congress has consistently provided more funding for exploration systems development than NASA has requested. This was true even in the FY 2013 budget despite reductions due to sequestration.

The first test flight of Orion and SLS without a crew, known as EM-1, was formerly expected in 2017. When NASA completed key decision point C on the SLS last year, why didn't NASA use the review to develop a budget to maintain the 2017 launch date instead of using the Joint Confidence Level development process to delay the launch and cut the budget?

General BOLDEN. Mr. Chairman, you mentioned the 2010 Authorization Act, and I was going to go back to that anyway because that is what established the bipartisan priorities for this agency, and I will just review them. They're the James Webb Space Telescope, exploration through the Space Launch System and Orion, and ISS at that time extended to 2020. We have subsequently gotten it extended to 2024, and we recently got the agreement from our Russian partners that they too believe that we should extend ISS to 2024.

We have done everything that we promised in the appropriations—in the Authorization Act, and we continue to be focused on those as our key priorities. We have actually accomplished, as you have already mentioned, many of the things that many people would not have believed we would have done by now. If you go to Michoud, we are actually welding barrel sections for SLS. If you go down to the Cape, we're going through the study of Orion from its first flight trying to get it ready. We are working on the next milestone for Orion where we will go through a similar process that we did for SLS and the ground systems so that we can establish an availability date for the first integrated flight of Orion and SLS.

We have taken the funds that the American taxpayer has allowed us to have, and I think we have delivered on the promises that we've made to this Congress and to the American public.

Chairman PALAZZO. I don't think you actually answered the question. So after the decision point C was made, why didn't NASA go back and use the Joint Confidence Level to try to maintain the 2017 target?

General BOLDEN. The team did what I asked them to do. I originally said I am willing to accept a 30 percent confidence level where NASA accepts as a general rule a 70 percent confidence level, and so that everybody understands what that is. That says that we are 70 percent confident that we can do this project within the budget that we proposed and by the date that we proposed. Once we went through KDP-C, I could have said okay, let's go back to a 30 percent confidence level. That would have almost guaranteed that we wouldn't make 2017 or any other date, and I have promised this Committee and others that we're past telling you that we're going to do something and then not performing.

I think if you look at our performance over the last few years, whether it's in science, in human exploration or anything else, for the most part we have delivered on time, and that's because we have chosen a very structured process like the Joint Confidence Level process to tell us when we think things are going to be available and how much they're going to cost.

Chairman PALAZZO. Okay. I understand that, and I just want to kind of remind people that several times you've testified in front of this Committee that we were absolutely on schedule for 2017 launch and that even the lower level funding requests that came from NASA, Congress always exceeded what the President's ask was because of the importance of SLS and Orion.

The NASA Advisory Council (NAC) recently voted unanimously to find that NASA's proposed Asteroid Redirect Mission, or ARM, ought to be repurposed toward a mission to Mars itself. They claim that ARM's asteroid retrieval aspect didn't efficiently contribute to the journey to Mars and that the scientific material provided by ARM would be a duplication of work performed by OSIRIS-REx. NAC was further skeptical of ARM because NASA already has a robotic asteroid sample return mission in OSIRIS-REx, which would cost significantly less than the ARM. Have you considered the NAC's alternate proposal of simplifying ARM into a Mars mission that functions purely as a solar electric propulsion test bed?

General BOLDEN. Mr. Chairman, ARM is a precursor for Mars. ARM is a critical component of getting humans to Mars. Among the things that the ARM mission does is it forces us so it is providing us the opportunity to upgrade our solar propulsion to high-energy solar electric propulsion that will enable us to move large masses from Earth to Mars or from lunar orbit to Mars. That is essential. The NAC has said that no matter what we do with ARM, we must not lose that demonstration.

The second thing that ARM allows us to do, provided we're successful in getting a portion of an asteroid or an asteroid into orbit around the moon is, it allows us to put humans in connection with that particular piece of an asteroid to learn how to operate in low-gravity or no-gravity environments, the way we're going to have to do it when we go to Mars. So ARM accomplishes several, two at least, of the primary functions or technology developments that even the NAC says we have to do.

The other thing, you know, I appreciate the fact that people appreciate that we're going to bring back some samples with OSIRIS-REx. What people don't appreciate is that we're going to have astronauts interacting with an asteroid in orbit around the moon, and that is not being done by any other mission on the books. It has not been done before.

And then finally, there is a small thing that is on my mind all the time, because Chairman Smith hosted Dr. Holdren and General Shelton and me to what I tell him all the time was the most substantive hearing I have participated in, and that was one on near-Earth objects, and at that time Mr. Posey, Mr. Brooks and others bombarded me with demands that I tell them what we were going to do if an asteroid was inbound, and I finally gave up and said I would pray. That was not a good answer. That was not a tech-

nical answer. It made big time with my priest but it didn't help anywhere else.

Chairman PALAZZO. All right. Well—

General BOLDEN. Today if asked that question, I would tell them that we now have a mission underway which is called the Asteroid Redirect Mission that is going to inform our ability to actually deflect an asteroid or do something to protect this planet. So, two years ago in the hearing, my answer was repeatedly, we don't have a thing we can do. That was the reason I resorted to my religion. Today I can tell you have a mission that is on the books that is being developed that will answer the question from Mr. Posey and Mr. Brooks and anyone else who is concerned about the threat from near-Earth asteroids.

Chairman PALAZZO. We can definitely probably hold additional hearings. I think we've held two—

General BOLDEN. Yes.

Chairman PALAZZO. —already on near-Earth objects and the threats that they may pose to Earth and the human race. But in essence, you disagree with your advisory committee?

General BOLDEN. Mr. Chairman, I don't disagree with the advisory committee. That's not my place. They are an advisory committee. That means in fact—you know, I find that—two of the people that I respect the most who are astronauts, are Buzz Aldrin and Gene Cernan, because I have to choose between their beliefs. Gene Cernan says I should be going to the moon. Buzz Aldrin says I should be going to Mars. I don't disagree with either of them. I respect their opinion. But only one of them, you know, is right as a number one priority. I happen to choose Buzz Aldrin's number one priority as Mars because moon is on the way. We will put people back on the moon but we can do that on the way to Mars. You can't get to Mars if you stop at the moon.

Chairman PALAZZO. All right. Well, I appreciate your responding to my questions, and of course, you know, without consensus in the scientific, the exploration and international communities, not to mention the people here on Capitol Hill, I think you will be challenged to make ARM last longer.

General BOLDEN. Mr. Chairman, may I—

Chairman PALAZZO. I really am three and a half minutes over, and I know she's going to take at least three and a half minutes over too. Hopefully she won't. This is a well-attended hearing. But at this time I recognize Ranking Member Edwards for her questions.

Ms. EDWARDS. Thank you, Mr. Chairman, and you've come to know me so well.

Administrator, I want to go back to the budget proposal because I indicated this in my opening statement about this idea of constancy of purpose for NASA and what's required, and so I'm really confused. Part of me thinks it's kind of a game where the proposed reductions to SLS and Orion from the FY 2015 enacted levels and then Congress come back and the Administration proposes one thing, Congress comes and puts it in. Here we go again. The proposal is one thing, and I don't know, is there an expectation that Congress is going to say well, SLS and Orion of course, those are signature important programs and we'll put the money in. If this

is an important priority for the agency and for the nation, why don't you just put it in the budget and not have us sit there and ask questions about why it's not in the budget? And knowing that the proposal that you have in front of us probably doesn't support the integration that's necessary. It may not support the pathway along to EM-2. What's the real number for SLS, Orion? And maybe we should pencil that in.

General BOLDEN. Congresswoman, I honestly believe that the number that we put in the President's budget will get us to the target dates and the target achievements that we say. As I have responded to this and many other committees, when you give me more money, I appreciate it and I use it, and what we do is, we buy down risk. We were able to get to a 70 percent confidence level on SLS and Orion, or SLS and the ground systems, because we did have more money. I was willing to accept a lower probability but I don't think we should operate that way. So if you gave me more money today and told me to spend it on SLS, that's not going to change the date of availability for SLS for EM-1. I would much rather take the money as we have it planned out to make a sustainable program.

We are not talking about one flight. In fact, when we go through the milestone review for Orion, we're going to give you a budget plan and a date that we think we can make for the second flight of Orion and SLS because that's the critical flight for us, not the first flight. The second flight is the first human flight, and so we made the decision that for Orion, then KDP-C and other milestones would look at the first human flight. If you tell me to put the money into SLS for EM-1, I can do that, and then we have a one-flight program that I've got to later figure out how to sustain.

Ms. EDWARDS. Okay. So, I appreciate your saying that, but let's just remember this day when that is said because if we come down the line, we're going to take you at your word—

General BOLDEN. Yes.

Ms. EDWARDS. —that you don't need that, and so then I want to ask you about the impact of the cuts that are proposed to aeronautics on our ability to maintain leadership in aviation and aeronautics with an increasingly competitive global environment. We've had that conversation before on this Committee where it feels like aeronautics kind of gets short shrift. So can you explain those cuts?

General BOLDEN. The cuts came at my direction because that's—when I looked at the top line that I was willing to submit, which was over what we had been asked to submit, I had to decide where we could make the most, where we could pick up the most with money that we had, and aeronautics was once again an area that I had to take some funds from.

So it was simply prioritizing funds that we had and trying to see what we could do the most with. Dr. Jaiwon Shin and his team did a new strategic plan, they have six strategic thrusts, and we think with the funds that we put in the budget, we'll be able to continue to make progress in those areas.

Ms. EDWARDS. So let me just ask you then about Europa and the Europa mission really quickly because there are also proposed reductions in Planetary Science in the middle of the development of a very ambitious Mars 2020 mission. So can you explain that?

General BOLDEN. Yes, ma'am. You know, I get this from the planetary scientists all the time. In July, we will achieve something that has never before been done by anyone, any country, any anything. We will have satellites that will be studying, orbiting several planets in the solar system and the dwarf planet Pluto, and we will have a spacecraft that is in interstellar space. We managed to do that with limited funds because we appreciate everything that the Congress has given us but it is limited, and so we can either take stuff off the plate or we can figure out ways to do the best we can to achieve the missions that you have given us, and sometimes we have to come back and tell you it can't be done in the time frame that you want. People want Europa in 2022. It can't be done in that time frame. We will continue to say that. We know about how long it will take us to put a mission on Europa. So it's simply a matter of prioritization again.

All of you have mentioned in your opening statements that we're over the Budget Control Act number. Yes, we are, maybe.

Ms. EDWARDS. Oh, you didn't hear that complaint from me.

Because the time is limited, even though I'm going over, out of respect for the Chairman, I didn't want to go here but now that you've taken me to Asteroid Redirect, in our authorization, and we know that it is not law, but you've promised a roadmap on sort of laying out what the choices are and how we're going to get to Mars, and what happens is that you come in front of the, you know, Committee, and with all due respect, you haven't provided the roadmap but you've said this is the direction that we're going using the Asteroid Redirect, and it feels like we're missing a little bit of communication here.

It would be important for this Committee to have a roadmap, to have something that says here are the choices and this is why we've decided to go in this direction, and instead what we get is a budget line for Asteroid Redirect that doesn't say here are the choices but says this is the choice we've made. So which is it? Have you all just ditched any other possibilities and everything is focused on the Asteroid Redirect as the way to go to Mars? Because if that is true, then what's the point of providing a roadmap?

General BOLDEN. Congresswoman, the place we're going is Mars. Our ultimate focus is the journey to Mars, and everything comes back to that. When you talk about getting to Mars, we need high-energy solar electric propulsion. We need to be able to operate in and around low-gravity, no-gravity bodies. The Asteroid Redirect Mission is going to provide that. We need a sustained low-Earth orbit infrastructure from which we can operate. The International Space Station is vital to that. We've gotten the International Space Station to agree that we will extend it to 2024. That is essential. We have to supply the International Space Station.

That takes us to Commercial Crew and Cargo. I want to get away from dependence on the Russians. We now have American commercial cargo capability demonstrated. The importance of two providers was ultimately eminently demonstrated when we lost Antares and Cygnus last October because when we launched SpaceX 6, it was loaded with everything that would've been on Cygnus. So without having two providers, redundancy and American providers, we would not have been able to do that.

We are on the road to having commercial crew availability in 2017. So that's going to take us to Mars. If I don't have commercial crew and cargo, the International Space Station, I can't get to Mars.

Ms. EDWARDS. My time is like totally gone, but I'm just going to say to you that I think that this Committee, many of us want to figure out a way that we can best support the ultimate goal of Mars, but we have to have some level of communication with the Committee laying out what the alternatives are, what the choices are, and not just have you come to the Committee and say this is what we're doing. Our job is to take in the information and say this is how we as a Congress, as an American people, feel that we need to go in this direction, and that hasn't happened yet. It would be a really good idea offline, online, whatever it is, bring it in to us, put it on paper, lay it out for us so that we have the ability in subsequent authorizations to help figure that out with you and not just be told a direction that we're going without any level of communication.

Thank you very much.

General BOLDEN. Yes, ma'am.

Chairman PALAZZO. Thank you, Ms. Edwards. I now recognize Mr. Brooks for five minutes.

Mr. BROOKS. Thank you, Mr. Chairman.

General Bolden, the acronym NASA stands for the "National Aeronautics and Space Administration." I underscore the words "aeronautics and space," yet each year almost \$2 billion of NASA funding is diverted from aeronautics and space to Earth sciences, i.e. global warming and climate change and similar initiatives. To the extent America wishes to spend taxpayer money on global warming and climate change, I'd submit these programs should be paid for out of the Environmental Protection Agency's budget, not America's aeronautics and space budgets.

General Bolden, given a choice between adequately funding NASA's aeronautics and space efforts such as the Space Launch System, the various telescopes, planetary sciences and things of that nature so that America's space program is no longer reduced to hitching a ride from Russia to get to the Space Station and diverting NASA funding to the study of the Earth's environment, a subject I submit is better suited to the Environmental Protection Agency, what is your preference and why?

General BOLDEN. Congressman Brooks, NASA since its inception has had responsibility for exploring the universe and helping us understand it better, and also taking care of this planet, which I think it happens to be my favorite planet. If I followed the logic that you just presented, since science is missing from the acronym—and people have suggested that NASA drop science from its programs because it's not in the acronym. However, that would be absurd to do. NASA is eminently responsible for science and we provide four areas of science—Earth science, astrophysics, planetary science and heliophysics—and that is our portfolio and we cover that adequately with the funds that we are given. We are able to do things. We provide instruments and satellites that are used by other operational agencies. We don't do weather forecasting. We don't do operational science.

Mr. BROOKS. I understand that. If I could please interject for a moment, my question is one of choice. Do you want aeronautics and space money, NASA money, going to aeronautics and space or are you comfortable with the diversion of about \$2 billion a year to global warming, climate change initiatives, which in my judgment should be funded by the Environmental Protection Agency, thereby freeing up that \$2 billion for aeronautics and space.

General BOLDEN. Congressman, my choice is to distribute the money in the best way that we feel possible to cover our portfolio because we do feel that science, aeronautics, human exploration and technology development are critical missions or critical functions that NASA has to do. We don't divert money from science for human exploration. We don't divert money from human exploration for science. We present what we think is a logical budget that will enable us to achieve all of our missions any time that we lay out in those budgets, and I think we're doing that very well. I think—

Mr. BROOKS. Well, General Bolden, if I might continue, in my opinion, based upon what I have seen since the cancellation of the shuttle program, since America has been reduced to hitching a ride from the Russians for our astronauts, America is losing ground and could arguably no longer be the preeminent space program, which was a position we've held since the 1960s.

Given this choice, if Congress were to shift NASA Earth sciences funding, roughly \$2 billion a year, to restoring America's preeminence in space and requiring that global warming and climate change study be paid out of the Environmental Protection Agency's existing budget so that you still have that kind of Earth science being funded but out of the Environmental Protection Agency, which seems to be a more logical agency since we're talking about the environment, would you support that shift of \$2 billion a year to NASA's aeronautics and space programs with the understanding that the EPA would be doing the environmental work on global warming and climate change?

General BOLDEN. Mr. Chairman, there is only one agency that sends people to space, as you all have said. That's NASA. Right now there is a preeminent agency that provides the instrumentation that gathers the data to do the work of EPA and NOAA and others that you say. If we stop doing that, there is no other agency that does it. The reason that our earth science—

Mr. BROOKS. Now wait a second—

General BOLDEN. —had an increase this year was because we build satellites for NOAA.

Mr. BROOKS. There's nothing that would stop the EPA out of their budget from hiring NASA to put those satellites up there, is there?

General BOLDEN. That's what we do right now, so why do it and pretend we are not—

Mr. BROOKS. But right now it's cutting into the space program, I would submit, and as a consequence, I think you've got a very good argument out there that America is losing ground and the highest ground, and that's space, and we're doing it because aeronautics and space has not been adequately funded over the years.

General BOLDEN. Congressman—

Mr. BROOKS. Now, I'm trying to figure out a way to improve funding for aeronautics and space, and if I understand correctly, here you are, the NASA Administrator, and you're saying no, we don't want that \$2 billion for aeronautics and space and we don't want the Environmental Protection Agency to take over an environmental issue, which would be global warming and climate change initiatives. Am I erring in my interpretation of your remarks?

General BOLDEN. Congressman Brooks, if you're saying that I disagree that we should take the money that NASA has in Earth science and shift it to aeronautics and space, you are absolutely right. I disagree. I think that the balance of funds that NASA has today in our science, human exploration, aeronautics and space technology portfolios is about right, I am really sorry that you don't believe that we are the preeminent agency in the world for exploration in space.

I just came back from the Space Symposium, and there is no one out there who agrees with anyone who has that low opinion of NASA and the United States. We are the preeminent leader in the world, always have been, always will be.

Mr. BROOKS. Well, let me break it down. When it comes to human spaceflight, we are no longer the preeminent country in space. When it comes to non-human space endeavors, I think you can make an argument that America still has preeminence. But when you put the two together and when Russia has reduced the United States of America to saying if we want to go to their space station, we can do it by a trampoline, that's not the kind of preeminence at least I'm accustomed to having seen the Saturn V rocket built, researched and developed in the Fifth Congressional District of Alabama.

Chairman PALAZZO. The gentleman's time has expired.

Mr. BROOKS. Thank you, Mr. Chairman.

Chairman PALAZZO. At this time I recognize Mr. Beyer for five minutes.

Mr. BEYER. Thank you, Mr. Chairman.

General and Administrator, NASA's Wallops Flight Facility and Mid-Atlantic Regional Spaceport play a critical role in our nation's launch infrastructure providing half of the cargo resupply launches to the ISS as well as other important NASA and DOD missions. It's one of only four operational sites in the United States capable of orbital launch, and only one of two on the East Coast capable of supporting NASA's human spaceflight programs, and it's my understanding that last year Wallops nearly tied Vandenberg AFB for the number of launches. And last fall, the Congress with bipartisan and bicameral the support, appropriated \$20 million for NASA's Wallops for the long overdue range upgrades as well as support recovery from the Orb-3 accident last October. I was pleased to learn that the first \$5 million was actually—of the appropriate funding was released last week but I think I and all the Virginia delegation are concerned about five months after the bill is signed into law, the other \$15 million still hasn't flowed into Wallops. Can you tell me when that funding is going to come to Wallops and what the delay might be?

General BOLDEN. Congressman, we have continued to build Wallops up to what we consider to be a 21st century launch complex. It is our intent that Wallops will be returned to the capability of launching medium- and small-class orbital vehicles, and we will see that when Orbital Sciences is ready to launch again, the facility will be fully up and running. But if you look at the funds that we have expended through the years at Wallops, we don't count a particular pot, you know, for work on the pad or whatever. We're trying to restore it to a 21st century launch complex.

The \$5 million that we contributed to the repairs on the pad were because we took the leadership in trying to get the three teams together, meaning Orbital, Mid-Atlantic Regional Spaceport (MARS) and the State of Virginia to move, to get some movement on restoring the pad. So we felt it was essential to do that.

I would have to remind people that what is not counted because it wasn't in our budget but we were able to find ways to do it was, how did we get Wallops to the point where it could launch in the first place. We brought people up from Stennis, we brought people up from Kennedy, we brought people up from Langley to enable MARS and the State of Virginia to have an operating launch pad. So we have always supported Wallops with funds over and above what shows up in the budget for a particular budget line, so—

Mr. BEYER. Thank you, General.

General BOLDEN. —I pledge we'll continue that.

Mr. BEYER. We look forward to the other \$15 million. That would be great.

General BOLDEN. Yes, sir.

Mr. BEYER. I was very impressed with this notion of constancy of purpose and our Ranking Member Edwards' concerns. Much is made of it, and reading through all this, you see there's so much on your plate. Just look at the budget—exploration, space operations, science, aeronautics, education, et cetera, in specific programs, SLS, Orion, commercial crew, JWST, heliophysics, Earth science, et cetera, Mars, exoplanets, ISS, Landsat. Is there any way you can tell me what NASA's constancy of purpose actually is?

General BOLDEN. Oh, Mars is the planet that is most like Earth. It is the one that we believe may sustain life, probably did sustain some type of life and will sustain life when humans get there in the 2030s. It is critical for us to understand Mars like every other planet in our solar system so that we better understand planet Earth. We've been exploring Mars for about 40 years. Every precursor has been with one purpose in mind, and that's being able to put humans on that planet one of these days. That is the reason we have Curiosity there. That's the reason we're going to put Mars 2020 there, the reason we're going to launch InSight next year.

Mr. BEYER. So is it safe to say if I'm explaining NASA's constancy of purpose to a high school physics student, I'd say you can look at all this through the lens of Mars?

General BOLDEN. That is one example, and it depends on—if you're talking to kids in high school, some of them are going to have no interest in planetary science, so some of them may be interested. They may be techies, and then I need to be able to show them the constancy of purpose in NASA's Space Technology Mission Directorate that's enabling like them the young people back

here from Carnegie Mellon in a university that's noted for its computer science.

Mr. BEYER. So——

General BOLDEN. They've got to believe they can come to NASA and contribute also.

Mr. BEYER. I was clear and now I'm confused again. So it sounds like we have just a huge buffet at NASA rather than a single focus or a singled constituted purpose. Is there a way to define it clearly? We opened with all the concerns about we cut money from this and we added money to that, and where was our constancy of purpose?

General BOLDEN. When I talk about constancy of purpose, I'm really talking about exploration, and that is the primary focus of this agency in trying to keep up with the charter that established NASA in 1958 to understand our universe. We believe that if we can put humans on Mars, our journey—if we can shore up our journey to Mars and say we're going there, we may wander along the way as people always do when they're on a journey but that's the ultimate destination, here's the plan that we have in place that Congresswoman Edwards mentioned. We have three things we've got to do. We're Earth-reliant right now. We've got to get away from being Earth-reliant and that means we've got to spend some time in the proving zone. We've got to go back to the lunar environment so we'll be in cislunar space, and ultimately we want to be Mars-ready. We want to be Earth-independent.

So it takes all of these little pieces that I mentioned. Congressman Perlmutter just came in. He is one of my biggest cheerleaders for MAVEN. You know, we've got to understand Mars's environment and what happened to it in order to understand Earth's environment right now and what might happen to it if the magneto gets turned off, and——

Chairman PALAZZO. The gentleman's time has expired. At this time I'd like to recognize Chairman Smith for five minutes.

Chairman SMITH. Thank you, Mr. Chairman. Mr. Chairman, let me say at the outset that I think we've heard excellent questions today from both sides of the podium. I still think we're searching for more direct answers to a lot of those questions, and to that end, Director Bolden, let me go to the Asteroid Redirect Mission for a second.

It is amazing to me that the Administration actually thinks that changing this mission and securing an asteroid and taking it into orbit and around the moon and now change it to getting a boulder from an asteroid and putting it into orbit is going to somehow attract the American people's attention and inspire them.

But the main point I want to make here is that the NASA Advisory Council actually made a recommendation to you all, and it found "Instead of relocating a boulder from an asteroid, we suggest that a more important and exciting first use of this new solar electric propulsion stage would be a round-trip mission to Mars, flying it to Mars orbit and then back to the Earth-Moon system and into a distant retrograde lunar orbit." Why isn't the Administration following its own experts' advice?

General BOLDEN. Congressman Smith, we believe, I believe that we are going to stand a better chance——

Chairman SMITH. So you disagree with your experts? And you're entitled to do that.

General BOLDEN. I agree with some of my experts, who happen to think the Asteroid Redirect Mission is awesome.

Chairman SMITH. In the last two years, all the experts have recommended the NCR mission, and you all keep——

General BOLDEN. Mr. Chairman——

Chairman SMITH. —forging ahead.

General BOLDEN. With all due respect, Mr. Chairman, if I lined up the experts and had them sit——

Chairman SMITH. All of these experts have been unanimous. These experts have been unanimous in not recommending the ARM Mission, and you all just keep forging ahead, and I'm asking you why you're ignoring all these experts' advice.

General BOLDEN. Mr. Chairman, because I believe in constancy of purpose. I believe that my job is to determine the direction in which this agency is going to go, recommend it to you and to the President, and then pick that path and follow it. We are on a path——

Chairman SMITH. Director, I'd rather you listen to the experts more than maybe yourself in this particular instance.

General BOLDEN. I don't—I listen to the experts, and I——

Chairman SMITH. Well, I wish you would heed them and do what they recommend, but on that same subject of ARM, and another example of what I'm talking about, NASA's Advisory Council also said that you should conduct an independent cost estimate of ARM, and so far you have not committed to doing so. Will you commit today to conducting that cost estimate of ARM and the two mission options?

General BOLDEN. We committed to the——

Chairman SMITH. That's a pretty easy answer, yes or no.

General BOLDEN. We committed—because what you say we committed or what they recommended, we committed to them that when we get to beyond the mission concept review, which we have now done, that we will have an independent cost assessment——

Chairman SMITH. When can we expect to see that independent cost estimate since you're now at that point?

General BOLDEN. I will get that to you, sir. We are not—I don't have a date for an independent cost assessment on the option that we've selected for ARM.

Chairman SMITH. Well, do you have a month?

General BOLDEN. Mr. Chairman, I will take that for the record and I will get it to you.

Chairman SMITH. Is it this year, the next six months, the next three months?

General BOLDEN. Mr. Chairman, you know, I will take it for the record and I will get back to you.

Chairman SMITH. Okay. You're kind of proving what I said about these answers.

All right. Let me go to the next one. You proposed an overall cut in Planetary Science by \$76 million, Orion by \$98 million, SLS by \$344 million, and you've cut other space programs as well. That is why I happen to think the Administration is starving NASA.

But in regard to SLS and Orion, those are over \$450 million worth of cuts. You've got a situation where the GAO has said those \$400 million cuts are a risk to the program, and now the launch date has gone from 2017 to 2018. It seems to me that the Administration's actions contradict their words, because if you look at the money, Earth Science may be a priority but Space is less of a priority.

General BOLDEN. Mr. Chairman—

Chairman SMITH. When you look at the money, can you come to any other conclusion?

General BOLDEN. Yes, sir. I would say—I would request that people look at performance, that you look at achievement. I would ask people to look at the fact that we flew Orion in December. We finished—

Chairman SMITH. But if you look at the budget, if you look at the budget and you're cutting space and you're increasing Earth Science, doesn't that suggest that the Administration has a greater priority for Earth Science than Space?

General BOLDEN. Mr. Chairman, if we look at the money, we spent—since this Administration has come into office, we have spent \$49 billion on—

Chairman SMITH. I understand all that, but if you look at the cuts, don't cuts mean something?

General BOLDEN. Cuts mean that we are trying to effect—we are trying to select priorities and get the missions and the goals—

Chairman SMITH. That's my point. Your priority is not space; it's something else.

General BOLDEN. Our priority is—our priority is very clear. We are on a journey to Mars. We are trying to continue to get support from this Congress and the Administration on that journey to Mars. We have demonstrated that we know what we're doing.

Chairman SMITH. Then why did you cut the Space programs? You have SLS slipping a year. You're not going the right direction if Space is a priority. I'm not saying it's not a priority but it's less of a priority because of what those cuts represent.

General BOLDEN. Mr. Chairman, we have provided an availability for launch date for SLS and the Exploration Ground Systems as we have gone through our formal process of evaluating schedules and—

Chairman SMITH. And it's gone from 2017 to 2018.

General BOLDEN. We never presented a formal finding. We did not go through the formal process when we came up with a date of 2017. It's like Europa. I think I can do Europa in 2029. We will know—

Chairman SMITH. You don't consider 2017 to 2018 to be a delay then?

General BOLDEN. I do not consider it to be a delay, Mr. Chairman.

Chairman SMITH. This may be the only Administration in history that doesn't consider going from 2017 to 2018 being a delay. I happen to think it is.

I'll yield back. My time is expired.

Chairman PALAZZO. Thank you, Mr. Chairman. At this time the Chair recognizes Mr. Perlmutter for five minutes.

Mr. PERLMUTTER. Thank you, Mr. Chairman.

Administrator Bolden, good to see you. I do think that Chairman Smith and I are in total agreement on our desire to get our astronauts to Mars and to be very focused in that respect, and there are obviously other things that need to be done, whether it's looking back at Earth or looking farther into space. I would take issue with a couple of my colleagues. You know, to me, NASA is by far the preeminent space exploration agency in the world.

Now, I think what's important, and I think the real problem here—and the Chairman and I have had this conversation—is that I think we can get to Mars, and I would like to see us accelerate the time frame of us getting to Mars and do the other things that are important in terms of weather satellites and a number of the other responsibilities that you all take on, and I'd like to pull up a chart, because I think this is the real problem, and we've had this conversation.

So this is NASA's budget as a percentage of the federal budget over the last 40 years, and so as a result, we see when in the early years in 1962 through 1968 where your budget peaked, which was our effort to get to the moon, and it succeeded. But we had as a nation, we had to dedicate ourselves to doing that, and it cost us money, and since then, we have not been prepared as a nation to make it the priority that it was back then, and so you then are in a position where you have finite resources, which I think are too low for your agency, if our goal is to get to Mars and get there sometime within my lifetime. You know, I want to see us get there by 2020. I have no idea exactly how you can do it but I want to make sure you have the resources to do it and to do the other things that are important to the mission, whether it's MAVEN and understanding the atmosphere and what the heck happened as a precursor to us going to Mars.

And so I'd like you just to kind of respond to my rant if you would, and your budget as a percentage of federal spending.

General BOLDEN. Congressman, I appreciate your rant to be quite honest, and in many ways you're correct. But I don't want people to lose sight of what we've been doing over the last 40 years. We have been flying robotic precursors throughout this solar system for 40 some-odd years now. We have been on Mars, the only nation in the world to successfully land an operating vehicle on Mars. So those precursors are very important to our human journey to Mars.

We can't get there without the precursor missions because there are things we still don't understand. We can't get there without developing the technologies such as solar electric propulsion. We can't get there without developing the techniques such as operating in and around low-gravity and no-gravity bodies, all things that the ARM mission we hope will do. We can't get there without Commercial Crew and cargo. We have to get away from reliance on the Russians.

When we lost Columbia, nobody planned for that. The only way we were able to sustain our occupancy of the International Space Station was to call on our partners the Russians and to rely on them for a period of time. That has been far too long. With the funding that this budget requested, we can return the launch of

our astronauts to American soil and that is absolutely critical. I don't think—when it gets down to the basic fundamental question here, I don't think there's any disagreement between me and anybody on this panel. We all want to get humans to Mars. There is a correct way to do that and we cannot do it by saying we're going to fly a one-way mission or we're going to fly a solar electric propulsion vehicle out and bring it back. There is a progression through which we have to go. We've got to go from being Earth-reliant, go to the proving ground, and then get on out to Mars and be Mars-ready. And those are programs that are slow-developing that take time to make sure that we're doing the right thing, and that's what we're doing. We——

Mr. PERLMUTTER. All right. Well——

General BOLDEN. We are trying to institute constancy of course.

Mr. PERLMUTTER. Well, I do want to thank you and I felt it was a very successful mission, the first test flight of Orion, and I do want to see us accelerate. So to some degree I do agree with the Chairman. If we can continue to have our major focus getting to Mars, that's what I would like to see it be. I think we've got to, if that's the kind of mission and dedication we have, you have to see some increase in your budget so that we can do all the steps necessary to get us there and get us there promptly. Because if we're going to really have a mission that the nation can embrace and embrace enthusiastically, like they did that first test flight, we've got to keep it moving. You can't have too much time lag——

General BOLDEN. Yes, sir.

Mr. PERLMUTTER. —through this process. And with that, I have a whole bunch of other questions but I'll save those for my next round.

General BOLDEN. Yes, sir.

Mr. PERLMUTTER. And I yield back to the Chairman.

Chairman PALAZZO. I want to thank the gentleman.

At this time the Chair recognizes Mr. Rohrabacher for five minutes.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman.

The one thing that I've learned in my life is that people who try to do everything for everybody end up not being able to do anything for anybody. And that's why it's so important to make sure that we have goals in mind that are achievable as a package rather than just independently each goal is an important goal. And I would just have to say that I believe that we are not doing that. And I say "we." I don't mean just you. I mean all of us. We're part of the team that's—we are America's space team and it's not just NASA. It's all of us in this committee as well.

I think we have overreached and it will prevent us from accomplishing some very important goals that—we hear the arguments and I think they're legitimate arguments about having NASA being involved in global warming research and other things that are not—shouldn't be priorities. I understand the position you're in and you're doing a job in defending what the Administration's goals are and the Administration hired you on to this job to do this.

But let me just say I don't think that we are going to achieve the goals, even the important goals, unless we start being more realistic.

Let me ask you. I of course have been one over the years promoting—rather than the trip to Mars I’ve been promoting, utilizing the commercial involvement in space in order to let us accomplish things that are accomplishable in space. And the Commercial Crew launch system, and by your own budgets have suggested that the idea of going the more commercial direction actually is a valid methodology of achieving our space goals, our certain space goals at a cost-effective way.

And I understand that of course we’ve got—we’re now dependent on the Russians to buy six seats per year from the Russians in order to do—in order to maintain Space Station at a cost of \$76 million per seat, is that correct?

General BOLDEN. That’s approximate, sir.

Mr. ROHRABACHER. Okay.

General BOLDEN. Presently.

Mr. ROHRABACHER. And basically we are looking forward to the fact that Commercial Crew, the Commercial Crew Program will free us from that obligation. And, however, just a two year delay in what we have expected from Commercial Crew, we have a two year delay. That by my calculation is \$900 million extra that we’re spending for the Russians because the Commercial Crew formula has had to be pushed off for two years. Is that right?

General BOLDEN. That is correct, sir, and that is a delay. When I came into this position and we presented the Commercial Crew Program to this Congress and the Administration, we proposed a level of funding that would have had us launching this year. We did not get that level of funding. We did not get the—

Mr. ROHRABACHER. That’s correct.

General BOLDEN. —continuous support, and so we now hope to launch in 2017.

Mr. ROHRABACHER. Well—

General BOLDEN. If we don’t get what we ask for this year, then—because we now are working on contracts—

Mr. ROHRABACHER. Well, General, let me note that—I agree with what you’re saying, and the reason why we’ve had—we did—you didn’t get the money is because we’re draining money off for other projects like flying off to Mars in the long run and costing us almost a billion dollars because we haven’t—you know, we’re not doing things responsibly. That’s a billion-dollar waste as far as that—I’m concerned.

And let me just put it this way. If you calculate that—if you are calculating that a Commercial Crew approach and doing this through a commercial rather than through the old system that we had is actually going to save money in the long run, why are we—and we’re pouring—at the same pouring money into global warming, but also in the SLS and the Mars concept of putting a man on Mars rather than just rely on robots. Don’t we have—there’s been some indication by one of the companies that’s providing us Commercial Crew, SpaceX, that the owner of that company has said, well, he himself is interested in financing a trip to Mars. So if we do—if we have recognized that there is validity to letting the private sector get involved in this, why are we spending so much in the long run on Mars, which is costing us money in the short run because we’re not budgeting correctly? Why don’t we just hold

off on spending money and going to Mars to see if the private sector can contribute to that effort?

General BOLDEN. Mr. Chairman—or Mr. Congressman, the reason we're spending the money on it or we're investing is because experience has told us that only nations do the things that we're trying to do. Commercial companies will follow I hope. Commercial companies followed us to low-Earth orbit. We now have two companies that provide cargo support and hopefully two years from now will provide crew support. But that's only because we blazed the trail.

There is—I don't care what anyone says. Getting to Mars is hard and there is no commercial company that without the support of the government and without the support of NASA is going to independently take a trip to Mars, so I would hope that no one on this Committee—

Mr. ROHRABACHER. The same—let me—

General BOLDEN. —buys into that.

Mr. ROHRABACHER. So let me note that the same thing could have been said in terms of providing transportation to government programs for astronauts, the same thing could have been said about the commercial sector 10, 20 years ago. The private sector has a lot to contribute and I would hope that we don't have our long-term projection into Mars as a government program doesn't cost us these extra billions of dollars that could be put to use by NASA or by the private sector in accomplishing some goals right now. Thank you very much—

General BOLDEN. Yes. Thank you.

Mr. ROHRABACHER. —Mr. Chairman.

Chairman PALAZZO. I want to thank the gentleman.

At this time the Chair recognizes the Ranking Member of the full committee, Mrs. Johnson.

Mrs. JOHNSON OF TEXAS. Thank you very much, Mr. Chairman, and I apologize for being late. I had an essential meeting that I had to attend.

And let me welcome the Administrator and thank you for your long-time and continued service to this nation.

As the Chairman and others have indicated, we're here to review NASA's fiscal year 2016 budget request. And before I discuss specifics, I'd like to say that I appreciate the President's commitment to NASA as expressed in his budget request, as well as his support for R&D overall. It is clear that he understands the importance of investing in our nation's R&D enterprise, of which NASA is a key component.

So while I may differ on some of the specific funding decisions reflected in this budget request, I think that NASA's overall request is a good starting point for our deliberations, and I hope that Congress will at least equal that budgetary top line, if not exceed it.

Because the reality is that successive Congresses and Administrations have tasked NASA with a number of critical important endeavors and yet we have lagged in our providing the resources needed to carry them out. The truth is that NASA's buying power has actually decreased, as it has been pointed out here, by 15 percent from fiscal year 2005 to fiscal year 2013 and is expected to

continue to decline if the budgetary outlook doesn't improve. So, Mr. Chairman, the hardworking men and women of NASA really does deserve better.

Let me cite an example. Just about a year ago, a distinguished panel of the National Academies completed its review of the Nation's Human Space Exploration Program. The panel was headed by former Governor and OMB Director Mitch Daniels, an individual well known for his fiscal conservatism, which makes the panel's conclusions even more impressive, namely America's Human Spaceflight Program is worth continuing. Mars is the appropriate goal. The government needs to come to a consensus on a pathway to Mars—and I don't believe that commercial is going to happen until first the government reaches it, a set of interim destinations and milestones of course, and it's going to require funding above the constant dollars if NASA is to succeed.

So that's pretty unambiguous advice that we have failed to follow. So it came as a bit of a shock to me that the very next budget request for NASA to be submitted after the report's release would actually propose cutting the funding for the Space Launch System of Orion—two fundamental enabling elements of the Human Exploration Program—is directly counter to the National Academies' findings, and I think that Congress needs to correct that.

Neither has NASA yet told us how it plans to get to Mars. What's the pathway or the roadmap? NASA needs to look beyond just the next four or five years and lay out the milestones it needs to pursue to get humans on Mars, as the National Academies panel made clear. Defining such a roadmap is not just for NASA's benefit. None of what NASA has done has been for NASA's benefit as such. It has benefitted our nation and our world.

Congress and the American people will need to be confident that NASA has a well-thought-out plan if we are going to be able to sustain support for such an ambitious understanding over the coming years. I am sure we will discuss further during this hearing so I won't pursue this any further now.

NASA is a crown jewel of America's research and development enterprise. It advances knowledge, promotes technological innovation, projects a positive image of America throughout the world, and inspires especially our young minds. Its workforce is dedicated and accomplished and I really do think that NASA deserves our support.

I want to ask this question as my time is running out. How do NASA employees beyond your leadership feel in terms of their confidence of gaining greater steps towards reaching Mars and the goals for getting there when when we are not providing the adequate money?

General BOLDEN. Congresswoman, I'm a person who believes in metrics. The best metric we have for how NASA employees feel is something that's done by the Partnership for Public Service, and it results in a listing of best places to work in the Federal Government. For the last three years, the number one place to work in the Federal Government in our class has been NASA, and I think that speaks to the attitude, the enthusiasm, the excitement of the people in the agency.

I just came back from Georgia Tech last week. Young people want to come work for us because they're excited about what we're doing. And they want to do things that have not been done before. They are excited about Mars, and the workforce. There are all kinds of intangible things that you do that tell you what the attitude of a workforce is. If you go over there right now, we're engaged in a fitness challenge that goes over the next two weeks or so, I mean people stepping in line as they order their sandwiches. That may not seem like a significant thing to most people, but to us, that says that we have a workforce of 18,000 people who are enthusiastic about what they're doing, who are excited, and who believe we can deliver on the things that we say we can deliver.

We're on a journey to Mars. We have a plan to get there and we have delivered on that plan. As we go through the budget horizons, within the budget horizon we've flown Orion into space. We've tested the RS-25 rockets that are going to go on the first two missions. We've fired the solid rocket booster out in Utah. We have done the things that are inside the budget horizon because that was a concrete plan with money put toward it.

We talk to your staffs about 20, 30 years out and so I would hope that they all were very much aware of the deliberations that were going on on the Asteroid Redirect Mission, the fact that we had two options—that we were looking at two options, that we came to the decision that we did because we were looking for the best option that supported the journey to Mars and kept us on that journey.

So I hope that if you talk to any of my employees, they would tell that they're excited about what we're doing.

Mrs. JOHNSON OF TEXAS. Thank you. My time is expired.

[The prepared statement of Mrs. Johnson of Texas follows:]

PREPARED STATEMENT OF FULL COMMITTEE RANKING MEMBER
EDDIE BERNICE JOHNSON

Good morning, and welcome Administrator Bolden. I look forward to your testimony, and I thank you for your continued service to this nation.

As the Chairman has indicated, we are here to review NASA's Fiscal Year 2016 budget request. Before I discuss specifics, I would like to say that I appreciate the President's commitment to NASA as expressed in this budget request, as well as his support for R&D overall. It is clear that he understands the importance of investing in our nation's R&D enterprise, of which NASA is a key component. So while I may differ on some of the specific funding decisions reflected in this budget request, I think that NASA's overall request is a good starting point for our deliberations—and I hope that Congress will at least equal that budgetary top line, if not exceed it. Because the reality is that successive Congresses and Administrations have tasked NASA with a number of critically important endeavors, yet we have lagged in providing the resources needed to carry them out. The truth is that NASA's "buying power" has actually decreased by 15 percent from Fiscal Year 2005 to Fiscal Year 2013 and is expected to continue to decline if the budgetary outlook doesn't improve. Mr. Chairman, the hardworking women and men of NASA deserve better.

Let me cite an example. Just about a year ago, a distinguished panel of the National Academies completed its review of the nation's human space exploration program. The panel was headed by former governor and OMB Director Mitch Daniels, an individual well known for his fiscal conservatism. Which makes the panel's conclusions even more impressive, namely: America's human spaceflight program is worth continuing, Mars is the appropriate goal, the government needs to come to a consensus on a pathway to Mars—that is, a set of interim destinations and milestones—and it's going to require funding above constant dollars if NASA is to succeed.

That's pretty unambiguous advice.

So it came as a bit of a shock to me that the very next budget request for NASA to be submitted after the report's release would actually propose cutting the funding for the Space Launch System and Orion, two fundamental enabling elements of the human exploration program. It's directly counter to the National Academies' findings, and I think Congress needs to correct that.

Neither has NASA yet told us how it plans to get to Mars—what's the pathway or roadmap? NASA needs to look beyond just the next four or five years and lay out the milestones it needs to pursue to get humans on Mars. As the National Academies panel made clear, defining such a roadmap is not just for NASA's benefit. Congress and the American people will need to be confident that NASA has a well thought-out plan if we are going to be able to sustain support for such an ambitious undertaking over the coming years.

There are other examples in the budget request that I could cite as areas of concern: the cuts made to NASA's Education program, to Aeronautics, and to Planetary Science, among others. However, I am sure we will discuss them further during the hearing, so I won't pursue them here. Instead, I will close by

saying again what I have said many times already: NASA is a crown jewel of America's research and development enterprise. It advances knowledge, promotes technological innovation, projects a positive image of America throughout the world, and inspires. Its workforce is dedicated and accomplished. NASA deserves our support.

Thank you, and I yield back the remainder of my time.

Chairman PALAZZO. Thank you, Ms. Johnson.

At this time the Chair recognizes Mr. Lucas for five minutes.

Mr. LUCAS. Thank you, Mr. Chairman.

And thank you, General, for being here today.

Clearly, many of our colleagues are very concerned about how we not only maintain the flow of scientific accomplishments and the support of the American public, and a great deal of focus here has been on Mars and what it requires to get there. Let me take you back for a moment, though, a little closer to home and let's talk about the James Webb Space Telescope. There are a few things I think that have caught the imagination of the public to the degree that the Hubble has over the course of the last 25 years, tremendous science. It's also brought the American public along with us. James Webb, with its literally quantum leap forward, I personally believe has the ability to continue that attention span of the American public.

But let's talk for a moment about the process of getting that done, the delays we've gone through, the setbacks, some of the challenges with the cryocooler. Do you believe that the telescope will still be able to launch on schedule and still be within budget?

General BOLDEN. Mr. Congressman, I firmly believe because I have personally been involved in the oversight of the James Webb Space Telescope from the time we brought our restructured plan to this Congress and to the White House. So I can speak with confidence that we're on schedule and below cost right now for delivering James Webb in 2018. I think we will make that.

You mentioned the cryocooler. That presented a technological challenge that, you know, we always know that they're going to be difficult things but I work with Wes Bush, the Chairman of Northrop Grumman Corporation. We have telecoms every month because we both realize the significance of the James Webb Space Telescope. So it is something that I take very seriously and I think we're going to launch in 2018.

Mr. LUCAS. And the differences, of course, between Hubble and James Webb where we're putting out in orbit, the fact that we can't repair it, it has to be perfect the first time.

General BOLDEN. That's the challenge.

Mr. LUCAS. One of the miracles of NASA was the fix—

General BOLDEN. Yes.

Mr. LUCAS. —on Hubble early on, one of the great accomplishments.

Tell me, James Webb is a rather substantial portion of your budget and has been in recent years. Hopefully, we're on the verge of completion of that. Where do you envision that slice of the pie winding up when it's not committed to the development and the testing and the launching of James Webb?

General BOLDEN. That slice of the pie that some people refer to as a wedge is what is now going into the planning for the non-budget years, the out years, 20, 30 years out. And there are a number of projects that are being considered, WFIRST and AFTA, an advanced telescope for space, telescopes on the moon. There are any number of things that the science community has no shortage of ways that they would like to spend the wedge, but I assure you that we have what we call a strategic implementation planning process where we try to look at the things that come in—we help inform the decadal surveys which Chairman Smith referred to, but we will get input in the planetary decadal survey, for example, in 2021. So we're trying to do our research and inform them now such that when they recommend something to us, it is something that is achievable.

Mr. LUCAS. Once again, Director, your personal involvement demonstrates the importance of the James Webb and—

General BOLDEN. Critically important.

Mr. LUCAS. —enhances your level of confidence that we will get there on time, on budget, and in the way that we need to be.

Let's come even a little closer to home so to speak for just a moment to that and discuss the unmanned aerial systems. NASA is expected to build one, the UAS Traffic Management System, UTM, in FY 2016 to help integrate all of this into the National Airspace System. I guess my question is when we've talked about private challenges and opportunities in all of these areas, explain to me again why NASA is taking the lead on this traffic management instead of somebody in the private industry.

General BOLDEN. Because we have the expertise. You know, if you look at the Langley Research Center and Ames Research Center and to some extent Glenn, we have the national capability, the national expertise is resident in NASA. We could pass it off to industry except people like working for us, and so people come to NASA when they want an answer about things that deal with aeronautics, and we're very proud of the packages that we have delivered to the FAA and to the airlines, for example.

There is an en route traffic management package that we delivered to the FAA that's being tested by American Airlines primarily out of Dallas. I went down and worked with them or talked to them several months ago and they are thrilled with the package. We have a departure package that is in the hands of U.S. Airways down at Charlotte right now. We're working on unmanned aerial systems trying to help the FAA go about revising their regulations so that people can get unmanned aerial systems into the National Air Transportation System.

Mr. LUCAS. Are you confident, General, that we're going to wind up with a system that can support what potentially will be a very complex environment out there with the interest shown by industry and everyone? It's hard to tell just where this—

General BOLDEN. Yes.

Mr. LUCAS. —will ultimately lead to.

General BOLDEN. I am very confident that we will make advances. I am not confident that we will stay ahead of industry and entrepreneurs. So, you know, as you said, NASA can only do so much. We work with the FAA, we work with the Department of Defense, we're working with industry, we're working with everyone, but the pace of spending on technology is not keeping up with the pace of innovation on the part of the private sector, and that's why when we talk about needing money for NASA's Space Technology Program, that is not just about space. The Space Technology Program looks across our—much of their work is done to support the Science Mission Directorate. We've got to put more money into technology development if we're going to keep pace with the private sector. Otherwise, they'll dwarf us.

Mr. LUCAS. Thank you, General.

Thank you, Mr. Chairman.

Chairman PALAZZO. At this time the Chair recognizes Mr. Knight for five minutes.

Mr. KNIGHT. Thank you, Mr. Chairman.

And, General, I have a couple questions. I know a lot of people have been talking about the A in Aeronautics in NASA and so I have a few questions but I would like to make a couple comments that I do believe that it is a top goal to go to Mars. I think that that is a laudable goal for humankind. I think that over the last 60 years we've seen quite a lot of jumps and leaps, and in your business you can't jump a step because when you do, you lose data and you lose lives. So I understand that very well.

There are a couple systems in aeronautics that have made our lives better and have made our war fighter better. And I know that Ranking Member Edwards hit on one with the winglets on our airliners. But you have a couple systems that have gone into place in the last couple years like our GCAT and our collision avoidance for our war fighter being now employed in our F-16s in their day-to-day efforts. And also with the F-15 sonic boom jousting that you did much testing on in the last five or ten years, which I appreciate because if you could ever do that, then I wouldn't have a five hour flight back to California; I'd have an hour-and-a-half flight.

So I appreciate all of those missions in aeronautics. I don't appreciate the three percent budgeting for aeronautics, and I think that that's a bone of contention probably with many people on this dais and I'm sure we can talk about that.

But one of the programs that was talked about was the James Webb and it is true; once the Webb telescope goes, it's gone. But there is a telescope that we bring back to Earth every day and we fly it about three or four times a week, and that's SOFIA. SOFIA takes up fourth and fifth graders, teachers, and does great science projects about three or four times a week. It's a joint mission with Germany. I know you know this very well. And Germany has just

placed a whole bunch of money in reconfiguring and redoing the SOFIA telescope.

So I'd like to hear a little bit of the status of SOFIA, the future of SOFIA because there's been such changes that we're going to have a senior review by about '18 or '19, which would have been five years into the project, which is—that's about right. And now we've heard that we're going to be in spring of 2016, which is only two years into its fully operational period. So I'd like to hear just a little bit of status on SOFIA.

General BOLDEN. Congressman, SOFIA is doing awesome, as you said. It represents a unique capability in that it is an airborne platform, and we can change out the instruments on it. That's the advantage we have there.

The reason that we moved the senior review up was very similar to the reason that we had an early senior review with Hubble. In the early days of Hubble the senior review was scheduled to be years away. We knew that we were going to want to upgrade the observatory, and in order to do that, the best way to do it was to hold a senior review to look at both the present performance but also what are the things that we need to be thinking about in the future to enhance its ability to perform.

So the senior review is not just to determine whether or not it's performing and whether it's worth the money we spend on it but will also give us some guidance as we go forward about what we should think about for future instruments. So I would say, you know, an important part of the future of SOFIA is how much are our German partners going to be willing to put in because it is a partnership? It's a critical partnership, but if they say that we're not going to put in any more money so you pay for it, then that puts us at a—you know—

Mr. KNIGHT. No, sir, and I agree—

General BOLDEN. —a fiscal dilemma.

Mr. KNIGHT. —it is a partnership and I think that their commitment, because of the refurb and all of the work that they've done in the last year is—but I will go back to aeronautics and talk about this just a little bit more in my last 45 seconds.

You know, we're going to move forward with other programs out in aeronautics and they're going to enhance our lives and they're going to help us survive in a crash, help us maybe maintain a better lifestyle. Intelligent flight control systems I know is something that NASA is working on and I appreciate NASA for doing digital fly-by-wire and all of the kind of experiments to get us up to this.

So that's what I will say. With the three percent—it doesn't look like the commitment to aeronautics is as much as it has been in the last 40 years. And part of that might be because we don't have a solid X-Plane mission. And if we would revisit the X-Plane mission, and I know that that's something that you've talked about and I know that that's something that NASA has talked about, but in today's age an X-Plane mission might be a joint effort, not with the Air Force but with a private industry. And you've seen that with other things like the Dream Chaser or other programs.

So that is my request that we revisit that.

General BOLDEN. Yes, sir. Thank you very much.

Mr. KNIGHT. Thank you, Mr. Chair.

Chairman PALAZZO. The Chair wants to recognize Mr. Johnson for five minutes.

Mr. JOHNSON OF OHIO. Thank you, Mr. Chairman.

General Bolden, you and I have had chances to talk. I think you know that I'm a big NASA fan, you know, from Buck Rogers to James Kirk to the real-life accomplishments of John Glenn and Neil Armstrong and so many other pioneers of space travel. I'm one who believes that regardless of the mission that the sciences, technologies, and great marvels of discovery that have been realized through our space program have bettered our country and have bettered the world in so many, many ways.

So that is a backdrop for my questions. Just one right up front, General Bolden, does NASA believe, do you believe that the Asteroid Mission will help with planetary defense, which is contrary to the findings of the Small Bodies Assessment Group and the asteroid experts?

General BOLDEN. Congressman Johnson, as I have said before, I don't want to overpromise or over-commit but we believe that the Asteroid Redirect Mission, when flown and if the science is the way that we think it is will inform those who follow us in developing concrete technologies and systems to deflect asteroids or to protect the planet if you will. So it will contribute to our ability to deflect asteroids, and that's why I told both Congressman Posey and Congressman Brooks, I can answer the question today. I couldn't two years ago. We have a plan to do that.

Mr. JOHNSON OF OHIO. Okay. General Bolden, you know, the United States is presently sanctioning the Russian Federation in the field of high-tech exports as a result of Russia's actions in the Ukraine. Last summer, the Russian Deputy Prime Minister Dmitry Rogozin even threatened to cut off American access to the Station saying that we could get there by jumping on a trampoline if we wanted to, what absurdity.

If the Russian Federation followed through on these threats and withdrew cooperation, how would the Space Station be affected?

General BOLDEN. Congressman Johnson, we have a plan today. When people ask me about my contingency plan, we're two years away from having our own capability of sending our crews to the International Space Station. That will take us away from reliance on the Russians. We currently are—contrary to what's in the paper and the political and diplomatic relations between the two countries, Station continues to be the perfect example, the role model if you will for international relations and collaboration and cooperation.

Mr. JOHNSON OF OHIO. Let me point out, General Bolden, you know, in kind of an explanatory to what some of my colleagues have said. This is what we mean, what you just commented on there, that we're two years away from being able to deliver to the Space Station ourselves. We can't disregard what's in the media. We can't disregard the public perception. And when we tell you—and I'm one that agrees that we are and we will remain forever the premier space explorer in the world. I understand that. The general public does not. And when they see and they read in the media that we have to hitchhike with the Russians to the Space Station, that's the perception that is out there. And you know as well as

I do that reality is oftentimes dictated by perception. It's not reality.

If absolutely necessary, then could Boeing or SpaceX send a human mission to the Space Station in the near future?

General BOLDEN. No. If you're calling the near future sooner than 2017, no.

Mr. JOHNSON OF OHIO. Okay. All right.

Do you think NASA could down-select to one provider immediately and devote all of its resources to be ready sooner, any plan mitigation that you could do to get us ready sooner?

General BOLDEN. I think the path on which we are currently embarked with two providers, it maintains competition, it guarantees that I will have the safest vehicle possible, and I think if we down-selected to one, it would not speed up the process at all. It may even slow it down because then that one provider becomes the monopoly that dictates to me what it can or can't do and what it will and won't do.

We have fixed-price contracts with them today and I can tell you, it's interesting to engage with the two providers in discussions about what we think the vehicle should be able to do because they know that if they don't perform—you know, they have a contract right now that's for up to six missions.

Mr. JOHNSON OF OHIO. Um-hum.

General BOLDEN. It is not a good business model to say I'm going to fly six missions and then I'm going to get out of this. So they all want to be the contractor for life for Commercial Crew.

Mr. JOHNSON OF OHIO. I get—

General BOLDEN. So they want to perform

Mr. JOHNSON OF OHIO. I get that. And of course from your background you understand the relevance of the question. The Russians are getting increasingly testy with their rhetoric, with their boldness, with their trouncing upon their European friends and neighbors, everything from cutting off gas supplies to forcing us to jump on a trampoline to get to the Space Station. So what happens over the next two years if tomorrow the Russians were to say you're out? What would we do? What's NASA's plan?

General BOLDEN. Well, Congressman Johnson, first of all, the Russians can't say you're out because it's not a Russian or an American space station. The Russians can decide to withdraw from the International Space Station, which we'd have to adjust, but as I have said before, we would not—

Mr. JOHNSON OF OHIO. But what if they were to say we're not taking your people up there? What would happen? Because they could certainly say that. We might get mad about it and we might try to bring world pressure—

General BOLDEN. Congressman, I'm—

Mr. JOHNSON OF OHIO. —but in the time—

General BOLDEN. If—and I hate dealing in whatever we call them—

Mr. JOHNSON OF OHIO. Now don't go there because you—in your background you know you've got to have contingency plans for every—

General BOLDEN. And I do. And I do.

Mr. JOHNSON OF OHIO. —outcome.

General BOLDEN. And that's why I said we have probably the best contingency plan possible, considering where this nation is, and that contingency plan is to fully support Boeing and SpaceX to flying in 2017.

Mr. JOHNSON OF OHIO. No, I'm asking you what you're going to do over the next two years if the Russians say you're not going with us.

General BOLDEN. I am going to continue to work with my Russian partners to continue to encourage them to be as enthusiastic about maintaining the International Space Station as they are now. I would call it to everyone's attention the same Deputy Prime Minister Rogozin who was going to put me on a trampoline Tweeted out after my meeting with my counterpart that the Russians had decided that it's a good idea to stay with the Space Station until 2024.

Mr. JOHNSON OF OHIO. Well, General, I'll—

General BOLDEN. That's what I do.

Mr. JOHNSON OF OHIO. I respect you greatly and I respect what NASA does, but what you've basically told me is that there is no option, there is no plan within the next two years if the Russians pull out, other than hoping like hell that they don't. And I would say I understand the pressures that you're under and I understand that that may be an avenue, but things have changed a lot over the last two years in our relationship with the Russians, and I hope somewhere in the dark rooms of NASA you guys are considering what we're going to do if they pull the plug because they could.

Mr. Chairman, I yield back.

Chairman PALAZZO. The Chair now recognizes Mr. Babin for five minutes.

Mr. BABIN. Thank you, Mr. Chairman.

General Bolden, thank you for being here.

Over the past several years, part of the NASA Authorization Act of 2010 NASA has been systematically reducing its footprint and operational costs by closing various facilities, laboratories, and test structures. And it leaves many in the ranks and surrounding communities to question if a center closure perhaps is next.

Relative to the Johnson Space Center, which is in my district, Texas 36, are you aware of any organization, government, university, or private sector, proposed to any NASA officials or official at headquarters or at the center that management and operation centers be turned over to an academic institution or other entity similar to that of the Jet Propulsion Laboratory to operate as an FFRDC?

General BOLDEN. Congressman Babin, I am aware that that is a recommendation that is out there forever. As long as I am the NASA Administrator, it is not a thing that I'm considering. So when you go back home to Houston, you can let people know there is no plan, not even the remotest plan to accept a recommendation from the experts that we turn JSC into an FFRDC.

Mr. BABIN. Okay.

General BOLDEN. That is not going to happen, not on my watch.

Mr. BABIN. Well, I'm glad to hear that because that's—that is what's floating around out there around JSC, I can tell you that.

All right. What is—what will—obviously your perspective on that, you obviously would not support that. That's my—

General BOLDEN. I am saying the way that we're organized today, we have something called TCAT. I hate to use another acronym.

Mr. BABIN. Um-hum.

General BOLDEN. We're looking at our technical capabilities. We're trying to find out how in this budget environment we maximize the utilization of the talent that we have, and that determines what we do to facilities. I see us reducing facility footprint everywhere because we don't need the historic infrastructure that we've had. I do not see us reducing to the point where we close a center, not in the foreseeable future.

I cannot say that, you know, down the road I don't know what will come when someone else is sitting in this chair as the NASA Administrator, but there is nothing that we've done, no studies that we've conducted that say that would be the wise thing for us to do right now. We have one FFRDC. It is the Jet Propulsion Laboratory and that serves our purpose.

Mr. BABIN. Okay. Thank you. It's good to hear that.

All right. To follow up on my previous question, relative to the agency's strategic planning and operational structure, are you confident that collectively the centers and their industry partners have the critical capabilities, resources, and infrastructure, as well as operational experience required to successfully implement the agency's core missions and objectives? And that would include engineering, mission operations, training, research, and systems development.

General BOLDEN. I'm confident that the pathway that we're on, the budget that we have, and the pathway on which we're embarked is actually shaped by the budget that we have, so that everybody remembers that. I'm confident that we have the right people, the right facilities, and the like.

You're probably aware, Dr. Ellen Ochoa, the Center Directorate at Johnson, made a major change in her organizational structure because she was trying to get to where she thinks we need to be to support an exploration program. So, you know, that's the prerogative of the team in the local areas as to how they organize to best do—to help us accomplish the agency's strategic mission. And she has to have the flexibility to do that.

That causes, you know, a little kerfuffle because that means we're not going to operate the same way we did yesterday, and I like the way we operated yesterday if I happen to be a person who's affected by it. But all of our centers are making minor tweaks to be able to fit into the Mars pathway if you will.

Mr. BABIN. Right. Okay. So would you agree that JSC has a unique role in NASA's deep space exploration objective?

General BOLDEN. Now, if Ellen Ochoa decided she was going to pull out of the International Space Station, I'd be affected. I'd be worried. That—they are vital—

Mr. BABIN. Okay.

General BOLDEN. —you know. It's not like a threat from Russia pulling out of the International Space Station.

Mr. BABIN. Absolutely.

General BOLDEN. That's where it's run so that's the reason that—you know, my contingency plan, again, going back to that, is to make sure that Ellen Ochoa and her team at the Johnson Space Center and Patrick Scheuermann and his team at Marshall, who happen to be the two primary centers for day-to-day operations of the International Space Station, make sure that they stay happy and appropriately occupied and manned is—I don't know what the right term is—peopled—staffed. Staffed.

Mr. BABIN. Staffed.

General BOLDEN. And as long as Marshall is doing the science work for Station, and Johnson doing the human exploration, the human spaceflight preparation with our astronauts, as long as they're doing what they're doing and Kennedy Space Center is doing what it's doing, all the centers continue to do what they're doing today, then we're strong and we will continue to be the dominant operator of the International Space Station on whom everyone depends, to include the Russians.

So I appreciate everyone's concern. You know, it would—I just appreciate everyone's concern.

Mr. BABIN. Absolutely, because there's a lot of concerned people there.

General BOLDEN. Yeah.

Mr. BABIN. Thank you.

I yield back, Mr. Chairman.

Chairman PALAZZO. I want to thank the gentleman.

I also want to remind the Administrator that Goddard Space Flight Center and Stennis Space Center—I know, you just—you mentioned the other—

General BOLDEN. I said all the other centers. I didn't want to—because I can't always remember all nine—

Chairman PALAZZO. It's like a grandfather trying to remember all of his grandkids' names.

General BOLDEN. That's true. All I need to do is look in front of me.

Chairman PALAZZO. It's—

General BOLDEN. Stennis—

Chairman PALAZZO. I've witnessed that personally—

General BOLDEN. As you know, Mr. Chairman—

Chairman PALAZZO. —by my parents—

General BOLDEN. —everything that goes through space goes through Mississippi, as we say at Stennis.

Mr. BABIN. And, Mr. Chairman, I'm fixing to have a grandkid today.

Chairman PALAZZO. Congratulations.

Mr. BABIN. Thank you.

Chairman PALAZZO. Congratulations.

In closing, I want to follow up on your exchange with Chairman Smith. You said that you never formally committed to the 2017 launch date for EM-1. However, you have testified before this committee that the President's budget request for fiscal year '14 and fiscal year '15 would keep the EM-1 launch date for 2017. You even told this committee that if Congress gave you \$300 million more, you wouldn't notice it.

NASA could have presented Congress with a budget that kept the 2017 date, but instead they chose to delay the program, and I hope we can work together to keep SLS on track.

With that, I want to thank General Bolden for his testimony and the Members for their questions. The record will remain open for two weeks for additional written comments and written questions from Members.

This hearing is adjourned.

General BOLDEN. Thank you very much, Mr. Chairman.

Chairman PALAZZO. Thank you.

[Whereupon, at 10:52 a.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by General 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 Fiscal Year 2016”***

Questions for the record, The Honorable Charles F. Bolden Jr., Administrator, National Aeronautics and Space Administration (NASA)

Questions submitted by Rep. Steven Palazzo, Chairman, Space Subcommittee

QUESTION 1:

NASA's congressional budget justification states that the FY 2016 budget redefine the Earth-observing satellite responsibilities of NASA and the National Oceanographic and Atmospheric Administration (NOAA). It also describes new proposals for the Sustainable Land Imaging program, under which NASA works with the U.S. Geological Survey (USGS) on future land remote-sensing satellites.

- a. How is the transfer of Earth observation programmatic responsibilities to NASA from NOAA and USGS impacting NASA's priorities?

ANSWER 1a:

The President's FY 2016 budget continues a balanced program that advances knowledge of the Earth as a system through flight, research, data systems, applications and technology development. The FY 2016 budget provides an increase to Earth Science for the Sustainable Land Imaging (SLI) program and responsibility for the atmospheric, radiation, and altimetry measurements that have been transferred from NOAA to NASA (see answer to subpart b.). The budget also includes other priorities such as the Orbiting Carbon Observatory-3 (OCO-3) mission, the NRC Decadal Survey Tier-1 recommended Climate Absolute Radiance and Refractivity Observatory (CLARREO) technology demonstration, and balanced research & analysis activities as recommended in the National Research Council (NRC) Decadal Survey. Thus, the budget supports continued investments in many critical, recommended, NASA science activities.

QUESTION 1b:

How much is NASA planning to spend in FY 2016 on Earth observation data continuity missions and/or Earth observation programs that were previously the responsibility of NOAA or USGS?

ANSWER 1b:

Approximately 9 percent (~\$182M) of the FY 2016 NASA Earth Science budget enables Earth observations relevant to NOAA and USGS. This fraction of the budget funds NASA implementation of several missions and instruments that previously were funded through the NOAA budget request, such as Radiation Budget Instrument (RBI), Total Solar Irradiance

Sensor 1 and 2 (TSIS-1 and TSIS-2), Ozone Mapping and Profiler Suite-Limb (OMPS-L), and Altimetry Follow-On (AFO). It also includes SLI, as the Landsat series of satellites (with the exception of Landsat 6) always has been in NASA's budget.

\$ millions		
	FY15	FY16
SLI	64.1	78.9
RBI	44.9	45.3
OMPS-L	4.3	5.7
TSIS-2	0.4	1.0
TSIS-1		16.0
AFO		35.9
Total	113.7	182.8

The 2007 NRC Decadal Survey (p. 6) states the importance of making these measurements as follows:

Recommendation: *NASA should ensure continuity of measurements of precipitation and land cover by:*

- *Launching the [Global Precipitation Measurement Core Observatory] GPM mission in or before 2012, and*
- *Securing before 2012 a replacement for collection of Landsat 7 data.*

The committee also recommends that NASA continue to seek cost-effective, innovative means for obtaining information on land cover change.

Sustained measurements of these key climate and weather variables are part of the committee's strategy to achieve its vision for an Earth observation and information system in the next decade.

QUESTION 1c:

What steps, if any, is NASA taking to ensure that programmatic responsibilities that have been transferred from NOAA and/or USGS will be reimbursed in full by those respective agencies?

ANSWER 1c:

NASA is not taking any specific steps, as they are unnecessary. The President's budget request contains the necessary funding for NASA to carry out these responsibilities.

QUESTION 1d:

If NOAA and USGS reimbursed NASA for the Earth observation programs and instruments that they are currently responsible for, how would this impact NASA's ability to carry out missions recommended by the National Academies in their decadal surveys?

ANSWER 1d:

As stated above, the President's budget request contains the necessary funding for NASA to carry out an integrated Earth observation program. This program is congruent with the 2007 Decadal Survey that assessed Earth observation needs as a whole, rather than focusing on which agency was implementing specific missions. The Decadal Survey (p. 7) states: "In developing the recommended set of missions, the committee recognized that a successful Earth observation program is more than the sum of its parts." The section on "New Observations for the Next Decade" explains the prioritization of missions (p. 6-7), and states that relative rankings are based (in part) upon the:

- *Contribution to the most important scientific questions facing Earth sciences today (scientific merit, discovery, exploration)*
- *Contribution to applications and policy making (societal benefits)*
- *Contribution to long-term observational record of Earth*

QUESTION 1e:

Has NASA conducted an opportunity cost analysis of the choice to take responsibility for Earth observation programs/instruments from NOAA or USGS? If so, please provide your analysis. If not, please explain why NASA never conducted an opportunity cost assessment prior to taking responsibilities of NOAA or USGS Earth observation programs/instruments?

ANSWER 1e:

The NRC has identified the need for integrated observations of the Earth from space. NASA is the nation's civil space Agency -- even the nation's weather satellites operated by NOAA are designed and developed by NASA. The FY 2016 President's budget request recognizes the importance of NOAA's focus on weather prediction for life and property protection, which relies on short term/near term forecasting. Thus, the decision was made for NOAA to focus on weather and for the responsibility and budget for all other civil Earth observations to be in the hands of NASA. This division of labor is appropriate and working well.

Regarding SLI, since the start of the Landsat program and with the exception only of the failed privatization attempt for Landsat 6, NASA has historically been budgeted to design, build and launch the Landsat series of satellites. After launch and on-orbit commissioning, the Landsat satellites are operated by USGS, which also processes, distributes, and archives the Landsat measurements and data products. Additionally, several of the measurements that NASA has recently taken over from NOAA were originally developed, demonstrated, and initiated by NASA missions several years ago. For example, Topex/Poseidon, a joint NASA-CNES mission, was the forerunner for the Jason altimetry mission. The first Clouds and the Earth's Radiant Energy System (CERES) instruments (the predecessor instrument to NASA's current Radiation Budget Instrument) were launched on the NASA-Japanese Tropical Rainfall Mapping Mission (TRMM) and NASA's Earth Observing System (EOS) missions. Thus, NASA not only has the expertise but also the heritage and experience with developing these types of instruments.

QUESTION 1f:

Will NASA be reimbursed by other U.S. agencies for the costs associated with the Sustainable

Land Imaging Program? Please explain.

ANSWER 1f:

With the exception of the unsuccessful Landsat 6 mission, NASA has been budgeted and tasked to design, build and launch the Landsat series of satellites that have carried out highly successful land imaging since 1972. NASA always has held the budget for design and development of these satellites. NASA's Landsat work has always been funded from within the NASA budget – not on a reimbursable basis. This successful model continues for SLI.

QUESTION 1g:

How much does NASA estimate it will cost to execute the USGS requirement to develop a Sustainable Land Imaging Program?

ANSWER 1g:

The FY 2016 NASA budget request for SLI is \$78.9M. An important clarification is that requirements for the SLI are a key part of the integrated Earth observation constellation, not only derived from the USGS-user community. Refer to the answer of 1b for relevant text in the Decadal Survey along these lines.

QUESTION 1h:

Has NASA conducted any studies on how the Joint-Program Development Office (JPDO) model could be expanded to include any or all Earth observation programs that are of operational and/or data continuity relevance to USGS or NOAA? If so, please provide those studies.

ANSWER 1h:

The Joint-Program Development Office (JPDO) was established by Congress in 2003 to plan and coordinate the development of the Next Generation Air Transportation System (NextGen). NASA served on the JPDO which was a multi-agency public/private initiative that has now been disbanded with JPDO's functions replaced by FAA's NextGen Office (per publically available January 23, 2015 Department of Transportation Inspector General memo).

A study of the JPDO is not warranted as the U.S. Group on Earth Observations (USGEO), a subcommittee under the National Science and Technology Council (NSTC), is in place to perform a similar function. The 13-agency USGEO works to coordinate, plan, and assess Federal Earth observation activities in cooperation with domestic stakeholders. At USGEO, user requirements (including both operational and data continuity aspects) will be brought forward to be considered in the development of Earth-observing missions.

QUESTION 2:

In the 2016 Budget Justification NASA states that under a new framework "NOAA will be

responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts and warning to protect life and property." The Budget justification also stated that responsibility for TSIS-1 and future ocean altimetry missions are transferred to NASA.

- a. Isn't it true that altimetry missions contribute to directly to NOAA's ability to issue weather forecasts and warning to protect life and property?

ANSWER 2a:

Altimetry missions provide valuable data for Earth Science research by providing detailed measurements of sea levels on Earth to gain insight into ocean circulation and climate change in addition to enhancing capabilities for weather forecasts.

QUESTION 2 b:

Isn't it also true that Jason-3, an ocean altimetry mission, is currently a NOAA program?

ANSWER 2b:

Yes, NOAA funds Jason-3, which is being developed and launched by the Joint Agency Satellite Division (JASD) within NASA's Science Mission Directorate (SMD). In partnership with NOAA, JASD manages the development and launch of reimbursable satellite programs, projects, and instruments such as Jason-3.

QUESTION 2C:

If so, please explain how NASA's description of the revised framework requires NOAA to be responsible for ocean altimetry missions but that in practice NASA is tasked with satisfying the requirement?

ANSWER 2c:

The FY 16 President's Budget proposes to move the funding responsibility from NOAA to NASA for the development of specific ocean altimetry instruments for the European ocean altimetry mission, now titled Sentinel 6 (a Jason-series follow-on). NASA would be programmatically responsible for the instruments provided to these ocean altimetry missions following Jason-3. Prior to this change, NASA was the acquisition agent for NOAA for Jason-3 instruments. However, we expect NOAA's ocean altimetry data needs will continue to be met by future European and NASA missions.

QUESTION 3:

Between FY 2012 and FY 2015, NASA received over a billion dollars more than it requested for Exploration Systems Development. Yet the dates for Exploration Mission 1 (EM-1) and Exploration Mission 2 (EM-2) slipped, and contractors now indicate that more funding is necessary to stay on schedule. The Administrator testified on multiple occasions that the amount of funding requested for the SLS and Orion would keep the EM-1 and EM-2 launch

dates on schedule. Why did additional funding lead to delays?

ANSWER 3:

The integrated launch date for Exploration Mission-1 (EM-1) has not yet been determined -- it is to be determined after all three programs complete their Critical Design Reviews (CDRs). NASA has identified an Agency Baseline Commitment for the SLS and EGS which supports a launch capability readiness date of November 2018 at 70 percent and 80 percent Joint Confidence Level (JCL), respectively, to the EM-1 launch readiness date. The FY 2016 President's budget request provides the funding level needed to keep SLS, Orion, and EGS on track for the first integrated launch of EM-1. NASA has identified an Agency Baseline Commitment for Orion for the first crewed launch as the EM-2 readiness date. NASA's Agency Baseline Commitment for Orion supports a launch capability readiness date in 2021, and a 70 percent JCL of 2023..

QUESTION 3a:

After the KDP-C process was completed for SLS, why did the Administration push back the launch of EM-1 instead of requesting the amount of funding necessary to preserve the original 2017 launch date?

ANSWER 3a:

SLS and Orion are progressing along an efficient path for completion of detailed design and for manufacturing, assembly and testing. The President's Budget supported funding estimated to be needed to meet the KDP-C readiness date.

QUESTION 3b:

If NASA receives only the \$1.356B in funding, as requested, will the SLS program's internal launch readiness goal of a 2017 launch of EM-1 continue to be realistic?

ANSWER 3b:

Please see response to Question #3a, above.

QUESTION 3c:

Why do you continue to have confidence in the budgeting process despite these major discrepancies?

ANSWER 3c:

NASA requires that a Joint Confidence Level (JCL) analysis be completed and submitted at Key Decision Point (KDP)-C for all projects above \$250M. JCL analysis provides a cohesive and holistic picture of the project's ability to achieve cost and schedule goals by systematically integrating technical, cost, schedule, and risk data. As an integrating framework, a JCL can show the impacts of risk to a project as well as highlight the relationship between cost and

schedule. This relationship can be extremely important in situations with constrained budgets. A complete JCL analysis can also facilitate transparency with stakeholders on expectations and probabilities of meeting those expectations

QUESTION 3d:

Why should Congress view NASA budget requests as reliable indicators of program needs when they have consistently proven to be wrong?

ANSWER 3d:

Since institutionalization of the JCL in [2009], NASA has greatly improved its track record of delivering programs and projects at their committed cost and schedules. In the case of SLS, NASA is on track to meet its Agency Baseline Commitment KDP-C goal of an EM-1 launch readiness date in November 2018. NASA's baseline JCL policy of budgeting projects at the 70th percentile and funding to at least the 50th is a sound strategy. Use of JCL analysis improves project planning by systematically integrating cost, schedule, and risk products and processes while providing a cohesive and holistic picture of a project's ability to achieve cost and schedule goals.

QUESTION 4:

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

ANSWER 4:

NASA has a goal of sending a human mission to Mars in the 2030s. The President's FY 2016 budget request 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 President's Budget also funds the development of technologies that are critical for making future exploration activities affordable and sustainable. The specific funding levels for future missions will also depend on factors including the incremental development of hardware like SLS and Orion, as well as 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 extant 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 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 4a:

If not, how much more funding would NASA's exploration programs need to meet the ultimate goal of a human mission to Mars?

ANSWER 4a:

Please see response to Question #4, above.

QUESTION 4b:

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

ANSWER 4b:

Please see response to Question #4, above.

QUESTION 5:

Following the first crewed flight of Orion and SLS, additional flights are expected to occur approximately once every two years. The Chairman of the NASA Advisory Council has testified that the low flight rate projected for SLS and Orion is a serious problem. Additionally, the NASA Advisory Council adopted a recommendation expressing concern that the low flight-rate of the SLS "could increase the likelihood that SLS will be unable to meet its exploration objectives due to cost, safety or mission success issues." With such a low launch rate it will not just be difficult to maintain program momentum, it will be difficult to keep flight teams sharp and mission-ready.

a. What is NASA doing to address these concerns?

ANSWER 5a:

SLS is being designed to be capable of supporting a long-term flight rate of one per year with a surge capability of three per year. The actual cadence of missions beyond 2022 will be defined in the coming months and years based on mission needs, available resources, and cost effectiveness. NASA is presently examining the safety aspects of the SLS flight rate.

QUESTION 5b:

What flight rate for SLS and Orion would you consider optimal, based on safety, maximizing the return on NASA's development investments, or other criteria?

ANSWER 5b:

NASA is reviewing the post-EM-2 flight rate for SLS/Orion. We are currently identifying follow-on missions as part of achieving the goal of safely putting humans on Mars.

QUESTION 5c:

What would it take to achieve that optimal flight rate, in terms of funding or other factors?

ANSWER 5c:

Please see response to Question #5B, above. In the past, NASA has used additional funding to get ahead on procurements, address high-risk items, and add reserves to manage unknown-unknowns as they arise.

QUESTION 6:

Under NASA's planned Asteroid Redirect Mission, the first crewed mission for Orion/SLS will be to an asteroid that has been redirected into orbit around the Moon.

- a. What work is NASA doing to define options for subsequent Orion/SLS missions? Are these options described in official mission planning documents? If so, please provide the Committee with these documents?

ANSWER 6a:

The specific Exploration Mission (EM) to be flown in support of the Asteroid Redirect Mission (ARM) is yet to be determined. NASA has defined EM-1 mission objectives and is defining mission objectives of EM-2 (first crewed mission of Orion) and EM-3, including systems test and demonstration, and risk reduction for the ARM crewed mission and future missions.

NASA continues to refine mission architecture and the evolution plans. For example, SLS evolution from an initial 70 metric ton (to low-Earth orbit or LEO) capability to a 105 metric ton and finally a 130 metric ton capability is tied to mission requirements. The series of missions NASA has planned in the "proving ground" of cis-lunar space follow a sustainable approach to developing the capabilities required to get humans to Mars.

Mission options to follow ARM include further use of the advanced solar electric propulsion bus used for ARM; addition of potential deep-space habitation systems; additional potential return missions to the asteroid boulder for expanded science and/or resource utilization; support for commercial and/or international missions in the lunar vicinity; and/or beginning mission trajectories to Mars vicinity. This effort will culminate in a one-year crewed mission in cislunar space, further paving the way for a crewed mission to Mars.

Specific future missions will depend on factors including the incremental evolution of SLS and Orion, as well as other assets 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 the recently released "NASA's Journey to Mars – Pioneering Next Steps in Space Exploration."

QUESTION 6b:

How soon will NASA need to make a decision regarding the next Orion/SLS destination and/or mission following the Asteroid Redirect Mission? What work is being done to develop those missions?

ANSWER 6b:

Orion and SLS are foundational capabilities that will enable the U.S. and its partners to undertake any deep-space exploration mission over the next several decades. As part of their development efforts, Orion and SLS are building the designs, hardware, and sustainable manufacturing capabilities needed to produce these deep-space vehicles for the long term. They are flexible systems designed to support the full range of missions necessary to prepare for crewed expeditions to Mars in the 2030s.

Please see response to Question #6a, above, regarding future missions.

QUESTION 7:

While Congress has appropriated about \$1.2B for the development of Orion crew vehicle in each of the past three years, the Administration has requested approximately \$100M less for the third year in a row. Why does the Administration continue to request cuts for Orion while publically calling for human missions to Mars?

ANSWER 7:

The budget numbers for 2016-19 in the FY 2015 President's budget request are identical to that requested in the FY 2016 President's budget request for those same years. NASA has a goal of sending a human mission to Mars in the 2030s. The President's FY 2016 budget request 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 out-year projections in the President's FY 2016 budget request set us on a course for achieving the goal of humans on Mars.

QUESTION 8:

The Government Accountability Office (GAO) and the NASA Inspector General (IG) have cautioned that EM-1 could be delayed because of potential schedule risks for the Exploration Ground Systems program. The Administration has requested an additional \$58.8M for the ground systems program, how will this additional funding mitigate the risks identified by GAO and the IG?

ANSWER 8:

FY 2016 is a vital year for the Exploration Ground Systems (EGS) program. A majority of EGS projects required for the SLS/Orion EM-1 launch will be completing development and will enter into individual sub-system testing in preparation for integrated system verification and validation testing beginning in early FY 2017. The Administration's request for additional funds in FY 2016 is consistent with this EGS baseline plan for achieving EM-1 launch readiness, and with previous President's budget requests. While the Administration's request does not specifically target the cautioned schedule risks, it does support a credible plan and is required to meet the Agency's SLS/Orion EM-1 launch readiness commitment.

QUESTION 9:

The Administration requested \$1.356B for SLS in FY 2016. What percentage of this work is related to EM-2 or other future missions?

ANSWER 9:

The President's FY 2016 budget request for SLS is focused on the first flight of SLS on EM-1.

QUESTION 9a:

When does NASA expect to begin work to support EM-2?

ANSWER 9a:

In developing the Orion, SLS, and EGS, NASA is seeking to build a sustainable National capability for the long-term human exploration of space. NASA is keeping each element of the program – SLS, ground systems, and Orion – moving at its best possible speed toward the first integrated launch, optimizing each element effort's schedule while being aware of the overall plan. This is best achieved when each program is allowed to progress on its own schedule, rather than being linked too tightly to the others. When tasks related to EM-1 are completed on any of the three programs, the workforce can progress to EM-2. SLS has also flight hardware and materials in hand for EM-2, including ring sections, barrel panels, and dome caps for the core stage; four RS-25 core stage flight engines; and case segments for the solid rocket boosters. The manufacturing tooling at NASA's Michoud Assembly Facility (MAF) and the assembly and launch processing facilities at Kennedy Space Center (KSC) being put in place now will be used for EM-2 and all subsequent SLS and Orion missions.

QUESTION 9b:

Why has NASA not reported these amounts separately as recommended by GAO?

ANSWER 9b:

NASA concurred with Recommendation #2 in GAO's report, "Space Launch System - Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability" (GAO-14-631), noting, "NASA has documented tactical (near-term) and strategic (in preparation for Mars) capabilities for SLS. Planning for specific missions will follow standard applicable NASA mission selection and review processes for ongoing operations."

QUESTION 9c:

Will the requested funding provide the SLS program with reserves appropriate to address challenges and reduce risk during the current stage of development?

ANSWER 9c:

The program uses both fiscal and schedule margin, as well as descope options, to achieve milestones with allocated resources. Together, at this point in time, these margins and options are sufficient to maintain the program's cost and schedule commitments for EM-1 launch readiness.

QUESTION 10:

The President proposed extending the life of the International Space Station (ISS) to at least 2024. What is NASA's plan after the ISS is deorbited?

ANSWER 10:

NASA will use the unique environment of the ISS to conduct the research and technology demonstrations necessary to keep our crews safe and productive on long-duration spaceflights. We will then travel beyond LEO to the proving ground of cis-lunar space. These steps will build the foundation for further deep-space exploration. With the technologies and techniques we develop, we will enable expeditions to multiple destinations, ultimately allowing us to pioneer Mars and other destinations as we lay the groundwork for permanent human settlements in the solar system.

NASA is also working to encourage the growth of a LEO space economy that will continue to develop even after the end of the Station's lifetime. 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 any remaining NASA interests and other Government and commercial users safely, reliably, and at a lower cost.

QUESTION 10a:

Does NASA have any plans to develop another government space station or space habitat?

ANSWER 10a:

NASA does not currently have plans to develop another Earth-orbiting space station. Specifics of future missions will depend on factors including the incremental evolution of SLS and Orion, as well as other assets to support humans in deep space, such as a potential habitation capability. Any future missions will require the addition of habitation capabilities initially in the proving ground of cis-lunar space.

QUESTION 10b:

Is NASA working with private space companies to develop private space stations or space habitat?

ANSWER 10b:

NASA's journey 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 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 the areas including habitation systems. Four of the awards will address habitat concept development, and three will address Environmental Control and Life Support Systems (ECLSS). In addition to advancing capabilities for NASA required for beyond-Earth-orbit habitation, the advances made through this effort by the selected commercial companies may be applicable to any private space stations/habitats.

In addition to the NextSTEP program, a two-year demonstration of habitation technology will begin later in 2015 when Bigelow Aerospace's Bigelow Expandable Activity Module (BEAM) is flown to ISS on a SpaceX Dragon spacecraft. Astronauts will use the Station's robotic arm to install the module on the aft port of the Tranquility node, then activate a pressurization system to expand the BEAM structure to its full size using air stored within the packed module. During the two-year test period, station crew members and ground-based engineers will gather performance data on the module. While the BEAM demonstration supports a NASA objective to develop a deep-space habitat for human missions beyond Earth orbit, the results of the demonstration could also have applications to private space stations/habitats.

QUESTION 10c:

How will NASA ensure that any future space stations will be procured using FAR and not through other means that reduce competition, favor a specific company, or compete with existing private sector capabilities?

ANSWER 10c:

NASA does not currently have plans to develop another Earth-orbiting space station. NASA is committed to determining the most appropriate procurement mechanism that stimulates maximum competition for future space vehicles. Such determination will be dependent on a number of factors and will be consistent with Federal laws and regulations as well as Agency guidance.

QUESTION 10d:

What other options has NASA explored related to microgravity environments similar to the ISS?

ANSWER 10d:

Throughout its history, NASA has availed itself of a variety of platforms for the conduct of microgravity research. The Agency anticipates continuing to use diverse microgravity environments in the future, potentially including commercial systems and deep-space habitation capabilities.

QUESTION 11:

The ISS is a unique environment that is necessary for testing equipment and systems that will be required for deep space exploration. How is NASA coordinating this research across the mission directorates and what challenges do we face in completing the necessary testing and validation for these systems before the ISS is deorbited?

ANSWER 11:

NASA's near-term strategy for exploration involves:

- Using the unique environment of ISS to conduct the research and technology demonstrations necessary to keep our crews safe and productive on long-duration spaceflights;
- Partnering with commercial entities to develop the capacity to transport cargo and crew affordably to LEO;
- Working in collaboration with NASA's Science, Space Technology, and Aeronautics Research Mission directorates to better understand exploration destinations, improve our ability to work there, and understand aerodynamics at Mars and upon Earth return;
- Continuing to work with international partners to jointly explore our solar system;
- Moving outward to deep space with Orion and the SLS to take us there.

NASA's Advanced Exploration Systems (AES) Division is formulating approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond LEO. This work is important to enable exploration missions and ensure that they are safe, affordable, and sustainable. Activities focus on crewed systems for deep space, and robotic precursor missions that gather critical knowledge about potential destinations in advance of crewed missions. Major products include systems development for reliable life support, early products for Asteroid Redirect Mission (ARM), deep space habitation, crew mobility systems, advanced in-space propulsion systems, advanced space suits, and autonomous space operations. As prototype systems are developed, they are tested using NASA ground-based facilities, as secondary or hosted payloads, or flight experiments on the ISS and cargo spacecraft. The AES Division works with the Space Technology Mission Directorate to infuse technologies into exploration missions, and with the SMD on robotic precursor activities. The Space Technology Mission Directorate supports exploration by investing in capabilities needed for deep-space exploration including advanced life support, entry, descent, and landing technologies, advanced space robotic systems, advanced thermal management technologies, advanced batteries and fuel cells, lightweight structures, cryogenic storage and transfer capabilities, and in-situ resource utilization.

NASA's human forays into deep space depend on advanced exploration systems such as those mentioned above. The deep-space habitation capability is critical and will be developed in collaboration with international and commercial partners. The Agency is executing its near-term plans and advancing continued plans to develop and demonstrate critical Mars-capable habitation systems on ISS, and then will progress into developing the deep-space habitation capability in cislunar space. Those critical systems and elements include: lightweight habitat structures, radiation monitoring and mitigation techniques, advanced environmental control and life support systems (ECLSS), fire safety, next-generation autonomous systems, and lightweight crew health

systems. A near-term example that will be delivered to the ISS is the Bigelow Aerospace's Bigelow Expandable Activity Module (BEAM) being delivered on a SpaceX Dragon spacecraft.

Other examples of NASA's overall habitation system development efforts being conducted include:

- NASA is currently investigating several radiation monitoring and mitigation projects, including sending next-generation radiation dosimeters on Mars robotic missions (e.g., Curiosity), the ISS, and the Orion flights (EFT-1, EM-1, and EM-2). This information will feed into new radiation models, assisting habitat designers with the development of deep-space habitats that will protect the crew from the radiation hazards in deep space.
- Fire is always a concern on spacecraft. The ability to identify early stages of fire, suppress the fire, and conduct a controlled cleanup after spacecraft fires will be extremely important on a Mars mission. NASA is currently investing in a project called SAFIRE, which will perform a series of flight experiments during the destructive return phase of cargo missions from the ISS to test large-scale flammability of various materials in microgravity. The data collected by these experiments will be crucial to developing deep-space habitats and systems to protect against -- and deal with -- the risk of fire on board spacecraft.
- One of the largest challenges for developing deep-space habitation is the development of an advanced environmental control and life support system that has greater reliability and lower logistics requirements than do the current ISS ECLSS systems. NASA is currently working on multiple investment activities to systematically address these advancements in these areas. The Agency intends to complete the majority of the development and testing of these next-generation systems on the ISS to ensure they are reliable for our missions beyond low Earth orbit.

NASA's System Maturation Teams also serve a critical integration function, defining the capability gaps that need to be filled for future missions, and coordinating between organizations involved in helping to fill those gaps.

Of critical importance are the activities and demonstrations on ISS that support these capability gap closures.

QUESTION 12:

Operation of the ISS has become increasingly expensive. The Operations portion of the budget has risen from \$2.26B in 2010 to \$2.96B last year. What is NASA doing to find efficiencies in the operating budget for the ISS?

ANSWER 12:

Since the ISS was extended to 2020 in 2011, NASA has implemented efficiencies in sustaining activities, some content reductions and cutbacks in operations overhead. ISS continues to look for further efficiencies. Ongoing activities to responsibly lower the O&M cost of the ISS include changes to our contracts to incentivize efficiency, lower overhead cost, and targeted enhancements in technology investments to reduce manpower-intensive processes. These activities have already been assumed in the FY 2016 President's budget request.

QUESTION 13:

NASA is projecting the ISS budget to increase from \$3.1B in 2016 to over \$4B in 2020, with the majority of that increase coming from the ISS Crew and Cargo Transportation line. Why will these transportation costs increase significantly when commercial crew costs were supposed to be in line with what NASA is paying Russia (adjusted for inflation), and there were supposed to be efficiencies since the new commercial crew vehicles could also carry a significant amount of cargo?

ANSWER 13:

The outyears in the budget are notional and may change. The notional increase in the ISS Crew and Cargo Transportation line is due to cargo transportation, not crew transportation. The largest driver is an increase in cargo transportation flights in the outyears. To date, we have only been able to launch four Commercial Resupply Service flights in one fiscal year. Our plan for the outyears increases to six or seven flights per year.

QUESTION 14:

NASA now relies on two private companies to provide cargo to the ISS. These companies operate under fixed-price contracts and their services are purchased by NASA rather than managed by NASA. Last year, Orbital ATK had a mishap on one of their cargo missions to the ISS that resulted in the loss of cargo, including supplies for the astronauts in orbit. What was the impact of this mishap on the ISS?

ANSWER 14:

The Orb-3 mission was carrying logistical support for the crew, spares system components, and research hardware. Operationally, there was no impact in maintaining full support for the crew of six as supplies had been stockpiled onboard the ISS. In addition, a wide portfolio of onboard research had been built up, enabling the crew to execute a minimum of 35 hours of research per week during subsequent increments. The SpaceX-5 and SpaceX-6 manifests were adjusted to account for the logistical loss from Orb-3, with a balanced priority of the upmass provided to the ISS research community. Spare hardware was also pulled from the shelves and flown. Specific research teams and companies were affected with the loss of their hardware and the ISS Program has been working with those entities to re-fly their cargo in upcoming flights.

QUESTION 14a:

Will NASA be able to keep the planned number of cargo flights in light of the hold on Orbital ATK flights?

ANSWER 14a:

Orbital-ATK is still on contract to deliver the remaining cargo to the ISS at the previously agreed to contract price. The number of flights to deliver cargo on contract was reduced by one, given the company's plan to utilize Atlas V and an upgraded version of Antares. Both of these launch vehicles allow for more cargo to be transported than the previous Antares, thereby resulting in fewer flights to carry the planned cargo.

QUESTION 14b:

How will research be affected if the number of cargo flights is reduced from what was planned?

ANSWER 14b:

As mentioned above, Orbital-ATK can reduce the remaining number of flights and still carry all planned cargo. With respect to the Orb-3 loss, several research samples for the Japanese and Europeans were lost, as well as commercial research which resulted in a significant delay in achieving their science objectives.

QUESTION 14c:

How will the delivery of critical supplies and spares (orbital replacement units) be affected?

ANSWER 14c:

Please see response to Question #14, above.

QUESTION 15:

The Center for the Advancement of Science in Space (CASIS) is contracted by NASA to manage the activities of the National Lab portion of the ISS. Of the \$15M that NASA gives CASIS every year, approximately \$12M is used for CASTS overhead and operations rather than grants. Is NASA concerned about the high percentage of funding that goes to administration rather than research?

ANSWER 15:

NASA is actively monitoring the progress of the Center for the Advancement of Science in Space (CASIS) in fully utilizing the National Lab portion of the ISS. The non-grant funds that are utilized by CASIS are directly applied to building and maintaining utilization of the National Lab, which is at 100 percent. NASA does not consider the non-grant funds an overhead, but rather an essential part of executing the Cooperative Agreement to fully exploit the National Lab.

QUESTION 15a:

What steps is NASA taking to ensure that CASIS leverages that base investment to attract additional outside investments.

ANSWER 15a:

While NASA's ISS Division acts as the liaison between the Agency and the CASIS, it does not manage CASIS or determine the research priorities for use of the ISS as a National Laboratory; CASIS has the responsibility for determining those priorities. As NASA has a Cooperative Agreement with CASIS to exploit the National Lab portion of the ISS, NASA and CASIS collaborate on the strategic and tactical level to ensure that ISS resources are being utilized consistent with NASA's overall mission, including returning benefits to humanity and enabling the commercial market in LEO. NASA believes this helps to ensure that research from a wide range of disciplines is carried out aboard ISS. CASIS works to an Annual Program Plan (APP), which stipulates yearly goals for the organization. CASIS provides NASA quarterly status reports, including end-of-year reports, which provide updates of work done versus the APP. Per one of GAO's recommendations in its report, "International Space Station - Measurable Performance Targets and Documentation Needed to Better Assess Management of National Laboratory" (GAO-15-397), NASA and CASIS will develop targets for the high-level metrics that NASA tracks beginning in FY 2016.

QUESTION 16:

The Administration proposed extending operation of the ISS through 2024 while the NASA Authorization Act of 2010 (P.L. 111-267) authorizes operation of the ISS through at least 2020. What congressional action do you believe is needed to permit operation through 2024?

ANSWER 16:

The extension of ISS operations will allow NASA and the international space community to accomplish a number of important goals, and ensuring the consistency between statutory references of ISS' operational period with the Administration's decision to extend its life until at least 2024 will allow NASA to maximize its potential, deliver critical benefits to our Nation and the world, and maintain American leadership in space. Congressional action through continued appropriations is required to permit operation of the ISS until 2024.

QUESTION 17:

NASA has consistently requested more funding for the Commercial Crew Program than the program has subsequently received. The program received \$392M, \$525M, \$696M, and \$805M, over the last four FYs. NASA officials now claim that the agency must receive the full request of \$1.24B or the program will be unable to stay on target and contracts will have to be renegotiated.

- a. How has the Commercial Crew Program been able to retain the 2017 target date, despite receiving significantly less funding than the amount the Administration previously considered essential?

ANSWER 17a:

The target date for Commercial Crew availability has slipped from the 2015 timeframe due to receipt of less-than-requested funding levels. The FY 2016 budget request and current contract schedules support certification by the end of 2017. The request is based on awarded contracts with 2017 launch dates and is not an estimate. If less funding is received, NASA will have to delay milestones for both partners proportionally, and lifecycle costs will be increased.

QUESTION 17a (i):

Has the Administration over-stated the funding needs, or are partners contributing their own resources in order to stay on schedule?

ANSWER 17a (i):

Please see response to Question #17a, above.

QUESTION 17b:

Why did the Administration design an acquisition strategy based on unrealistic funding levels?

ANSWER 17b:

The Administration and NASA believe it is important for the successful operation and utilization of the ISS to have domestic crew transportation capability as soon as possible in order to reduce reliance of foreign entities and to no longer outsource jobs and taxpayer funds to other countries.

QUESTION 17c:

Does NASA have a contingency plan if it does not receive full funding for the program? If yes, what is it? If not, how does NASA justify such an unrealistic budget request without a backup?

ANSWER 17c:

Please see response to Question #17a, above. If less funding is received, NASA will have to delay milestones for both partners proportionally, and lifecycle costs will be increased.

QUESTION 17d:

Would NASA prefer to remain reliant on Russia for ISS access rather than focus development resources on one contractor?

ANSWER 17d:

Competition in the Commercial Crew Program (CCP) has been critical to ensuring that NASA and the Nation receive the best value for U.S.-based crew transportation to ISS. Competition is the fundamental basis for establishing fair and reasonable pricing for all requirements, and it both incentivizes companies to expand their commercial customer base by selling services to others and takes advantage of opportunities for efficiencies to support reasonable prices. It also

incentivizes the companies to invest their own funds and share in system development costs. In addition, it ensures that if one provider's vehicle is grounded due to an anomaly, NASA would still retain a domestic option for the transport of its astronauts to the ISS. The value of competition in CCP has been noted by the Office of the Inspector General, the Government Accountability Office, and the Aerospace Safety Advisory Panel.

QUESTION 18:

NASA has consistently stated that multiple providers are necessary to ensure redundant capabilities in the event that one of the systems does not work. The NASA Authorization Act of 2010 requires the Orion crew vehicle to be designed for crew transport to the ISS in the event the commercial crew contractors are unable to perform that function. Why has NASA refused to fulfill the requirements of this law?

ANSWER 18:

NASA is complying with the NASA Authorization Act of 2010 -- the Orion design could accommodate ISS crew transportation requirements. NASA anticipates that commercial crew transportation services to ISS will be available in 2017. This is the fastest way to achieve crew transportation capability. Orion could be used to support the ISS, but this would force a major shift in development for Orion. This would be a highly inefficient use of the Orion and the SLS. The SLS is a heavy lift launch vehicle and has payload capability far and above that which is necessary to support ISS crew rotation and resupply activities; therefore, launching an SLS for ISS-related activities would be a highly inefficient use of the system that is simply not cost-effective. In an emergency, the SLS could be used for LEO operations. In addition, the Orion is a crew vehicle that is primarily designed for deep space exploration and, if needed for an emergency, could function as a backup vehicle for the ISS crew. The current Orion design is specifically designed and tailored for deep space exploration and a high-speed reentry to Earth, which includes systems that are not necessary for LEO missions. Launching the Orion capsule for use in LEO would also be an inefficient use of a robust system intended for other purposes.

QUESTION 18a:

Under what statutory authority is NASA deriving the ability to ignore this law? What is the legal precedent for this action?

ANSWER 18a:

Please see response to Question #18, above.

QUESTION 19:

According to the Administration's current interpretation of termination liability requirements, the SLS and Orion crew vehicle programs are required to account for termination liability on their contracts as part of the Federal Acquisition Regulations. How does NASA account for termination liability on the Commercial Crew Contracts? What is the current value of the termination liability on each of the contracts?

ANSWER 19:

Termination liability on the Commercial Crew Transportation Capability (CCtCap) contracts is accounted for in the same manner as the SLS and Orion contracts, which is consistent with Agency policy and the FAR requirements. Under incrementally funded contracts, the total amount of funds obligated on the contract at any given time is for performance of the work according to the contract schedule and milestones, including any potential costs that the contractor anticipates it would incur due to contract termination. Each contractor is responsible for accounting for its own potential termination costs. Termination liability held by the contractors is proprietary information, and we recommend that the Committee contact the contractors for further details.

QUESTION 20:

The Aerospace Safety Advisory Panel (ASAP) released its annual report in January. This report was highly critical of the leadership of the Commercial Crew Program and what it called a lack of transparency. NASA contends that the Commercial Crew Contractors will be at least as safe as government-run programs.

- a. Since the government is essentially funding the entire development of these systems, how can NASA justify this lack of transparency?

ANSWER 20a:

To protect the integrity of the procurement process, NASA needed to control the data it released following award of the initial Certification Products Contracts and after the award of the follow-on CCtCap contracts. The CCtCap procurement blackout and protest period caused the agency to restrict data and product releases to all parties for an extended period of time of almost one year. Protecting the procurement process helps ensure the best selection for the Nation was made.

QUESTION 20b:

What have you done to ensure the ASAP has full access to the information it needs to provide Congress and the Administration with an honest assessment of this program?

ANSWER 20b:

After the GAO protest was concluded and a public decision was released in January 2015, NASA took immediate steps to inform its key stakeholders, Congress, the Aerospace Safety Advisory Panel (ASAP), and the public about Commercial Crew contract details, including:

- the CCtCap Source Selection Statement was posted on NASA's website;
- NASA provided detailed briefings to our Congressional oversight committees on the status and plans of the CCP, including in-depth descriptions of the CCtCap contracts;

- NASA provided two in-depth briefings to the ASAP. One on the status of the industry partners designs and technical risks and another on the overall progress of our industry partners and the CCP as a whole;
- NASA conducted a press conference regarding the CCtCap contracts, which included representatives from both industry partners; and
- NASA has posted a public version of the CCtCap contracts on the NASA website.

Now that the constraints of the procurement and litigation process have been lifted, NASA plans to continue its information transparency initiatives and we are confident that this will provide all our oversight groups with sufficient insight into the human spaceflight programs at the Agency.

QUESTION 21:

The current agreement with Russia to transport astronauts to the ISS expires in 2017. NASA has already procured additional seats for 2018 in the event that the Commercial Crew contractors are not prepared to take astronauts to the ISS. If the contractors are ready by 2017, is NASA still obligated to pay for the additional Russian Soyuz seats?

ANSWER 21:

Yes. NASA is working with American companies to send crews to the ISS. Commercial Crew transportation system development is in the early stages and the first flight test is currently projected to occur in late 2017. To ensure continuous and uninterrupted American presence aboard the space station, the Agency has begun the Soyuz seat contract process, which has a three-year lead-time. Once NASA determines that U.S. companies are able to meet NASA's transportation requirements, these U.S. spacecraft will become our primary way of sending American astronauts to the space station and the Soyuz vehicles procured would be used as a backup transportation option to maintain our continuous presence in space. Full congressional funding for the Commercial Crew Program is required or further slips in U.S. capability will occur and sole reliance on the Russians will continue. A contract for seats in 2018 provides NASA with some flexibility to use these Soyuz seats when needed. This flexibility will allow for improved return of scientific research and ensures our Commercial Crew partners reach an operational tempo in a safe manner.

The first crewed flight of the Orion capsule is planned for no earlier than 2021. It will not be available during this timeframe.

QUESTION 21a:

If so, please explain why U.S. taxpayers should send money to Russia rather than fund the incremental modifications to Orion so that it can serve as a backup and comply with federal law?

ANSWER 21a:

Please see response to Question #21, above.

QUESTION 21b:

How does the process for bartering services work under our agreements with the ISS partners? If we bartered-back Soyuz seats that we already paid for, what would NASA get in return? Is there anything of comparable value that the Russian's could provide?

ANSWER 21b:

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).

As noted above, NASA would plan to utilize all procured Soyuz seats.

QUESTION 22:

Associate Administrator Bill Gerstenmaier has testified before the committee that government funding for the Commercial Crew Program is as high as 90 percent, compared to private sector funding. What can NASA do to encourage more private sector funding of Commercial Crew and other contracted programs?

ANSWER 22:

Competition in the Commercial Crew Program has been critical to ensuring that NASA and the Nation receive the best value for U.S.-based crew transportation to ISS. Competition is the fundamental basis for establishing fair and reasonable pricing for all requirements, and it both incentivizes companies to expand their commercial customer base by selling services to others and takes advantage of opportunities for efficiencies to support reasonable prices. It also incentivizes the companies to invest their own funds and share in system development costs.

QUESTION 22a:

Do you see a value to encouraging the partners to put more skin in the game as they did in the cargo program? Why or why not?

ANSWER 22a:

Yes, please see response to Question #22, above.

QUESTION 22b:

Is NASA trying to create a market, or trying to develop a service for NASA?

ANSWER 22b:

As part of our strategic, stepping stone approach to deep-space exploration, NASA is obtaining an ISS transportation service and also facilitating the development of a U.S. commercial crew transportation capability, with the goal of launching NASA astronauts from American soil in the next couple of years. This initiative to facilitate the success of U.S. industry in providing crew transportation to LEO will end the United States' sole reliance on Russia and ensure that we have safe, reliable and cost-effective access to the ISS and LEO.

More broadly, NASA is working to encourage the growth of LEO space economy that will continue to develop even after the end of the Station's lifetime. 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 NASA and other Government and commercial users safely, reliably, and at a lower cost.

QUESTION 23:

NASA is requesting a \$438M boost in Commercial Crew spending, in part because NASA would require additional funding if SpaceX and Boeing meet specific milestones in FY 2016. Chief Financial Officer, David Radzanowski, told reporters in February that this funding will only be needed if the milestones are met.

- a. If the companies do not reach their milestones, how will NASA account for the surplus in the program?

ANSWER 23a:

There would be no surplus. The contracts have fixed prices for the completion of development for each company's crew transportation system. The budget request for the Commercial Crew Program anticipates the partners will meet specific milestones on schedule. NASA is required to obligate sufficient funds on the contracts in advance to cover the upcoming scheduled milestones, prior to work beginning on those milestones. If the contractor's completion of a milestone is delayed, final payment for that milestone will be delayed as well. However, the funding still must be obligated on the contract as planned and the overall cost of the contracts remains the same.

QUESTION 23b:

Is there any funding from FY 2014 that was carried over into FY 2015?

ANSWER 23b:

Due to the late award of CCiCap and the ensuing protest, NASA was unable to obligate \$73M on the contracts prior to the FY 2014's end. If the protest had not occurred, NASA would have obligated 100 percent of the available FY 2014 funding. NASA carried-over \$385M in costs from FY 2014 into FY 2015. Of that amount, \$118M was related to incomplete Commercial Crew Integrated Capability (CCiCap) Space Act agreement milestones. The remaining \$267M was related to the CCiCap contracts. It should be noted that funding must be obligated on the contracts prior to work beginning on a milestone.

QUESTION 23c:

Do you expect funding from FY 2015 to augment the FY 2016 budget for the program? If so, how much?

ANSWER 23c:

NASA does not anticipate significant levels of carryover into FY 2016 in the Commercial Crew Program.

QUESTION 24:

The FY 2016 NASA budget request includes \$1.244B for the Commercial Crew program. This is a 55 percent increase above the enacted FY 2015 amount. Please help the Subcommittee understand what the consequences might be if Congress does not appropriate as much for Commercial Crew as NASA has requested.

ANSWER 24:

If less funding is received, NASA will have to delay milestones for both partners proportionally, and continue our sole reliance on Russia. The budget request is based on awarded contracts with 2017 launch dates and is not an estimate. The FY 2016 President's budget request is the amount needed to fund CCP, including planned CCtCap contract activities and the program office support. If NASA is unable to fund its contractual requirements, the partners may request contract cost adjustments, the certification dates will be affected, and overall lifecycle costs would increase. Thus, insufficient funding in FY 2016 will result in a delay to achieving certification and higher life cycle costs.

- a. For example, specifically how would the program be affected if Congress were to provide flat funding at the FY 2015 level (\$805M) instead of the requested amount? Alternatively, how would it be affected if Congress were to provide half the requested increase (\$1.024B)?

ANSWER 24a:

Holding the Commercial Crew Program at the FY 2015 level of \$805M would result in NASA's inability to fund several planned contract milestones in FY 2016 and could result in the contractors having to stop work or work at risk in early 2016. If funding were reduced to \$1.024B, NASA would still be unable to fund several planned milestones in FY 2016 and could result in the contractors having to stop work or work at risk in summer 2016. The continued underfunding of this capability by Congress would delay the goal of launching U.S. astronauts to ISS with U.S. vehicles by 2017 and would have a significant impact on NASA's ability to meet this goal. This would force a continued sole reliance on Russian capabilities, with current payments to Russia of around \$500M per year.

QUESTION 24b:

If you anticipate schedule delays as a likely consequence of reduced funding, is there a rule of thumb-perhaps a number of months per \$100M shortfall for projecting the delay that would result from a particular funding level?

ANSWER 24b:

There is no rule of thumb for converting dollar amounts into months of schedule. In the event NASA does not receive the requested funding level, the Agency would have to look at schedule adjustments to the program

QUESTION 24c:

At what funding level would NASA consider the option of downselecting from two commercial providers to just one? What would be the consequences of such a decision?

ANSWER 24c:

NASA does not intend to, and the contract does not provide for, down-select if received appropriations are less than the President's budget request. Having the dissimilar redundancy of two U.S. providers is critically important to full utilization of the ISS.

QUESTION 25:

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 25:

NASA cannot comment on the contractor's future business decisions.

QUESTION 25a:

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

ANSWER 25a:

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. These requirements are written at a fairly high level, and are not specific to a particular launch vehicle. 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 it 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 25b:

Would NASA or the commercial provider be responsible for the cost of additional testing and certification? If NASA would likely bear some of the cost, roughly how much might that be?

ANSWER 25b:

NASA's contracts with its commercial crew providers are for a service, not for a launch vehicle. NASA would expect its commercial service providers to meet the terms of their contract for the agreed to contract price. The contractor would be responsible for costs of additional testing and certification resulting from the contractor's decision to change its system.

QUESTION 25c:

How will this impact the 2017 launch readiness date?

ANSWER 25c:

NASA does not anticipate that a potential future change in launch vehicle would impact the 2017 launch readiness date. However, this is difficult to predict and depends on when the switch is to a different launch vehicle is made and the specific vehicle.

QUESTION 25d:

Since the Vulcan launch vehicle may end up carrying U.S. astronauts, what level of insight will NASA have in the development of that launch vehicle?

ANSWER 25d:

Should a Commercial Crew provider wish to move to a new launch vehicle for performance of the CCtCap contracts, NASA would have adequate insight into that vehicle to ensure that it met the Agency's crew safety requirements. NASA's level of insight is specified in the CCtCap contracts, regardless of which vehicle the contractor uses, and our level of insight is sufficient to enable NASA to ensure that the vehicles are meeting NASA's safety and performance requirements.

QUESTION 25e:

How does this affect the recent source selection?

ANSWER 25e:

The 2014 CCtCap selection is not impacted by a potential future decision by a Commercial Crew provider to change launch vehicles. NASA expects its service providers to meet the terms of their contract for the agreed to contract price.

QUESTION 26:

The Space Network Ground Segment Sustainment (SGSS) program breached cost and schedule baselines by nearly 30 percent according to the GAO. In the event of such a breach, NASA is required to present Congress with a new cost and schedule baseline. This new baseline was supposed to be done by November of 2014 and has been pushed back to June of this year.

- a. Why has it taken nearly two years to provide new cost and schedule baseline estimates for the SGSS program?

ANSWER 26a:

NASA undertook a review and evaluation of Space Network Ground Segment Sustainment (SGSS) in July 2013 after the Technical Critical Design Review (CDR) when the contractor cost-to-complete estimates were approaching – but not exceeding – the Agency Baseline Commitment (ABC). NASA requested the contractor to provide a detailed cost-to-complete for review. The Government review team did not accept the plan that was submitted by the contractor, and NASA requested the contractor provide a more realistic cost and schedule estimate-to-complete based on current performance. In February 2014, the contractor presented a more realistic plan to the SGSS project office and it was approved by NASA, and the contractor was directed to provide an over-target baseline proposal that was based on the new plan. NASA also prepared the initial notification to Congress that was submitted in March.

In July 2014, the contractor provided the over-target baseline proposal, which was then reviewed by the SGSS project office. Results of this review indicated a limited detailed basis of estimates and high level planning packages for work starting in FY 2016. There was not enough information provided in this proposal to adequately assess the proposal. In October 2014, the SGSS project office provided their assessment of the contractor's cost-to-complete proposal, identified and quantified the risks, and presented current contractor performance to the Standing Review Board (SRB) and a review team lead by the Space Communications and Navigation (SCaN) Program office. In November 2014, the Agency reviewed the recommendations and directed the SGSS project to obtain the detailed information from the contractor, provide the necessary assessment and reviews, and to report back to the Agency Program Management Council (APMC) by summer 2015 with new baseline cost and schedule recommendations. The contractor has provided the updated estimates with risks and updated plan with detailed schedule. The project has completed their analyses and presented them to the SRB and SCaN Program Review Team.

NASA convened the APMC SGSS Re-baseline Review on June 30, 2015; the APMC approved the project to continue, closed out the CDR and established the new ABC. The re-baseline includes an increase in both cost and schedule to address project overruns primarily driven by slower than planned software development. Based on the review, the APMC granted approval for the project to continue in Phase C with the content, schedule, and cost profile as presented. The new Final Acceptance Date is September 2019. NASA is providing the appropriate Congressional notification as required.

QUESTION 26b:

What has been descoped and to what extent could these impact operations for current and future programs?

ANSWER 26b:

The SCaN Program and the SGSS Project Office has conducted a thorough study of the SGSS descope options. Currently NASA's plan is not to descope any capabilities that affect any current or known future user's requirements.

QUESTION 27:

The ICESat-2 and SGSS projects had to be rebaselined shortly after each project was confirmed. With the experiences of these projects in mind, what actions is the agency implementing to ensure that baselines established at confirmation reviews are realistic?

ANSWER 27:

One of the processes NASA has at its disposal to help ensure the establishment of realistic baselines is the JCL --a process that combines a project's cost, schedule, and risk into a complete picture. In essence, the JCL is the probability that cost will be equal to or less than the targeted cost and schedule will be equal to or less than the targeted schedule date. This helps inform management of the likelihood of a projects programmatic success. As GAO has reported, cost and schedule performance on NASA projects has improved in recent years due in part to the use of tools such as JCLs. But while baselines established at confirmations are realistic, that does not mean they can perfectly predict each project's performance.

QUESTION 28:

A sample return mission is considered by some to be the "Holy Grail" of Mars exploration. How might such a mission be launched and would it need to be crewed? Has NASA initiated planning for robotic Mars missions beyond the Mars 2020 mission that is currently in development?

ANSWER 28:

NASA recognizes the scientific importance of collecting and studying samples from Mars, which is why NASA's SMD is working diligently to ensure a successful Mars 2020 mission with an effective sample caching system. Viable mission architectures for sample return could include robotic missions or crewed exploration systems. The viability and significance of specific Martian materials will be better understood once samples have been acquired and investigated by the next Mars rover. 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.

QUESTION 29:

In the 2013 Planetary Decadal Survey, the NAS committee placed the highest priority on the return of samples from Mars and determined that a sample return would have significantly higher science return and a much higher science-to-dollar ratio as compared to several rover missions. The Mars 2020 rover designs state that it will dig up samples and cache them to be

collected and returned to Earth by a future mission. Yet, 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.

- a. Do you believe an orbiter follow-up is a good use of NASA's funds and if so, why?
- b. Under NASA's FY 2016 budget request, will any funds be spent on planning for, or development of, a follow-up orbiter?
- c. What is the impact of selecting a follow-on mission to the Mars 2020 rover that may be unable to obtain the Martian samples cached by the Mars 2020 rover?
- d. For what reasons would NASA disregard the recommendation of the NAS committee and not conduct a sample return mission after Mars 2020?
- e. When does NASA plan to retrieve cached Mars 2020 samples?
- f. What, if any, international partnerships are NASA pursuing that may facilitate a return of cached Mars 2020 samples?
- g. How long are the cached samples designed to withstand the Martian environment without degradation or compromise of the scientific samples?
- h. When can we expect a mission to retrieve the samples Mars 2020 digs up?

ANSWER 29a-h:

NASA is exploring the merits of an orbiter as part of an overall strategy to address the strategic knowledge gaps for our journey to Mars. In addition to being responsive to the Decadal Survey, potential robotic missions in the 2020's will need to assure we protect our orbital communications infrastructure, continue the high-resolution survey of the Martian surface and seek out stores of resources that could support humans at Mars in the 2030's. Based on work in 2016 we will determine the best approach to address the Strategic Knowledge Gaps and lay out the steps toward achieving those goals.

During FY 2016, NASA expects to support mission concept studies and analysis by the science community of an orbiter's potential capabilities. While specific instruments and design of a Mars orbiter has not yet 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.

Surface operations at Mars, including operations related to the retrieval of cached samples, are dependent upon the support of orbiters. Orbiters provide capabilities such as higher-speed communications with Earth and reconnaissance of potential landing sites.

The Mars 2020 mission includes several international contributions that will enable the selection and caching of samples on the surface of Mars. In addition, NASA regularly confers with potential international partners to assess cooperation in the future exploration of Mars. Such efforts include conducting joint concept studies for missions that could contribute to returning samples from Mars. NASA expects that international partners will collaborate on future missions as their national priorities and funding availability allows.

At this time, no decision has been made on initiating development of an orbiter. Additionally, 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 30:

NASA does not appear to have budgeted for continued operations of the Opportunity rover or Lunar Reconnaissance Orbiter. Considering how cost-effective these investments are at this point, why doesn't NASA's request include funds for these projects?

ANSWER 30:

At this time, the Mars Exploration Rover Opportunity and Lunar Reconnaissance Orbiter (LRO) are fully funded through FY 2015 and both continue to return high-quality scientific data. These missions, which have been operating since 2004 and 2009, respectively, were not funded in the FY 2016 budget request given higher priorities.

QUESTION 31:

The Planetary Science Senior Review recently ranked the Opportunity rover's upcoming science plan higher than any other mission on Mars, but NASA hasn't requested any funding for the rover. Why do you believe, as you stated at a recent Senate Commerce Committee hearing, that Opportunity's "time has passed?"

ANSWER 31:

Now in the eleventh year of a 90-day mission, Opportunity long ago completed all of its original science requirements. As mentioned in our response to question 30, Opportunity is fully funded through FY 2015 and as the Planetary Science senior review found, it continues to return high-quality scientific data. However, scientific merit is only one aspect of the review process. Other performance factors include national needs, the technical status of the mission and budget efficiency. NASA then uses the findings to define an implementation strategy for the Planetary Science division as a whole and provide programmatic direction to the missions and projects concerned. Based on these overall criteria, Opportunity was not funded in the FY 2016 budget request given higher priorities.

QUESTION 31a:

If NASA does not use Senior Reviews to determine mission extensions, what is the purpose of Senior Reviews?

ANSWER 31a:

Please see response to Question #31, above.

QUESTION 32:

Testifying before the Senate Commerce Subcommittee on Space, Science, and Competitiveness, you said the Opportunity rover's "time had passed," and that you're cutting Opportunity's funding because "you have to make choices," between projects like Opportunity and InSight. This seems to be in stark contrast to the agenda the Administration has for the Earth Science Division. Why is NASA forced to make tough choices in the Planetary Science budget, the only planetary science program in the federal government, but is not forced to make these choices in the Earth science budget which is supplemented by research in 13 other federal agencies -two of which have actual Earth observation operational requirements directed by the National Space Policy?

ANSWER 32:

To the contrary, all SMD divisions—including Earth Science—continually make budgetary decisions that affect the number of missions, types of missions, and the length of missions.

While other Government organizations provide specific supplemental Earth study, only NASA captures a space-based, global view of Earth as a complex integrated system, and only NASA possesses the necessary technical and management expertise to build satellite systems that provide critical Earth observations from space. Indeed, measurements from many NASA Earth-observing research satellites are used routinely by other federal agencies to improve their operational products and forecasts. For example, measurements from NASA's Global Precipitation Measurement Core Observatory/GPM constellation, Moderate Resolution Imaging Spectroradiometer (MODIS), and the Jason-2 ocean altimeter mission are used routinely by NOAA and the Department of Defense weather services to improve global and regional weather forecasts and extreme event predictions. Soil moisture data from GPM, Gravity Recovery and Climate Experiment (GRACE), and soon Soil Moisture Active Passive (SMAP) are used routinely by NOAA and FEMA to produce daily flood hazard forecasts and drought monitoring products. Data from the NASA MODIS instruments are used by civil and Defense agencies for a variety of environmental forecasts including dust storm and visibility predictions.

Budget pressures have forced NASA Earth Science to make significant mission de-scopes and delays. In 2010, owing to budget shortfalls and increasing cost estimates for completion, the Global Precipitation Measurement (GPM) Low Inclination Orbiter (LIO) satellite was cancelled to allow the available budget to be used to complete the GPM Core Observatory without further delay.

The 2007 Earth Science and Applications from Space Decadal Survey recommended that NASA Earth Science Division develop and launch 15 new and critical Earth-observing missions before 2018. Given a constrained budget environment, the cadence of Decadal top-priority missions has fallen far short of the recommendations.

QUESTION 33:

NASA CPO David Radzanowski has said that while the Opportunity rover and Lunar Reconnaissance Orbiter don't receive any funding under the FY 2016 budget request, both vehicles could be reinstated in the future. If NASA halts funding for these vehicles, and later

decides to reinstate them, what would be the cost of reinstatement?

ANSWER 33:

At this time, NASA has not determined the cost of reinstating Opportunity or LRO at a future, unspecified date because neither mission was designed to be restarted post closeout. However, NASA's Planetary Science Division will reassess the condition and cost of maintaining both missions prior to closing the programs. The challenges associated with closing and restarting such a program include placing the asset into a state of hibernation such that it can be successfully re-awakened at a later date, reassembling the personnel that have the expertise to operate the spacecraft as well as ensuring the ground systems needed to support the mission remain intact. In particular, Opportunity and LRO were not designed to hibernate; a feature that needs to be taken into account at the start of the mission design, and thus, may not be technically feasible.

Nonetheless, SMD has experience and proficiency with long-term hibernation of missions, such as New Horizons, and reinstating missions post closeout when technically feasible. Most recently, SMD restarted the Wide-field Infrared Survey Explorer (now dubbed NEOWISE) after almost two years of inactivity to learn more about the populations of near Earth objects and comets. In the first year after the mission was restarted, the NEOWISE spacecraft discovered and characterized 40 near-Earth objects, three new comets as well as further observed and characterized 245 previously known NEOs and continues to produce valuable scientific data today.

QUESTION 33a:

What challenges are associated with closing and restarting a program in this manner?

ANSWER 33a:

Please see response to Question #33, above.

QUESTION 33b:

Are there any other programs of this type that have been closed and restarted at a later date?

ANSWER 33b:

Please see response to Question #33, above.

QUESTION 34:

Within the FY 2016 budget request's SMD, planetary science seems to take the biggest reduction with a five percent cut from FY 2015 enacted levels. Have you met or spoken with any organizations that suggest cutting planetary science would be beneficial?

ANSWER 34:

The FY 2016 President's budget request shows a total budget for Planetary Science of \$1,361.2M

for FY 2016, which is an increase of \$80M over the FY 2015 request and an increase over the enacted FY 2013 and FY 2014 levels. This request is part of a broader approach to maintain balance across NASA within a constrained fiscal environment, and to ensure that the President's FY 2016 budget request is consistent with available resources while still maintaining the highest priority science across the portfolio of Planetary Science programs. This budget strategy concentrates on implementing recommendations from the latest Planetary Science Decadal Survey, a process that is well supported by Congress and the science community.

To ensure top mission priorities of NASA and the planetary science community are accomplished, this budget provides the full five-year funding plan for the Mars 2020 mission, initiates formulation for a new mission to Europa as well as releases the next New Frontiers Announcement of Opportunity in 2016. Additionally, the FY 2016 request continues development of InSight (Interior Exploration Using Seismic Investigations, Geodesy and Heat Transport) and OSIRIS-REx (Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer); supports the production of planetary exploration enabling Plutonium-238 in partnership with the Department of Energy; provides for instrument contributions to the European Space Agency's (ESA's) BepiColombo, ExoMars and JUICE (Jupiter ICy moons Explorer) missions; and maintains support for planetary science technology and research awards.

QUESTION 34a:

How would cutting planetary science in favor of other programs contribute to NASA's mission?

ANSWER 34a:

Please see response to Question #34, above.

QUESTION 34b:

Do you believe the American people would favor a cut to planetary science?

ANSWER 34b:

Please see response to Question #34, above.

QUESTION 35:

The FY 2016 budget request includes funds for the European Space Agency's Jupiter Icy Moons Explorer (JUICE). What is NASA's role in JUICE?

ANSWER 35:

NASA's contribution to ESA's JUICE mission consists of one U.S.-led science instrument and hardware for two European instruments. Specifically, NASA will provide the transmitter and receiver hardware for a European-led radar sounder designed to penetrate the icy crust of Jupiter's moons to a depth of about 5 miles (9 kilometers). The JUICE mission's emphasis is in the study of Ganymede, although, its instruments can be used similarly during the potential close flybys of Callisto and Europa. This will allow scientists to see for the first time the underground

structure of these tectonically complex and unique icy worlds. The NASA contribution also consists of U.S.-built Ultraviolet Spectrometer to explore the surfaces and atmospheres of Jupiter's icy moons and how they interact with the Jupiter environment as well as components of the European-led Particle Environment Package to measure the neutral material and plasma that are accelerated and heated to extreme levels in Jupiter's fierce and complex magnetic environment.

Depending on the launch date of NASA's Europa mission, there is a potential the two missions would overlap; however, the missions would be complementary in science investigations. The JUICE spacecraft will make up to two close flybys of the moon Europa, several flybys of Callisto, and then will settle into orbit around Ganymede for an extended study of that moon while NASA's mission will focus on obtaining nearly global coverage of Europa through approximately 45 flybys. Together, these missions help provide scientists with a more complete picture of the Jovian system and the potential for life on its icy moons.

QUESTION 35a:

What does NASA hope to achieve by helping ESA with JUICE?

ANSWER 35a:

Please see response to Question #35, above.

QUESTION 35b:

Will JUICE overlap at all with a potential NASA Europa mission?

ANSWER 35b:

Please see response to Question #35, above.

QUESTION 35c:

Is there any chance a successful JUICE mission will eliminate the need for a NASA Europa mission?

ANSWER 35c:

Please see response to Question #35, above.

QUESTION 35d:

How will JUICE compliment or inform a Europa mission?

ANSWER 35d:

Please see response to Question #35, above.

QUESTION 36:

There appears to be a significant addition to the Astrophysics budget to support ISS-CREAM and other balloon-based investigations on cosmic rays. What new data does NASA hope to acquire with these missions?

ANSWER 36:

Cosmic rays are high-energy particles produced in a variety of galactic and extragalactic sources, including supernovae and active galactic nuclei (AGNs). Cosmic rays are critical to understanding the interstellar medium in this and other galaxies, tracing the physics at work during the formation of galaxies, where jets play a major role in the formation of stars, and in our ongoing search for dark matter.

As reported in the 2014 NASA Science Plan, the Cosmic Ray Energetics And Mass (CREAM) experiment will extend direct measurements of cosmic rays to higher energies, while allowing for direct identification of cosmic-ray particles—capabilities not available to ground-based experiments. ISS-CREAM (CREAM for the International Space Station-ISS) focuses on answering long-standing fundamental science questions:

- Do supernovae really supply the bulk of cosmic rays?
- What is the history of cosmic rays in the Galaxy?
- Can the energy spectra of cosmic rays result from a single mechanism?
- What is the origin of the steepening (“knee”) in the cosmic ray energy spectrum?

The CREAM instrument had six successful balloon flights over Antarctica during the local summer time from 2004 to 2010 for a total flight time of 161 days, the longest record for a single balloon-borne investigation. It measured individual cosmic rays over a broad energy range with precise elemental identification.

ISS-CREAM places this highly successful balloon-borne instrument on board the ISS. Lower backgrounds (because Earth's atmosphere will no longer interfere with data collection) and longer exposure times will allow for collection of at least ten times more data than obtained from the balloon version of CREAM. CREAM on the ISS will also extend cosmic ray measurements to energies beyond those observable with balloon flights, thereby providing keys to understanding the origin, acceleration and propagation of cosmic rays. The modified balloon instrument will be carried aloft on a Space X Dragon Lab cargo supply mission and attached to the Japanese Exposed Module for 1-3 years of operation. There has been no significant addition to the Astrophysics budget to support ISS-CREAM and other balloon-based investigations of cosmic rays. The ISS-CREAM, a demonstration mission to transform a balloon payload into a space mission, experienced a budget overrun. It should be noted, however, that the overall cost is still much lower than a typical stand-alone mission of opportunity.

QUESTION 36a:

Is this type of research extensible to other areas of research conducted at NASA?

ANSWER 36a:

Balloon-borne investigations provide fast, comparatively lower cost access to near space for substantive scientific investigations and flight-testing of new technologies in space-like conditions. These programs also provide a training ground for the principal investigators of tomorrow's major missions. To date, NASA's Astrophysics, Heliophysics, and Planetary Science divisions have utilized balloon-borne investigations to address their science requirements. It is possible that other proven balloon-borne payloads may be modified for use on the ISS. Any such investigation would be selected only after a proposal is submitted to peer review and technical evaluation for both the scientific merit and the programmatic feasibility of the associated proposal budget, schedule, and organizational qualifications.

QUESTION 36b:

What are the advantages to using balloon-based missions as opposed to other alternatives?

ANSWER 36b:

On the ground, high-energy cosmic rays are detected indirectly through observation of the cascade of particles created as they pass through the Earth's atmosphere. These observations are limited by uncertainties in atmospheric effects. Balloon-borne experiments, in contrast, can observe cosmic ray particles directly using high altitude particle detectors. Balloon experiments have the advantage of operating above most of the Earth's atmosphere, thus dramatically reducing uncertainty, while remaining inexpensive compared to the cost of a dedicated cosmic ray satellite. Balloons also have the advantage of being upgradable on shorter timescales compared to satellite experiments. This is an advantage for technology development, and it offers a robust training environment for young researchers.

QUESTION 36c:

How does ISS-CREAM align to recommendations of the 2010 New Worlds, New Horizons Decadal?

ANSWER 36c:

Cosmic-ray investigations address fundamental questions such as "What is dark matter?" and "What are the Properties of Neutrinos?" -- two of the four science frontier questions for advancing knowledge in the 2010 Decadal Report, "New Worlds, New Horizons in Astronomy and Astrophysics." The Astro2010 Decadal Survey Panel Reports pointed out that dark matter searches hinge on great advances in the sensitivity and sky coverage of high-energy gamma ray and cosmic-ray experiments.

ISS-CREAM addresses the science objectives of the Advanced Cosmic-ray Composition Experiment for the Space Station (ACCESS) prioritized in the Small Space-Based Initiative category of the 2001 Decadal Study Report "Astronomy and Astrophysics in the New Millennium." The Panel on Cosmology and Fundamental Physics Report specifically stated, "Precise measurements of various cosmic ray elements over a wide energy range are also necessary to constrain cosmic ray acceleration and propagation models and to determine the astrophysical background."

The importance of balloon-borne cosmic ray particle investigations was also discussed in the “suborbital” section of the 2010 New World, New Horizon Decadal Survey, where it was stated:, “The balloon program in particular is important for advancing detection of the cosmic microwave background and particle detection. These programs also provide a training ground for the principal investigators of tomorrow’s major missions. A growth in the budget by \$15M per year is recommended.” The Astro2010 Panel on Particle Astrophysics and Gravitation also recommended a broad program for particle detectors to be flown above the atmosphere, making use of the cost effective platforms provided by balloons and small satellites.

QUESTION 37:

The FY 2015 budget request stated that “Unless partners are able to support the U.S. portion of SOFIA costs, NASA will place the aircraft into storage by FY 2015.” That statement, along with the fact that the Administration significantly underfunded SOFIA in FY 2015, led the scientific community to believe the mission would be cancelled. Congress responded by continuing the observatory’s Operations in both appropriations and the house-passed Authorization bill. In the FY 2016 budget request, the President funds SOFIA at \$85M. How can the Administration work with Congress in the future to ensure such important programs are not cancelled without thorough and thoughtful review and input from stakeholders?

ANSWER 37:

The Administration values input from stakeholders in Congress and the scientific community, and will continue to consider input provided through decadal surveys, Congressional hearings, and other venues. The decision to propose, as part of the FY 2015 NASA budget request, to put SOFIA into storage was primarily a budgetary decision driven by the tight budget caps in the Bipartisan Budget Act of 2013. Among the possible Astrophysics projects considered for reduction, SOFIA was identified for two reasons. First, it is the only large strategic Astrophysics project that was not a first priority of a Decadal Survey. Second, its operations costs are the second largest of all NASA science missions, with only Hubble costing more.

QUESTION 38:

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. 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 38:

The multiple flyby mission, which has not been formally named but has features based on studies of the “Europa Clipper” concept, has an expected lifetime of three years. It has been designed to achieve more than 80 percent of the science envisioned in the previously studied Europa Orbiter concept at less than 50 percent of the estimated costs. The multiple flyby design builds on technologies and techniques developed for Cassini and Juno. A spacecraft in Europa orbit would continually be immersed in very high radiation, limiting the mission lifetime to a primary mission of just a few months and reducing overall mission data return; a multiple flyby mission

because it spends much less time in the highest radiation environment has a much longer lifetime and does not require custom designed ultra-high radiation parts, resulting in substantially reduced mission costs. 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 few weeks. The mission achieves near global coverage through approximately 45 flybys without sustained, life-limiting radiation exposure.

QUESTION 39:

The Europa Clipper is expected to be powered by solar arrays, but the ionizing radiation from Jupiter is expected to gradually degrade these cells and limit the Clipper's operational window to a few months. Why were solar cells selected as a power choice over one of the five available Radioisotope Thermoelectric Generators given the fact that they will limit the mission's operational window?

ANSWER 39:

As mentioned in the response to question 38, the multiple flyby Europa mission has an operational lifetime of three years, builds on technologies and techniques developed for previous missions, and only requires short duration close flybys in the intense radiation environment. Part of the mission concept review included an extensive evaluation of multiple power sources, which determined solar power to be technically feasible without the need for new development efforts (instead leveraging the solar arrays design from the Juno mission), despite the harsh radiation environment, as well as more cost effective. 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 39a:

How long can the Clipper's solar cells be expected to provide adequate power?

ANSWER 39a:

Please see response to Question #39, above.

QUESTION 40:

The FY 2016 budget request is only the second year that the Administration has requested funding for a mission to Jupiter's moon, Europa, despite guidance from the Decadal Surveys and Congressional direction that it be included in the agency's planetary science program. Why didn't the Administration request funding for a Europa mission before FY 2015?

ANSWER 40:

NASA recognizes the importance of Europa exploration and its potential to address fundamental questions related to life beyond Earth. The 2011 Planetary Science Decadal Survey identified the Jupiter Europa Orbiter (JEO) as one of the two highest priority missions of the planetary science

community. However, the projected cost of the JEO mission (\$4.7B in FY 2015) led the Survey authors to recommend major cost reductions before the mission was undertaken. In response to this recommendation, NASA has evaluated a variety of Europa mission alternatives with a range of decreased costs. These options included lander, orbiter, and flyby concepts. The Europa multiple flyby concept was chosen as the best of these three options and the Europa project is currently transitioning from Pre-Phase A study activities to Phase A formulation activities based on the Administration's FY 2016 request.

With the President's FY 2016 budget request and the FY 2014 funds that are still being expended, there is sufficient budget between FY 2015 and FY 2016 to conduct the planned Phase A activities to fully develop the requirements to support the System Requirements Review and conduct Key Decision Point B in 2016.

QUESTION 40a:

Why did the Administration request just \$30M for a Europa mission in FY 2016?

ANSWER 40a:

Please see response to Question #40, above.

QUESTION 40b:

What do you expect the Europa mission to cost in total?

ANSWER 40b:

The Europa mission as evaluated at KDP-A is estimated to cost approximately \$2B in FY15, not including launch vehicle and headquarters unallocated future expenses (UFE).

QUESTION 41:

The FY 2016 NASA budget request includes \$30M for a mission to Jupiter's moon Europa, which has been a congressional priority in recent years. The agency's congressional budget justification, released in February, states that "the leading [Europa] mission concept may require significant modification depending on what researchers learn in FY 2015."

ANSWER 41:

In 2014, Hubble observations suggested that plumes of water are being emitted from the surface of Europa, an intriguing development resulting in increased interest in a mission to Europa. Additional Hubble campaigns have been made to learn more about these plumes, and NASA is still waiting for peer-reviewed results of the 2015 Hubble campaign. As a result, analysis has begun to investigate how the mission concept could be modified to include direct plume interrogation if the new results justify such a change. Interrogating the plume might allow direct measurements of the subsurface materials.

Phase A efforts will be expanded to include potential options to more directly interrogate the plumes. It is anticipated that these studies will be concluded in 2016, in order to inform a decision on whether and how the mission concept should be modified.

QUESTION 41a:

What is the current status of this potential requirement for changes in the Europa mission concept?

ANSWER 41a:

Please see response to Question #41, above.

QUESTION 41b:

Please describe the types of changes in mission concept that appear most likely. What types of research finding might result in such changes being required?

ANSWER 41b:

Please see response to Question #41, above.

QUESTION 41c:

When is this issue likely to be resolved?

ANSWER 41c:

Please see response to Question #41, above.

QUESTION 42:

In documents provided to Committee staff in a recent briefing, NASA stated that the world will add 831M passengers to the aviation market from 2011 to 2016. What is the Aeronautics Research Mission Directorate doing to ensure that the National Airspace System, already the largest and most complex aviation system in the world, can handle its share of these additional 831M passengers?

ANSWER 42:

NASA Aeronautics supports a research agenda that looks beyond the near term time frame anticipating the needs and growth of National Airspace System (NAS) for 2025 and beyond. NASA is exploring the next stage of NAS development that is expected to involve integrated gate-to-gate flight trajectories for full trajectory-base operations. Networked enabled decision making will likely be a key part of this new operational architecture where decisions will be

made in a highly distributed manner, some made by humans, some by machines, some by ground based systems, and some on the flight deck. Highly advanced modeling and simulation systems are being developed by NASA to test new operational concepts and assure their safe and effective performance. Looking even farther beyond, research in fully autonomous systems capable of safely managing larger numbers of diverse aircraft in more highly complex airspace will be required to meet the demand for air travel and airspace usage reflected in the growth numbers above. NASA Aeronautics' long term research is investing now to prepare for the needs beyond NextGen.

NASA Aeronautics conducts research to advance operational and safety performance of the NAS. We work closely with the FAA and operational community to mature technologies for application in the near-term time frame supporting advanced automation for reducing delays, saving fuel, and enabling greater throughput and efficiency. Recent technology transfers to the FAA include automation to enable higher throughput arrivals in busy airports, smoother arrival flight paths for less fuel burn and noise, optimized airport surface movement reducing unnecessary stops and idling during taxi, and effective planning of takeoff times to fit easily in available slots in the en route overhead streams. Delays are also reduced during the en route portion of a flight using NASA tools that examine weather impacts that could force large excursions to the planned route and proposing new flight paths that prevent the resulting delays saving fuel, crew time, and passenger time. Solutions for such weather delay avoidance are being developed as tools for use by airlines at their system operation centers for effective fleet management, as well as tools for flight crews to take advantage of highly accurate performance data for the specific aircraft to manage single flights for reduced delay and fuel savings. Collectively, as these capabilities are accepted and deployed by the FAA and operators over the next 5+ years, NASA developed technologies will provide greater access to safe, efficient, and cost effective air transportation.

In addition, we are building enhanced collaborative relationships with global research partners to help set requirements and standards for airspace management that will enable efficient growth of airspace systems outside of the United States where the largest part of the above referenced growth is expected to take place. Safe and effective operations at all points on the globe are of vital interest to U.S. air carriers and our internationally travelling citizens. Working with foreign government sponsored research institutes and U.S. industry and system developers, NASA is working to mature our automation technology with U.S. industry for their application in international airspace. U.S. interests are well served as U.S. industry delivers the capability and sets the standards for global operations.

QUESTION 43:

Private companies have clear incentives to develop faster and more fuel-efficient vehicles. Yet, NASA's FY 2016 budget request prioritizes the Aeronautics Research Mission Directorate's (ARMD) 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?

ANSWER 43:

Long-term aeronautics research has long provided the basis for new concepts that ultimately lead to industry innovation and societal benefits. NASA has a history of undertaking research and development (R&D) efforts that are outside the scale, risk, and payback criteria that govern commercial investments, with the purpose of proactively transitioning the research findings to the aviation community. The majority of industry research investments are focused on more near-term product development. The Advanced Air Vehicles Program (AAVP) conducts cutting-edge research that generates innovative concepts, technologies, capabilities, and knowledge to enable revolutionary advances for a wide range of air vehicles - primarily those that are two generations beyond air vehicles now being developed. In addition, NASA efforts are generally pre-competitive to benefit multiple U.S. companies. The community vision for the research is based largely on improved environmental performance to address growing public concern about environmental sustainability, as well as enabling increased efficiency and flexibility of future air vehicles to achieve better economics and reduced fuel use. Additionally, in the case of vertical lift vehicles, the goals include improvements in speed, operating costs, and operational suitability to enable a broad range of new markets. These future vehicles will support worldwide growth in aviation while facilitating public acceptance by virtue of lower noise and diminished impact on local air quality and climate change. Also within the program is a project focused on improving the certification of composite materials – highly desired by multiple sectors of the aviation industry. The resources invested through the AAV Program also include stewardship for large NASA ground test capabilities such as wind tunnels. The overall size of the AAV Program is due to the combination of broad scope (multiple vehicle classes) and support for national ground test facilities and capabilities.

Notional air vehicle configurations and enabling technologies, defined by ARMD in collaboration with industry and academia, allow ARMD, the AAV Program, and the aviation community to estimate integrated air vehicle performance that could meet the community's performance goals for the longer-term timeframes. The program partners with the private and academic sectors in defining and executing research. As mentioned, NASA's research objectives and investments are generally higher risk and longer term than those of individual, private sector organizations. Complementary objectives are defined through coordination at multiple levels from corporate executive level through senior and middle management levels as well as at the technical level. This communication and coordination helps ensure that industry can draw from new, innovative ideas developed in partnership with NASA and refine them into specific products that help the U.S. maintain technological advantage in this increasingly competitive international market.

QUESTION 43a:

How does NASA ensure it doesn't duplicate or crowd-out private sector research in these areas?

ANSWER 43a:

Please see response to Question #43, above.

QUESTION 44:

ARMD's Advanced Air Vehicles Program is researching low boom technologies to demonstrate

low-boom supersonic flight. How much money would the ARMD spend on low boom research in FY 2016 if Congress were to fully fund NASA's budget request?

ANSWER 44:

The proposed FY 2016 investment in supersonics technologies, including low boom technologies, is \$30M. Since NASA partners with the private and academic sectors in defining and executing research, complementary objectives are defined by through coordination at multiple levels from corporate executive level through senior and middle management levels as well as at the technical level.

In addition, in the case of low-boom technologies, NASA is working with Lockheed Martin and Boeing under separate contracts to refine aircraft design concepts that would be capable of low boom flight. Complementarily, NASA is developing and validating computer-based analysis tools and technologies intended to enable the design and development of supersonic aircraft with low sonic boom signatures. For example, NASA has developed computational design tools that allow potential low boom aircraft configurations to be analyzed. Due to the complexity of the aircraft design, these analyses previously took several months, but with the NASA-improved tools the solutions take a day or less to develop. This efficiency enables industry to explore a much larger set of aircraft design ideas and options. In turn, private industry is adding further details and fidelity to these designs based on their experience in developing aircraft. Another area where NASA coordinates closely with industry and other organizations is in improving the techniques and methods for measuring sonic boom signatures. NASA has a leadership role in designing and running experiments, but industry participates by bringing their assets to improve data collection.

QUESTION 44a:

How is NASA working with industry partners like Lockheed Martin and Boeing who are also researching low-boom supersonic flight?

ANSWER 44a:

Please see response to Question #44, above.

QUESTION 45:

What, if any, amount of NASA's proposed budget will be used to advance research and development in hypersonic aircraft?

ANSWER 45:

In the FY 2016 proposed budget, the investment in hypersonics is \$15M. This investment is aligned specifically towards key national needs identified by the Defense Department and supporting their nearer-term interests. NASA-unique capabilities advance the research and development in hypersonics with an emphasis on these national interest missions.

QUESTION 46:

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

ANSWER 46:

NASA has filed patent applications on a model UTM system. If patents are granted on NASA's system, the U.S. Government will own the rights to these UTM patents. NASA is developing a prototype of its UTM system and will conduct field tests and simulation studies to finalize the system requirements. The prototype and requirements to safely manage the UAS in the low altitude airspace will be provided to the FAA under a FAA-NASA Research Transition Team (RTT).

QUESTION 46a:

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

ANSWER 46a:

Please see response to Question #46, above.

QUESTION 46b:

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 46b:

NASA expects that there will be numerous entrants into the UAS market over the period of time. Therefore, the UTM technology developed by NASA will need to ensure access for the widest range of current and anticipated future entities. Current collaborators are helping identify the operational characteristics of the UTM, and NASA expects that UTM will support all current and future entrants who will operate in the lower altitude airspace. The UTM prototype is not restricted by the intellectual property of collaborators. Collaborators largely bring supporting services or infrastructure (such as low altitude radar surveillance systems) that UTM will interface with and use to provide its flight optimization and airspace management. As there could be many entities offering similar services or infrastructure, it would be up to the UAS or the UTM service provider to set up those relationships. UTM will be developed in a manner allowing efficient interface with the widest range of capability providers.

QUESTION 47:

Aside from research and development, what is NASA doing to help FAA develop UAS performance standards?

ANSWER 47:

In addition to the research and development that NASA is performing to support the

development of UAS performance standards, NASA is actively involved in transferring the technologies and research findings to the FAA and other stakeholders.

The driving force behind NASA's UAS research is to be able to transfer tools and solutions for operation in the civil airspace to the UAS community. NASA is working with other Government agencies, and the FAA in particular, as well as industry and the international community to develop, evaluate, and validate UAS performance standards related to sense and avoid, command and control, and ground control station design and displays.

Inter-Government Interfaces

NASA's R&D efforts require close coordination with the FAA's UAS Integration Office, industry standards organizations, and international organizations to ensure that NASA's research products are aligned with multiple agencies and nations to enable future routine UAS access to national and global airspace. The close working relationship that NASA maintains with the FAA's UAS Integration Office is critically important to ensure that NASA's research provides validated findings that inform the FAA's policy and rule making processes which includes the prioritization of key technologies to research, as well as the design of critical simulations and flight test campaigns.

Two key inter-government interfaces that NASA is involved in are the UAS Executive Committee (ExCom) and the Sense and Avoid Science and Research Panel (SAA SARP).

In response to integration challenges and the growing demand for UAS NAS access by government agencies, Congress created the UAS ExCom. The UAS ExCom was created in order to enable the Department of Defense, the Department of Homeland Security and NASA, in conjunction with the FAA, to obtain routine UAS access to the NAS in order to execute their agency missions of national defense, security, and scientific research. The composition of the UAS ExCom includes senior executives from all four agencies. NASA supports the work of the UAS ExCom through participation on its Senior Steering Committee and associated Working Groups.

NASA also supports and closely cooperates with the Defense-chartered Sense and Avoid Science and Research Panel (SARP).

Industry Interfaces

NASA works closely with industry and other government agencies on the FAA's UAS Aviation Rulemaking Committee (ARC) and RTCA Special Committee 228. NASA is involved at the executive level as a member of the UAS ARC and provides subject matter experts to support various working groups. This committee was formed to provide a forum for the Nation's aviation community to discuss UAS related issues, and provide recommendations to the FAA for various UAS rulemaking projects. This includes providing information and input to the FAA to help develop the means to continue integration of UAS with manned NAS operations that

address safety, capacity, and efficiency objectives consistent with global aviation.

A final area of collaboration, in which NASA is engaged with the FAA, is involvement in several International Civil Aviation Organization (ICAO) activities as part of the U.S. delegation led by the FAA and the State Department, including the Flight in Non-Segregated Airspace work, the UAS Study Group, the Civil Air Navigation Services Organization, and various ICAO working groups.

QUESTION 48:

The Committee has heard testimony that FAA's UAS test sites are prohibitively expensive and difficult to use. Does NASA's UAS research occur primarily at NASA facilities or does NASA use the UAS test sites as well?

ANSWER 48:

To date, NASA has not utilized the FAA UAS test sites. NASA research occurs primarily at NASA facilities. We have visited each of the test sites and catalogued their unique capabilities. Lack of NASA use is not a result of expense or high utilization charges but NASA did not have a mechanism to contract with the test sites. NASA issued a Request For Proposals from the test sites in June 2015. Responses were due in early July and the evaluation of the responses are ongoing. This will allow NASA to contract directly with the 6 test sites to support NASA research efforts.

QUESTION 48a:

How, if at all, has NASA used the FAA UAS test sites in calendar year 2014 or 2015?

ANSWER 48a:

There was no use of the UAS test sites during 2014 but NASA personnel did visit each test site as indicated previously. NASA intends to use all of the test sites to support research associated with the UAS Traffic Management research effort during 2015. In addition, NASA will engage at least one of the test sites to complement NASA's planned flight test campaign in 2016 that supports the validation of RTCA SC-228 Minimum Operational Performance Standards.

QUESTION 48b:

What are the respective benefits and drawbacks of FAA's UAS test sites as compared to NASA test sites?

ANSWER 48b:

This will be very difficult to answer until NASA has a chance to engage with and conduct research at the six test sites. This work is anticipated to commence in late CY 2015 or early CY 2016.

QUESTION 48c:

Are the FAA test sites more desirable testing ground than NASA facilities? Why or why not?

ANSWER 48c:

The test sites are not more desirable testing grounds for NASA's research nor were they intended to be. The test sites were established to offer industry capabilities and infrastructure to test and evaluate UAS related technologies in geographically diverse locations throughout the United State. As a Federal Government entity, NASA has adequate access to similar capabilities and infrastructure. However, the test sites do offer capabilities that complement NASA's capabilities and NASA intends to leverage these capabilities to support various planned research activities.

QUESTION 48d:

Does NASA plan on using FAA UAS test sites in the future? If so, please describe planned use?

ANSWER 48d:

In the immediate future, NASA intends to use all of the test sites to support research associated with the UAS Traffic Management research effort during 2015. In addition, NASA will engage at least one of the test sites to complement NASA's planned flight test campaign in 2016 that supports the validation of RTCA SC-228 Minimum Operational Performance Standards.

QUESTION 49:

Since the cancellation of the Joint Planning and Development Office (JPDO), how has NASA been coordinating NextGen-related R&D with FAA?

ANSWER 49:

Since the FAA has shifted their interagency coordination management responsibility from the recently canceled JPDO to the newly formed IPO, NASA has continued to successfully utilize both the NASA/FAA Research Transition Teams (RTTs) and IPO for coordination of NextGen-related R&D and subsequent transition to the FAA for their future implementation.

The NextGen IPO has continued to lead the coordination of several key technology focus areas, such as the prioritization of UAS related research and development across federal agencies, and the NextGen cross agency initiatives. The pace of delivery and impact of NASA's NextGen-related technologies have not been significantly affected by cancellation of the JPDO. Through the IPO, we are leading three NextGen initiatives jointly with FAA, Department of Defense), DHS, and the National Weather Service (NWS). In addition, through IPO facilitation, we are initiating four new RTTs to support these IPO NextGen initiatives and future collaboration for system-wide safety assurance and data management for NextGen and beyond.

QUESTION 49a:

Has the cancellation of JPDO affected NASA's involvement in NextGen implementation in any significant way?

ANSWER 49a:

Please see response to Question #49, above.

QUESTION 49b:

How would NASA know if the cancelation of JPDO was having an impact?

ANSWER 49b:

NASA is confident that the collaboration for NextGen advancement with IPO will have continued impact, because we have formed four new RTTs. We coordinate on the future vision through the IPO, and we are continuing to deliver critical results to industry and FAA.

Through the Efficient Flow Into Congested Airspace RTT, NASA has just delivered the Terminal Spacing and Sequencing (TSAS) capability and plans to deliver the Flight Deck Interval Management (FIM) technologies by 2017. Through the Integrated Arrival, Departure, Surface RTT, NASA is working with the FAA on Metroplex Departure Scheduling on an interim deliverable supporting the FAA NIWG objective. As part of the new Applied Traffic Flow Management and Weather Integration RTT, NASA is working with industry and the FAA to develop oceanic flow management tools for flight efficiency and delay reduction. Dynamic weather routing tools for en route efficiencies accounting for weather impacts will also be delivered through this RTT.

Additional new RTTs are being pursued covering critical future needs in the areas of Data Management, Real-time System Wide Safety Assurance, and Autonomy. As part of this last RTT, NASA is coordinating with the FAA and the Defense Department to collaboratively explore near-term research objectives for safe, low-altitude small UAS operations and reduced crew operations.

QUESTION 50:

How much of the ARMD budget will go toward NextGen-related activities in FY 2016?

ANSWER 50:

NASA conducts research in advanced concepts and technologies for safe and efficient air traffic management systems that support both the current vision of NextGen as well as beyond NextGen concepts. Higher levels of automation as well as exploration of future autonomous approaches are the subject of research and development. Also supportive of NextGen, NASA pursues vehicle-focused research and development, and advanced tools and technology for ultra-efficient commercial aircraft, innovative approaches for low-carbon propulsion concepts, and research to enable routine, high-speed transport operations. Additional research is conducted to integrate multiple technologies developed

as part of the work above and demonstrate them in relevant environments; a specific example involves integration of unmanned aerial systems in the national airspace. Investment is also placed in the development of transformative aviation technologies that seeks to address the emerging needs of future NextGen states, and to develop the workforce of the future.

QUESTION 50a:

What NextGen-related work will NASA perform in FY 2016?

ANSWER 50a:

Please see response to Question #50, above.

QUESTION 50b:

What will this work cost in FY 2016?

ANSWER 50b:

The breakdown for ARMD funding for NextGen related activities is as follows:

Smillions		
Program	FY 15 Enac	FY 16 PBR
Airspace Operations and Safety Pro	154.1	142.4
Advanced Air Vehicles Program	128.7	127.1
Integrated Aviation Systems Prog	124.0	70.1
Transformative Aero Concepts Pro	36.6	36.5
TOTAL NASA INVESTMEN	443.4	376.1

In FY 14, NASA's contribution to NextGen programs totaled \$385M.

QUESTION 50c:

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

ANSWER 50c:

NASA spending in support of NextGen objectives in FY 2016 compared to FY 2015 is reduced due to the successful completion of the Environmentally Responsible Aviation Project as seen in the reduced funding level for the Integrated Aviation Systems Program. All other NextGen supporting research activities at NASA will continue much as conducted in FY 2015. In addition, NASA spending in FY 2015 was higher as a result of one-year activities funded through the Congressional FY 2015 augmentation. The reduction for FY 2016 funding in the total NASA investment line is due to a one-year FY 2015 funding augmentation that has yet to be renewed in FY 2016.

QUESTION 51:

In regards to NextGen, what are the biggest technological hurdles that NASA has yet to overcome?

ANSWER 51:

The commitment to implement NextGen is a national challenge supported by FAA, NASA, other agencies participating in the FAA Interagency Planning Office, and U.S. industry. NASA supports the identification of major technical challenges that the full stakeholder community aligns with, and the Airspace Operations and Safety Program specifically selects a subset of those to directly address in its R&D portfolio. For the 2025 time frame, NASA is conducting advanced development, demonstration, and technology transfer to the FAA and industry for near term implementation. The key demonstration activities supported by NASA include:

- Interval Management and Terminal Area Precision Scheduling and Spacing: decision support tools enabling more efficient arrival operations for dense terminal airspace;
- Integrated Arrival, Departure, and Surface/Metroplex
- Operations: delivering advanced automation for management of integrated, optimized movements of aircraft during arrival, precisely timed movement of aircraft on the airport surface, and managed departure of aircraft for effective entry into en route traffic lanes. This will be applied in conjunction with FAA implementation programs to improve operations at the busiest airports and metroplexes in the United States;
- Applied Traffic Flow Management, Domestic Enroute and Oceanic: supporting more tactical and strategic management of individual aircraft and fleets when faced with weather disruptions after departure. Applications will be developed to support traffic flows in domestic airspace and oceanic operations; and
- Technologies for Airplane State Awareness: supporting safety needs identified by the FAA led Commercial Aviation Safety Team (CAST) through development of technology and simulation capabilities that provides air carriers with tools to better train pilots to avoid hazardous circumstances of improper aircraft orientation and speed that could lead to accidents and safety incidences.

These activities are scheduled for completion in time for inclusion in FAA NextGen programs built to support system improvements for the 2025 time frame.

NASA is also funding work to address other technical hurdles that, although important now, provide benefits expected to be realized fully in time frames beyond 2025:

- Human factors studies to explore challenges associated with inclusion of more highly automated systems and their safe and effective interface with the human operator.
- Verification and Validation of complex systems to ensure that such systems governed by sophisticated software perform as designed and built.

Not all critical challenges are technical, and NASA will continue to collaborate with the research and operational communities to explore issues resulting from collaborative decision-making, organizational cultural alignment, and trust in highly automated and autonomous systems.

QUESTION 51a:

What is NASA doing to make sure these hurdles don't become a problem before 2025, when NextGen implementation across the U.S. should be completed?

ANSWER 51a:

Please see response to Question #51, above.

QUESTION 52:

In April, 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?

ANSWER 52:

Realizing the increasing need to consider cyber-physical security considerations, NASA will continue its investment specifically targeted to airspace management using internal workforce, external (e.g., contracts, grants, cooperative agreements and NASA Research Announcements or NRAs). Through a current NRA, NASA is exploring the security issues and mitigation strategies for advanced Communications-Navigation-Surveillance technologies addressing midterm airspace operations needs.

In addition, NASA Aeronautics is joined with others in the federal government to address the full national needs for research in security of cyber-physical systems (CPS) as a member of the CPS Working Group. NASA supported development of a solicitation for critical research in this area, and is reviewing select proposals for possible award that are well aligned with airspace management R&D needs.

QUESTION 52a:

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

ANSWER 52a:

Please see response to Question #52, above.

QUESTION 53:

The Administration's request for Space Technology reorganized the main programs and changed their scope while also proposing a major increase over last year's appropriation. Can you explain the nature of the changes to the structure of the programs and why NASA believes this is necessary?

ANSWER 53:

Space Technology is critical to making future space activities affordable and sustainable. Without new space technologies we are not sending people to Mars and the U.S. space industry will likely lose some of its competitive advantage. For FY 2016, the President’s budget request for the Space Technology Mission Directorate (STMD) includes a reorganization of financial accounts for the Crosscutting Space Technology Development (CSTD) and Exploration Technology Development (ETD) Program Reporting Attributes (PRA). This does not represent a reorganization of content within Space Technology. The FY 2016 funding structure merges two of STMD’s financial reporting attributes into one PRA named Space Technology Research and Development (STR&D). From FY 2012 to FY 2015, technology development efforts managed by the Game Changing Development (GCD) and Technology Demonstration Missions (TDM) programs have been funded from two different financial accounts. This constrains program managers as they allocate funds to projects, and places artificial limits on the size and scope of new projects because funding available for new awards is split between PRAs. This change will place all of the funding for the Directorate’s Game Changing Development and Technology Demonstration Missions within the same financial account, enabling the mission directorate to respond to the phasing requirements of individual projects and initiate more compelling new starts.

Outside of the funding consolidation, adjustments influencing Space Technology’s budget request are driven by upcoming project milestones of on-going development efforts, such as Solar Electric Propulsion (SEP) and Laser Communications Relay Demonstration, and to support required increases in Small Business Innovation Research and Small Business Technology Transfer. STMD requires additional funding to meet the development needs for the Solar Electric Propulsion and Laser Communications Relay Demonstration projects. The budget request for Space Technology is consistent with previous budget requests and is unrelated to the request to restructure the financial accounts.

QUESTION 53a:

What programs or projects are going to be changed or cancelled with this new structure?

ANSWER 53a:

No programs projects have been terminated as a result of this change, and the lower level funding structure will be maintained as it currently stands in FY 2015.

FY 2016 Content in FY 2015 STMD Budget Str	Change	FY 2016 Budget Structure
Crosscutting Space Technology Development Includes Early Stage Innovation, Centennial Challenges, Small Spacecraft Technology, Flight Opportunities, Game Changing Development (2 projects) and Technology Demonstrations Mission (2 projects) that are Crosscutting in nature and/or applicable to Science	Merge and Renaming	Space Technology Research and Development Includes Early Stage Innovation, Centennial Challenges, Small Spacecraft Technology, Flight Opportunities All Game Changing Development (2 projects) and All Technology Demonstrations Mission (2 projects)

Missions		
Exploration Technology Development Includes Game Changing Development (14 projects) and Technology Demonstration Missions (4 Projects) with an infusion path predominantly aligned with HEOMD needs		

Projects previously aligned under the ETD PRA (shown below) will maintain their existing Work Breakdown Structure (WBS account number), but will move into the consolidated STR&D account.

QUESTION 54:

NASA proposed the controversial Asteroid Retrieval and Redirect Mission (ARM), which would allow the Space Technology Mission Directorate to demonstrate Solar Electric Propulsion (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 54:

The development and demonstration of the advanced solar arrays and the Hall thruster based electric propulsion technologies are essential for efficiently performing future deep space human exploration missions such as a humans to Mars mission. Furthermore, advanced solar arrays and Hall thrusters have significant crosscutting utility to perform science missions, meet the needs of other Government agencies, and significantly improve the affordability and capability of our nation's commercial satellites. While ARM is planned to be the first demonstration of high powered solar electric propulsion, STMD will continue to explore alternative paths to demonstrate this critical capability. STMD's motivation to perform the high powered SEP demonstration resides in the fact that these near term SEP technologies are at the tipping point for ready application across the entire space sector within the next five years.

Less mature electric propulsion concepts such as the Variable Specific Impulse Magnetoplasma Rocket (VASIMR), represent candidates for longer-term investments but are not developed to the extent that a near term demonstration mission is under consideration.

In parallel, the AES Division within the Human Exploration and Operations Mission Directorate (HEOMD) selected three proposals for development contracts that will build further to advance the state-of-the-art in solar electric propulsion technology beyond the noted SEP systems currently ready for flight demonstration on ARM. These selections were for technologies currently in early research and development, toward 100 kilowatt thruster system ground demonstrations to be conducted by these companies within the next three years. These selections included the Ad Astra developed VASIMR system.

QUESTION 55:

The Space Technology Mission Directorate's Research and Development program contains elements similar to those of the Advanced Exploration Systems program in the Human Exploration and Operations Mission Directorate. What is NASA doing to ensure there is not a duplication of efforts between these two programs?

- a. How does NASA internally govern which technology development programs go into which program when they are both working on exploration technology development?

ANSWER 55 & 55a:

In general, STMD develops technology components that have multiple applications, including future NASA Exploration and Science needs. In contrast AES, and the technology programs within the Science Mission Directorate works upon integrated system advancement and demonstration, with occasional investments in technologies that are solely of interest to NASA missions. AES and STMD leadership frequently coordinate to ensure consistent technology prioritization, development and demonstration plans; eliminating any overlaps and addressing any gaps as they occur. STMD selects new work through competitive solicitations (external to NASA) as well as internally directed NASA work. In either case, STMD uses a Directorate Program Management Council (DPMC) to make funding and content selection decisions. Each of the other NASA Mission Directorates (HEOMD, SMD and ARMD) have representatives at the STMD DPMCs, where they provide input into the funding and selection decisions, examine the potential for synergy and partnerships, and identify any duplications to avoid. The Advanced Exploration Systems Office has management present to provide feedback and recommendations at all STMD decisional meetings. Upon selection, STMD then manages projects through the Program Management Council approved budget levels and invites AES and other MD reps to STMD program and project reviews to ensure coordination and in many cases partnerships in project formulation through completion. In general, STMD develops technology components for future Exploration and Science needs while the other Mission Directorates, particularly HEOMD's AES works upon integrated system advancement and demonstration. For example in the case of a next generation exploration space suit, STMD under Game Changing Technology developed suit components such as the rapid cycle amine CO₂ removal system and the variable oxygen regulator. AES has taken delivery of these components from STMD and is integrating them and testing them in the Portable Life Support System (PLSS) integrated suit development and demonstrations managed under AES. Finally, AES and STMD meet at least annually to examine their respective portfolios and determine if any rebalancing is necessary.

Not only does NASA coordinate internally, but the other Mission Directorates utilize STMD's Principle Technologists to evaluate all new technology projects within their funding lines. These subject matter experts are responsible for knowing what is under development in their domain (i.e. Entry Descent and Landing, Propulsion, Communications, etc.) by NASA, other Government agencies and industry, so Space Technology can be assured that an investment will make notable progress for the field of study. With limited budgets for technology development, NASA makes a concerted effort to prioritize content and minimize duplication to maximize the Agency's investment to bring the most gain to future missions.

QUESTION 56:

The request for NASA spending on education dropped by 23.7 percent in FY 2016. How would those cuts impact NASA's educational programs?

ANSWER 56:

The overall NASA Education request demonstrates the Agency's commitment to NASA's and the Federal Science, Technology, Engineering and Mathematics (STEM) Education five-Year Strategic Plans. The Federal STEM Education Five-Year Plan established a multi-agency collaborative framework for delivering federally-funded STEM education to more students and more teachers more effectively; and is designed to enable more strategic investment in STEM education and more critical evaluation of outcomes. NASA Education's FY 2016 request supports NASA's 2014 NASA Strategic Plan, Objective 2.4: "Advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets." Predicated on both these strategic plans, the NASA FY 2016 Budget focuses on competitively selected NASA-focused STEM engagements for K-12 learners and teachers, and internships, fellowships and scholarships for higher education students that use evidence-based learning in or outside K12 schools and higher education institutions.

The FY 2016 President's budget requests the same level of funding for Education programs as was requested for FY 2015. The FY 2015 appropriation provided the Aerospace Research Career and Development (ARCD) Program \$25M above the President's Request and the STEM Education and Accountability (SEA) Program \$5M above the President's request. Compared to the appropriated level, the request would support fewer new Experimental Program to Stimulate Competitive Research (EPSCoR) awards (with funding going first to any previous FY's multi-year awards that are not already fully funded). Within the SEA program funding for competitively selected, evidence-based STEM Education and Accountability Projects (SEAP) would be reduced by \$3M compared to the appropriated level. Support for Minority University Research and Education Project (MUREP) would be reduced by \$2M.

QUESTION 57:

What is NASA's role in education?

ANSWER 57:

NASA's role in education is to advance the Agency and the Federal STEM Education five-Year Strategic Plans by using NASA personnel, research, discoveries and other assets to inspire learners of all ages and their formal and informal educators. NASA through its educational investments has successfully engaged women and individuals from other underrepresented and underserved groups in STEM through diverse strategies, including K-12 student engagement in STEM design challenges through internships for graduate students in all NASA field centers. NASA Education broadens participation in STEM education using NASA's unique capabilities. The Office of Education leads, supports, represents, advocates for, and aligns with all of NASA's Education efforts in other NASA Offices, Centers and Mission Directorates, including SMD. Through an agency-wide coordinated STEM education portfolio consistent with Congressional and CoSTEM direction, NASA provides unique opportunities to learners, educators, and institutions, and access to mission content, web sites, people, resources, and facilities. The Education Coordinating Council, which includes representation from other NASA Offices, Mission Directorates, Centers evaluates and provides guidance regarding NASA investments in

STEM education to ensure the most effective NASA assets are made available to support the Nation's STEM education priorities.

QUESTION 57a:

What are your long-term goals for NASA's education initiatives?

ANSWER 57a:

The 2014 NASA Strategic Plan articulates the Agency's long-term goal for NASA education in objective (Objective 2.4) "...to advance the Nation's STEM education and workforce pipeline by working collaboratively with other agencies to engage students, teachers, and faculty in NASA's missions and unique assets." In an effort to help maintain the United States' global competitiveness, NASA's two education programs managed by the Office of Education are structured to support the growth of NASA's and the nation's diverse STEM workforce, help develop STEM educators, engage and establish partnerships with institutions, and inspire and educate the public.

QUESTION 57b:

How do you measure NASA's success in regards to education?

ANSWER 57b:

NASA is committed to measuring the effectiveness and impact of its educational activities. NASA's Education Coordinating Council (ECC), which is comprised of representatives from every NASA Center, JPL and Headquarters Offices and Mission Directorates, evaluates and provides guidance regarding NASA investments in STEM education to ensure the most effective NASA assets are made available to support the Nation's STEM education priorities. Through a data management system maintained by the NASA Office of Education, some performance data on common metrics are collected across the NASA Education portfolio. While the NASA Office of Education has primarily collected information on activity outputs, including counts of participants, outcome measures have been identified through research and the development of logic models to assess the effectiveness of our investments. Information on NASA Office of Education performance is available in agency performance reports, such as the Annual Performance Report and Annual Performance Plan. Evaluations of specific programs are available at: <http://www.nasa.gov/offices/education/performance/index.html>.

In terms of measuring effectiveness of agency coordination efforts, the Administration has developed and is monitoring progress of a Cross-Agency Priority (CAP) Goal to improve STEM education by implementing the Federal STEM Education 5-Year Strategic Plan. CAP goals are a management tool used to accelerate progress on Administration priority areas where the coordination of multiple agencies is required to achieve the end result. For more information on the CAP STEM goal, including strategies, indicators, and milestones, please visit: <http://www.performance.gov/node/3404?view=public#apg>.

QUESTION 58:

Over the last couple of years NASA has changed the way it administers its education-related programs. Especially of note is the move or termination of a number of education programs previously run out of mission directorates to allow for a competitive process run out of the Office of Education. The FY 2016 request includes nearly \$90M for the Office of Education, a \$29M cut from what was appropriated in FY 2015, as well as request of \$26M for education activities in the SMD. Why does NASA want to move education funding out of the mission directorates?

ANSWER 58:

NASA's budget request consolidates some education activities in an effort to reduce fragmentation within NASA. Previously, the program was composed of many smaller projects and it was difficult to determine whether the programs were having the desired effect. The new approach increases competition and funds the best programs. To minimize disruption to Mission Directorate stakeholders, NASA Education honors natural "sunsetting" (e.g., the end of grant or cooperative agreement performance period, end of an undergraduate or graduate student's multi-year scholarship or fellowship, etc.) for most formal and informal activities initiated by ARMD and HEOMD. Through this streamlined portfolio managed by the Office of Education starting in FY 2015, NASA is able to focus education efforts around the core priority areas in the NASA and Federal STEM Education five-Year Strategic Plans and support the goals of making STEM efforts more accessible to students, teachers, and institutions that need it most, using evidence-based approaches to inform funding and programmatic decisions. From across NASA centers, from the ARMD and HEOMD and other Headquarters Offices activities already have competed for funding from the STEM Education and Accountability Projects account. Details from this FY 2015- FY 2016 competition are available at:

<http://www.nasa.gov/offices/education/about/seap-overview.html>. A complementary competition open to the public is being managed by the SMD in its Science Education Cooperative Agreement Notice (CAN) NNH15ZDA004C. For information about SMD's competition see:

<http://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={AC77E7D1-79AD-07F7-28C0-43E5105C5436}&path=closedPastAnd>

NASA Selects Science Education Partners for STEM Agreements

<http://www.nasa.gov/press-release/nasa-selects-science-education-partners-for-stem-agreements>

QUESTION 58a:

What does this mean for educational outreach currently performed in the mission directorates?

ANSWER 58a:

At NASA, education consolidations are executed independently from NASA outreach. As budgets permit, NASA Mission Directorates continue outreach activities that did not meet the Federal STEM inventory definitions for an "education program."

QUESTION 58b:

How will NASA address concerns from the community that the key scientists working to teach students about human spaceflight will no longer be first in line to do so?

ANSWER 58b:

NASA-employed scientists, engineers, technologists and other experts continue to support education and outreach as time and budgets permit. NASA guidance, as established by NASA Policy Direction (NPD) 1388.1 Employee Participation in NASA Education and Communications Activities, differentiates between education activities and communications with the following definitions:

Education. Comprises those activities designed to enhance learning in science, technology, engineering, and mathematics (STEM) content areas using NASA's unique capabilities.

Communications. Comprises the comprehensive set of functions necessary to effectively convey - and provide an understanding of - the program, its objectives and benefits to target audiences, the public, and other stakeholders. This includes a diverse, broad, and integrated set of efforts: media services, multimedia products and services (including Web, social media, and non-technical publications), and public engagement activities and events. These efforts are intended to promote interest and foster participation in NASA's endeavors and to develop exposure to - and appreciation for - STEM.

NASA's restructured education approach, including Science Mission Directorate's restructured program, will continue to engage scientists and engineers in STEM efforts. Additionally, each Directorate continues to carry out communications activities. Science Mission Directorate's recent outreach activities related to the New Horizons flyby of Pluto is an example of how NASA continues to engage the public in NASA missions.

QUESTION 58c:

Why does the organization feel this is a better way to manage most of the education portfolio?

ANSWER 58c:

NASA's restructured education program reduces fragmentation of programs within the agency and ensures that taxpayer dollars are being used to support the most effective education activities. Additionally, NASA's focus on increasing collaboration and partnerships with other entities, including other federal agencies, supports the goal of expanding NASA's reach—making STEM efforts more accessible to the students, teachers, and institutions that need it most. NASA continues to provide significant funding for Space Grant (SG), Experimental Project to Stimulate Competitive Research (EPSCoR), and MUREP. Many of the grantees for these programs also perform education outreach.

QUESTION 59:

Why is the GLOBE program the only education program explicitly named in the restructuring of education programs in the SMD? Doesn't this imply that Earth Science education is more important than other science disciplines?

ANSWER 59:

GLOBE is unique due to its significant international reach and partnership with many organizations. Celebrating its 20th anniversary in 2015, the Global Learning and Observations to Benefit the Environment (GLOBE) Program has fostered international cooperation and collaboration among students, teachers, and scientists from 114 countries, giving more than 28,000 schools and nearly 22,000 teachers the opportunity to interact with each other across continents and oceans to better understand the Earth's climate. More than 100 million environmental measurements have been collected by students around the world. These data have been used by GLOBE students in their own science investigations about the environment, as well as by the larger GLOBE community and scientists in research and comparison with measurements from Earth-observing satellites. GLOBE is currently responsible for 109 Government-to-Government agreements on GLOBE implementation in respective countries. GLOBE is just as important as other projects to be funded by the SMD in the restructuring effort.

QUESTION 60:

How will the \$20M for STEM funding (in addition to the \$6M requested for GLOBE) in the SMD be distributed across science disciplines? Who in the mission directorate will decide which education programs are funded?

ANSWER 60:

The competitive process for restructuring science education within the SMD is currently underway, therefore it is premature to speculate how the funds will be distributed across science disciplines. However, distribution across the science disciplines is anticipated. Leadership within SMD will determine the exact selection of awardees. Understandably, as a matter of policy, Selection Officials are not publicly named in advance.

QUESTION 61:

Nothing motivates kids to study math and science like space exploration. On what basis did you find NASA's STEM education initiatives to be ineffective and in need of cutting in FY 2014 and FY 2015 and why is there such a significant decrease in the Office of Education request this year?

ANSWER 61:

The President's FY 2014 and FY 2015 budgets for NASA education aimed to improve the quality of NASA's programs, which had little hard evidence of effectiveness. The 2016 budget request would continue this effort to consolidate some NASA education activities in an effort to

reduce fragmentation within NASA and across the Federal government. Through a more streamlined portfolio managed by the Office of Education and in partnership with other agencies, NASA will be able to focus education efforts around the core priority areas in the Federal STEM five-Year Strategic Plan and better support the goals of making STEM efforts more accessible to the students, teachers, and institutions that need it most, using evidence-based approaches to inform funding and programmatic decisions.

QUESTION 62:

The NASA budget request includes a \$16M cut to the National Space Grant College and Fellowship program, setting funding for the program at \$24M. Space Grant is at work in all fifty states and rated highly effective in many states. The Administration proposed similar cuts last year but Congress funded the program at \$40M. Why was Space Grant singled out for such a large budget cut again?

ANSWER 62:

A September 2015 Executive Summary of the National Space Grant College and Fellowship Program Technical Assistance Project highlights key elements and findings in the planning of a future evaluation of activities and is available at:

http://www.nasa.gov/sites/default/files/atoms/files/space_grant_exec_summary_092915.pdf. The FY 2015 enacted Office of Education budget included funding for a second Space Grant competition beyond the NASA request for the historic competitive, multi-year base grants. The FY 2016 budget request only commits to the essential basic grant funding for each of the 52 consortia. The overall FY 2016 request for NASA's Office of Education was designed to enable NASA funds to reach beyond the 52 Space Grant consortia in every state. As explained in the FY 2016 budget narrative:

- \$24.0M for SG, a nationwide network of colleges, universities, and other organizations that provide NASA space-related opportunities to students, educators, and the public;
- \$9.0M for EPSCoR, which provides competitive research opportunities to institutions in targeted states;
- \$30.0M for MUREP, which provides competitive NASA research and study opportunities to students of underserved and underrepresented groups and competitive opportunities to enhance the research and technology capabilities of Minority Institutions; and,
- \$25.9 M for SEAP, which provides competitive opportunities that foster NASA-focused, evidence-based education opportunities at NASA Centers museums, planetariums youth serving organizations and other types of non-profit institutions.

The NASA request would allocate funding to the 52 Space Grant Consortia and to other types of institutions and stakeholders. Specifically, the STEM Education and Accountability (SEA) Program's two projects, MUREP and SEAP, would use competition to award grants and other

types of funding to minority serving higher and other types of education institutions, non-profits, NASA Centers, etc.

QUESTION 63:

In 2011, GAO found that NASA has historically relied on contractors to track termination liability, but that NASA has typically provided the contractors with additional funds to cover termination. When did NASA decide to stop providing contractors with additional funds to cover termination?

ANSWER 63:

NASA respectfully disagrees with the characterization of the 2011 GAO Report (GAO-11-609R) regarding NASA's approach to termination liability. The Report did not find that it typically has been NASA's past practice to provide additional funding to cover termination costs. Rather, the report noted that interviewed contractors had differing expectations regarding funding, some stating that potential termination costs were covered in the funding allotted on the contract and some assuming that it was NASA's practice to provide additional funding.

NASA's policy on handling Potential Termination Liability (PTL) contracts has been consistent that PTL is to be managed by the contractor according to the standard Federal Acquisition Regulations (FAR) clauses. Contractors are instructed through the contract's Limitation of Funds clause (LoF) of the total amount of funds allotted to the contract at any given time within which the contractor must contain all costs, including costs of performance and any PTL costs.

In rare cases, NASA has used clauses in which NASA agrees to cover termination costs that exceed the amount contractually obligated under the LoF clause. In these circumstances, however, NASA is required to keep up-to-date data on the contractor's potential termination liability costs, and to reserve enough budget authority equal to this liability within the same appropriation from which the contract is funded. Reserving or obligating these funds prohibits this budget authority from being used for other purposes.

It has not been NASA's policy to provide additional funding to cover termination costs. NASA's policy has been consistent through several Administrations that PTL is to be managed by the contractor within the funding provided under the standard FAR LoF clauses, with only rare exceptions. NASA issued formal guidance to this effect in 1992, 1993, 1997, 2008, and 2012:

- April 22, 1992, Funding for Termination Liability ("If a contract is terminated, the maximum amount NASA will pay, including allowable termination costs, is the funds obligated to the contract.")
- June 10, 1993, Procedures for Termination Liability ("If a contract is terminated, the maximum amount NASA is required to pay, including allowable termination costs, is the funds obligated on the contract.")
- March 19, 1997, Procedures for Termination Liability ("The maximum amount

NASA would be obligated to pay, as the result of a contract's termination, would be the funds obligated on the contract.”)

- June 25, 2008, Funding for Termination Liability. (“This continues to be NASA policy; termination liability costs shall be fully funded under the limitation of funds clause specified in the contract.”)
- March 26, 2012, Procurement Information Circular (PIC) 12-04, Termination Liability. (“These clauses delineate the amount of funding available on the contract to cover the costs of potential termination liability as well as the costs of performing work on the contract. If the contract is terminated, the clause limits the Government's liability to the amount of funds obligated on the contract.”)

QUESTION 63a:

Does NASA plan to provide contractors with additional funds to cover termination in the future?

ANSWER 63a:

NASA's Office of Chief Financial Officer, in consultation with the Office of Procurement and the Office of General Counsel, is reviewing how NASA addresses termination liability to better understand whether there are any alternate practices or techniques, within NASA's authority, for managing termination liability.

QUESTION 63b:

What are the budgetary consequences of not providing contractors with additional funds to cover termination?

ANSWER 63b:

Employing the LoF clause in incrementally funded, cost-reimbursement contracts as described above limits the obligation of NASA to fund reimbursable costs incurred by the contractor, to include any potential termination liability, up to the amount allotted for that contract as specified in the LoF clause. The anticipated result of this arrangement is that the contractor will factor in its potential termination liability in determining when it has incurred costs in an amount up to or approaching the total amount allotted towards that contract.

QUESTION 63c:

Might the switch in termination liability policy make contractors less likely to continue contract performance without full funding of their potential termination liability?

ANSWER 63c:

There has been no switch in termination liability policy. As noted above, NASA's policy has been consistent for many years. Contractors are aware of and agree to the funding terms of the Limitation of Funds (LoF) clauses when they sign the contract. Because using the LoF Clause is

the default NASA policy, program milestones associated with major contracts are negotiated with the knowledge that contractors will have to manage PTL costs according to the standard government-wide Federal Acquisition Regulation (FAR) clause.

QUESTION 63d:

Are termination liability policies now consistent and equitable across the programs?

ANSWER 63d:

Yes, NASA's policy on termination liability applies across the Agency. The few exceptions are reviewed on a case-by-case basis.

QUESTION 63e:

Which programs are not required to cover termination liability?

ANSWER 63e:

NASA's policy applies across the Agency and does not differentiate between programs. NASA's policy has been to use the standard Limitation of Funds clauses in incrementally funded contracts to require the contractor to manage their termination liability.

QUESTION 64:

ARM would require the Science, Space Technology, and Human Exploration and Operations mission directorates to each make significant contributions. How will each mission directorate's efforts be coordinated if NASA goes forward with the ARM mission?

ANSWER 64:

NASA's strategy for the ARM is to leverage ongoing activities in the STMD, SMD and HEOMD Mission Directorates. ARM has already required significant coordination across these organizations as part of the robotic and crewed mission concept definition leading to the successful Mission Concept Review on March 24, 2015. This coordination and strong teamwork between the robotic and crew teams will continue as we work toward Key Decision Point-B (KDP-B) in the first quarter of 2016. The team structure is facilitated by an experienced Senior Program Director with broad experience working across Mission Directorates and also via bi-weekly tag-ups with the Associate Administrators in the Directorates and the Agency Associate Administrator. Technical examples of this coordination include the robotic capture mission concept selected and the size and characteristics of the SEP System. These have been jointly agreed to by all three cognizant Mission Directorates based on extensibility of these systems to future human missions to Mars. Additionally, an investigation team has been formed to begin to define the details of requirements and operational aspects of implementing science and technology demonstrations. The FY 2016 NASA budget request establishes a new budget line item under AES within HEOMD to continue to formulate the integrated demonstration mission and align key technologies and capabilities for future exploration missions.

QUESTION 64a:

What is the decision process in place for delaying or descope other activities within those mission directorates to offset the additional program content from ARM?

ANSWER 64a:

NASA does not plan to delay or descope other activities within the Mission Directorates to offset ARM program content. We continue to work to optimize the overall exploration planning activities within the SMD, STMD and HEOMD Mission Directorates. ARM was chosen as a key exploration mission because of the ongoing activities in each Directorate, such as the Space Technology SEP development to enhance the technology readiness of solar arrays and magnetically shielded hall thrusters. Additionally, the mission heavily leverages and builds upon on-going work in In-Space Robotic Servicing where there is commonality with the robotic manipulators and the autonomous rendezvous and capture technology. ARM utilizes important technologies and developments in an integrated exploration demonstration mission which includes the SLS and Orion for the Crewed Mission.

QUESTION 65:

The Administration contends that the ARM mission is part of the journey to Mars and will assist the development of future human Mars missions. What specific mission elements of the ARM mission are necessary for a human Mars mission?

ANSWER 65:

NASA's approach to human missions to Mars is to utilize a building block approach for the developments and vehicles that are required. Once developed ARM will provide a highly efficient, large scale solar electric propulsion capability, needed in NASA's strategy to position future habitats, landers, and other elements in Mars orbit prior to a crewed mission. The application of advanced SEP for asteroid boulder redirection will demonstrate the applicability of large scale SEP technology for multi-ton objects in space, such as cargo for a Mars mission, and support reliabilities needed for human-scale Mars missions. It will also demonstrate the ability for robots to scout and prepare samples for later human use and retrieval, a key capability for eventual human visits to the moons of Mars and Mars itself.

The crewed component of the ARM plan also provides significant building blocks for Extra-Vehicular Activity (EVA), including sample collection and return, rendezvous and docking hardware and sensors, deep-space navigation, and the operational techniques required for deep-space navigation and the trajectory maneuvers. The crewed mission to a redirected asteroid boulder would enhance current test objectives for early flights of SLS and Orion to provide important additional experience beyond LEO toward the ultimate goal of a crewed mission to Mars. Flight operations for rendezvous, docking, and the integrated Orion-SEP vehicle stack in the lunar distant retrograde orbit (DRO) will provide important operational experience for integrated vehicle class missions in interplanetary-like orbits and environments. EVAs by astronauts to sample the asteroid boulder will further this experience for the transit to and from Mars.

QUESTION 65a:

What about these elements require an asteroid in distant retrograde lunar orbit to be tested? Is it not possible to accomplish those goals without the asteroid?

ANSWER 65a:

Interactions with an asteroid boulder in this region will allow NASA to test and gain operational experience for deeper space missions in a locale only a few days return from Earth. The primary benefit of having the asteroid boulder in the DRO is to test EVA techniques required to collect and obtain scientific samples from the asteroid boulder. The techniques are similar to what can be used on Mars and will require special handling, from initial extraction and containment through landing and removal from the spacecraft, to preserve the volatiles contained in the carbonaceous material. The ability to manage the regolith dust that covers the asteroid boulder surface to prevent damage to the EVA and Orion systems will serve as a pathfinder for similar techniques that could be utilized for mission to the Mars' moons, Phobos and Deimos. NASA is also considering how to implement potential partnerships, including with international partners and commercial entities, for which experiments with the multi-ton mass in the stable lunar orbit may be of interest. In addition, a significant amount of material -- tens of kilograms -- will be returned on this mission and can be utilized for potential *in situ* resource utilization techniques to extract water from planetary surface material.

QUESTION 65b:

What specific scientific mission tasks or goals require the presence of human astronauts on an asteroid in the current mission architecture?

ANSWER 65b:

The work of the astronauts in the asteroid boulder's microgravity environment will provide important engineering and safety data on regolith electrostatics, anchoring and extraction techniques applicable toward potential Mars moon operations in their microgravity environment. The ability of the humans to adapt and work in the environment as they are fixed on a work platform over the asteroid boulder will allow them to respond to scientists and other investigators on Earth in real time to select and obtain the samples that serve the interests. Human lunar and Mars robotic exploration has shown that a human presence allows for surface operations and scientific experiments to occur much more rapidly as compared to robotic-only operations.

QUESTION 65c:

Couldn't NASA avoid risking the lives of astronauts and defray the costs of the mission if it was simply fully automated mission such as the OSIRIS-Rex mission set to launch in 2016?

ANSWER 65c:

NASA carefully evaluates the risk of any mission involving our astronauts - missions to the ISS, servicing of the Hubble Space Telescope with the Space Shuttle, or missions beyond LEO. This

mission will be one of the early missions in the proving ground of cis-lunar space, and one of the objectives will be to test the performance of the advanced exploration space suit. This kind of test can only be performed with humans since the suit is uniquely designed to protect the astronauts while allowing them to perform useful work in the vacuum of space.

This mission is an early mission in the DRO, which is a potential staging ground for future human Mars missions and exploits the near-term learning opportunities in the lunar vicinity with limited return-to-Earth capabilities and minimal communications delays. Interactions with an asteroid boulder in the lunar distant retrograde region will allow NASA to test and gain operational experience in proximity operations and rendezvous with a non-cooperative target, astronaut experience in complex spacewalks, and sample collection, handling and return. The mission is cost-effective since it tests many of the elements required for Mars, including SLS, Orion, SEP, EVA, rendezvous and docking, navigation, complex trajectory planning, and operations in deep space.

QUESTION 66:

NASA officials have consistently stated that ARM is not a scientific mission, yet the SMD is carrying some of the costs associated with the development of the mission. NASA officials have also said that one of the key elements of the mission is having a human at the asteroid to make decisions about sample quality or answer investigative questions.

- a. What are the scientific goals of ARM and why do they require sending humans to an asteroid?
- b. What unique scientific opportunities will pieces of an asteroid directly from space provide us relative to the meteorites that constantly enter our atmosphere?

ANSWER 66a & 66b:

None of SMD's NEO Program funding is devoted to the ARM. Potential candidates for this mission are just a subset of the population of near-Earth asteroids that the NEO Program seeks to find in its primary mission. As our surveys find asteroids that might make good candidates for ARM, we further characterize them for our own NEO Program interests as well as for potential destinations for robotic or human spaceflight missions.

Obtaining pieces of an asteroid directly from space provides the opportunity to study and evaluate pristine samples from their original state, as opposed to those that are collected after entry through our atmosphere. From the time a meteorite suffers extreme frictional heating in passing through the Earth's atmosphere until it is collected and curated appropriately, it undergoes considerable alteration. Much of the materiel does not even survive this fiery entry. The vast majority of meteorites in terrestrial collections are known as "finds," meaning they were found after some time, in some cases tens of thousands of years, laying on the surface of the Earth. During this time they have been exposed to air, water and physical transport, all of which alter the minerals, metals, and organics in the meteorites. Even in the case of observed "falls," where the entry meteor is observed and the meteorites are collected very soon after reaching the surface, it can still be many days in the Earth environment before collection, and initial handling and storage of the specimens is frequently done by non-scientists before samples receive adequate protection and arrive at a curation facility. Direct collection from an asteroid

under sterile conditions while still in space is the only way to ensure pristine samples for analysis of the materials of which asteroids are composed. While this is important for the metals and minerals in these objects, it is absolutely critical for distinguishing original trapped gases, water, and organic materials from those found on Earth.

QUESTION 67:

ARM is a controversial topic in the scientific community with NASA's own Advisory Council unanimously adopting a finding that NASA should not go to an asteroid, and should focus on Mars instead. NASA has requested \$220M for ARM in FY 2016, and ARM has a goal to fit within a cost cap of \$1.25B, excluding the launch vehicle and many other leveraged costs. Has NASA ever spent so much on a project that has been advised against by the NASA Advisory Council?

ANSWER 67:

The NASA Advisory Council provides recommendations to the Administrator; ultimately the Administrator must decide what actions to proceed with to enable Agency priorities and goals. The Asteroid Redirect Mission is consistent with the Administration's National Space Policy to send humans to an Asteroid in mid 2020s and Mars in 2030s, is consistent with the 2010 NASA Authorization Act on the use of cis-lunar space to advance human space exploration, and is aligned with the Global Exploration Roadmap and interests of our International partners, which includes missions in the lunar vicinity.

QUESTION 67a:

Does the Administration believe the NASA Advisory Council is wrong to make these recommendations and findings?

ANSWER 67a:

The NASA Advisory Council's charter requires the council to draw on the expertise of its members and other sources to provide advice and make recommendations to the NASA Administrator on Agency programs, policies, plans, financial controls, and other matters pertinent to the Agency's responsibilities. Although the council provides recommendations, the Administrator must ultimately decide what the best course of action is to achieve NASA priorities and goals.

QUESTION 68:

A leading planetary science expert, MIT professor Richard Binzel, recently characterized ARM as a "farce" and "buzzword pyramid" stunt with little scientific merit and illustrated that it had little to do with going to Mars. These types of characterizations have become common in the science and space communities. With so much disagreement in the science and space communities, why has the Administration continued to push for this mission?

ANSWER 68:

The ARM is part of the overall plan for human exploration and pioneering, serving as an integrated demonstration of several ongoing technology developments for future human exploration and pioneering purposes. ARM is an early mission in the proving ground of cis-lunar space that also provides opportunities for testing the use of in-space resources, science, planetary defense, and technology demonstrations. It complements ISS, which is testing many exploration technologies and systems, such as long-term closed-loop life support for deep-space missions; allows for developing operational techniques in the proving ground of cis-lunar 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 engaged the Small Bodies Assessment Group (SBAG) in review of ARM pre-formulation activities, providing technical expertise and advice as documented in the "SBAG ARM Special Action Team Full Report." This document provides information and rationale for the relative benefits of ARM from science, planetary defense, and resource utilization perspectives. NASA utilized this input in support of the Mission Concept Review (MCR). With the selection of mission concept B, which will utilize Type C asteroids such as 2008 EV5, there is a potential for significant science from returning tens of kilograms of material for analysis upon return to Earth. Additionally, to prepare for future human exploration, this material can be studied to determine potential *in situ* resource utilization (ISRU) techniques to extract water and other constituents from the boulder that is returned to cis-lunar space.

QUESTION 69:

NASA has emphasized that ARM will give humans the opportunity to operate in space for long periods of time as preparation for a mission to Mars. Why is an asteroid mission the best way to acquire this experience?

ANSWER 69:

NASA will need to expand the duration of its space missions in order to execute crewed missions to Mars, which require crewed transit times on the order of six to nine months and total mission durations of up to three and a half years. Part of this expansion is understanding how humans perform in the microgravity environment; ISS plays a key role, enabling longer stays on orbit, such as the ongoing one-year mission with Scott Kelly. In a build-up approach, ARM will be a 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 it will help us begin to understand the radiation environment in deep space and its potential effects on the human body before subsequent missions of longer duration. It will also allow NASA to incrementally build operational experience with increasing communications time delays and independence from ground controllers. These efforts will culminate in a one-year crewed mission in cislunar space, further paving the way for a crewed mission to Mars.

QUESTION 69a:

Has NASA done any trade studies that demonstrate ARM is the most cost effective way to demonstrate these capabilities?

ANSWER 69a:

The ARM mission was selected from several alternatives since it utilized more of the ongoing development activities such as In-Space Robotic Servicing and SEP that were underway in the HEOMD and the STMD, while satisfying a multitude of capabilities that are required for deep-space exploration.

The mission leverages the STMD's SEP technology, including the advanced solar arrays and magnetically-shielded Hall Effect thrusters that feed forward to delivering cargo to Mars. The mission fully utilizes the existing capabilities of SLS and Orion in a manner that advances their operational maturity in a challenging and realistic way. The mission also advances EVA, the International Docking System Block II, Automated Rendezvous and Docking, and complex operations which all feed forward to future deep space and Mars exploration.

QUESTION 69b:

What process did NASA use to determine the cost and schedule differences and trades between this type of mission and others that have been proposed, such as a hab-module in lunar orbit?

ANSWER 69b:

NASA compared the cost of the ARM mission while leveraging the ongoing developments across the Agency with other preliminary estimates of a potential habitation module in cis-lunar space in order to determine the most cost effective approach to exploration. Technology readiness affects cost and schedule estimates. Deep-space habitation and solar electric propulsion are both key building blocks for pioneering missions to Mars. The ARM mission was determined to be a better overall use of resources as an early test mission for Orion and SLS to demonstrate exploration capabilities in the proving ground of cis-lunar space, including for advanced extra-vehicular activities. In parallel, NASA is working through the NextSTEP Broad Agency Announcement (BAA) and other means to advance the technologies needed for long-duration deep space habitation. NASA will continue to develop and update exploration plans and will continue to brief the Committee on those plans as they evolve.

QUESTION 70:

It's unclear from the budget how much NASA expects the ARM project to eventually cost. Why did NASA choose to distribute the costs for ARM across the budget?

ANSWER 70:

The guidance for robotic mission project formulation is a development cost not to exceed \$1.25B. This includes substantial Agency investments in the advanced SEP system development. The launch vehicle and Phase E are excluded from the project's development

cost target. Cost of deliverables to support the crewed mission, such as rendezvous and docking and Extra-Vehicular Activity tools, are part of NASA's continued investment in technologies and systems for human space flight on the ISS and beyond LEO.

The FY 2016 NASA budget request establishes a new line item under Advanced Exploration Systems within Human Exploration and Operations to continue to formulate the integrated demonstration mission. NASA chose to leverage developments already underway in the HEOMD and STMD to formulate a mission that would demonstrate the capabilities and technology advancements required to take humans to Mars. NASA will leverage the developments in these areas for the robotic and crewed missions, rather than pull the resources from their development. The Asteroid Redirect Robotic Mission (ARRM) is dependent on content funded from STMD and HEOMD). The Asteroid Redirect Crewed Mission is also heavily dependent on other HEOMD content.

QUESTION 70a:

Please provide a cost range for the project. If that cost does not include a launch vehicle, what launch vehicles (or how much capability) are planned to be used and how much does NASA expect that might cost?

ANSWER 70a:

The estimated development cost of the ARM project is \$1.25B. Our reference plan assumes a Delta IV Heavy launch vehicle for launch of the robotic mission with the estimated costs not to exceed \$470M. The SLS and Falcon Heavy launch vehicles are also being considered. The cost range for the project is planned to be provided as a result of early formulation, at Key Decision Point-B (KDP-B).

QUESTION 70b:

Why will NASA not commit to conducting an independent cost estimate of ARM and the two mission options?

ANSWER 70b:

NASA's ARM team engaged an independent cost assessment utilizing NASA expertise from outside the project as part of pre-formulation, which informed the selection of a robotic capture mission option for formulation. NASA will perform an independent cost estimate after acquisition strategy decisions and as part of the commitment decision for a cost range for KDP-B.

QUESTION 71:

At a recent meeting of the NASA Advisory Council, the Council appeared skeptical of NASA's \$1.25B cost estimate for ARM. Which aspects of the proposed mission are included in that cost estimate?

ANSWER 71:

The \$1.25B cost estimate includes the cost for the development of the robotic mission, including the SEP technology managed by the STMD. Costs for the robotic mission launch vehicle and Phase E, as well as deliverables for the crewed mission (rendezvous and docking system and EVA tools) are not included.

QUESTION 71a:

Which aspects are excluded, and how much would they cost?

ANSWER 71a:

Aspects that are excluded from the ARM robotic mission cost estimate are the launch vehicle and the mission operations phase. It also excludes costs pertaining to the Asteroid Redirect Crewed Mission, common rendezvous sensor technology (from In-Space Robotic Servicing), international docking system (from ISS), EVA accommodations and SLS/Orion mission costs. Please see response to Question #7a for launch vehicle cost assumptions. Modifications to Orion to support the mission are included in the Orion funding line.

QUESTION 71b:

Please describe the process by which the \$1.25B cost estimate was derived.

ANSWER 71b:

The cost estimates were derived from a detailed "bottom up" analysis of every system on the robotic spacecraft utilizing existing data (when available) and vendor cost estimates for new systems. In addition, NASA received cost estimates from five industry providers for the high power solar electric spacecraft bus. NASA performed two internal independent cost estimates based on similarly sized robotic spacecraft efforts. The industry inputs and the internal independent cost estimates were in reasonable agreement with the "bottom up" estimates.

QUESTION 72:

In the question and answer section of the hearing, you stated that ARM is a "critical component of getting humans to Mars." What makes ARM so critical?

ANSWER 72:

ARM integrates a variety of technologies and capabilities important to future crewed missions to Mars and other deep-space destinations. This includes high power, long-life SEP technology development, which has future science mission, commercial, and human exploration applications. The application of advanced SEP for asteroid boulder redirection will demonstrate the applicability of this class of SEP technology for efficiently and reliably moving large objects through interplanetary space, such as cargo for a Mars mission.

The crewed mission to a redirected asteroid boulder will enhance current test objectives for early

flights of SLS and Orion to provide important additional experience beyond LEO toward the ultimate goal of a crewed mission to Mars. Flight operations for rendezvous, docking, and the integrated Orion-SEP vehicle stack in the lunar DRO will provide important learning on this integrated vehicle class in interplanetary-like orbits and environments. EVAs by astronauts to sample the asteroid boulder will further this experience for the transit to and from Mars.

This mission prepares for future long-duration deep-space missions, but also exploits the near-term learning opportunities in the lunar vicinity, which feature return-to-Earth capabilities within a few days and minimal communications delays. As a result, lunar DROs offer an ideal proving ground for initial crewed operations to test the capabilities required to support future longer-duration deep-space missions. The round-trip missions for an exploration mission will include highly limited resources and no ability to immediately return to Earth. Interactions with an asteroid boulder in lunar distant retrograde region will allow NASA to test and gain operational experience in proximity operations and rendezvous with a non-cooperative target, astronaut experience in complex spacewalks, and sample collection, handling and return. This also provides NASA valuable experience practicing aborts and contingency procedures needed for operations outside the Earth's gravity well, and handling maintenance and repair, including with spacewalks.

In addition, the radiation environment in this region of space outside the Earth's Van Allen radiation belts is quite different than that encountered by astronauts on the ISS. Thus, we will gain valuable experience with radiation dosages as well as the character and composition of the radiation experienced inside the Orion vehicle, but without the dangerous levels of exposure projected for long duration (> 6 months) trips. The radiation environment here is scalable to that expected for astronauts and spacecraft in deep-space journeys such as one to Mars.

ARM is a cost effective mission in the mid-2020s, which complements well the learning on the International Space Station. In addition, HEOMD utilizes knowledge gained through the SMD's Mars Exploration Program as well as the ARM mission to enable NASA to retire significant risk in preparation for future Mars missions.

QUESTION 72a:

Are you saying that without ARM, you won't be able to formulate a plan to take humans to Mars?

ANSWER 72a:

No, ARM is a cost-effective means to advance exploration capabilities in cis-lunar space that we will need for Mars. Continuing human spaceflight activities in the mid-2020s will make it easier to achieve the long-term plan of sending humans to Mars. NASA's human exploration strategy is to move from today's reliance on Earth through the proving ground of cis-lunar space to an Earth-independent capability to extend human presence into the solar system and to the surface of Mars. This begins with research on the ISS, including the one-year crew mission that started in March 2015. It continues with crewed SLS and Orion missions in cis-lunar space, including to the redirected asteroid boulder. New capabilities for long-term deep-space habitation, deep-space, high-thrust in-space transportation, and further joint science/exploration/technology missions to Mars can enhance current plans and future opportunities.

Specifics of future missions will depend on factors including the incremental evolution of SLS and Orion, as well as availability of other assets to support humans in deep space, such as potential partner- provided systems and/or long duration, deep-space habitation. It will also depend on the ability to leverage technology developments, the ability to utilize possible *in situ* resources, as well as learning about the human ability to live and work longer in deep space.

QUESTION 73:

Similarly, in the question and answer section of the hearing, you said ARM "allows us to...learn how to operate in low-gravity or non-gravity environments." Are there no other ways to learn how to operate in these environments that would be more cost-effective?

ANSWER 73:

Please see response to Question #72a, above.

QUESTION 74:

The Humans Orbiting Mars Workshop recently found that a Mars mission by the mid-2030s was achievable with currently projected funding. Please share your thoughts on the Humans Orbiting Mars Workshop's findings.

ANSWER 74:

NASA has a goal of sending a human mission to Mars in the 2030s. The President's FY 2016 budget request funds development of systems for near-term human exploration of deep space destinations. The specific funding levels for future missions will depend on factors including the incremental development of hardware like SLS and Orion, as well as other assets to support humans in deep space, such as a potential habitation module. It will also depend on 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 ISS). As NASA learns from initial missions using SLS and Orion, the Agency will formulate cost and schedule details of future goals and hardware, and this analysis will be reflected in future budget requests.

QUESTION 75:

When will NASA provide a cost estimate of the Asteroid Redirect Mission to the House Committee on Science, Space, and Technology?

ANSWER 75:

A cost estimate for the robotic mission concept, performed to enter Phase A, can be shared with the Committee at the Committee's convenience. The cost range for the project, which will reflect decisions on spacecraft acquisition strategy, is planned to be provided as a result of early formulation, at KDP-B.

QUESTION 76:

Please explain why the Administration does not believe a balanced portfolio of exploration and science activities is in the best interest of the agency and the Nation.

ANSWER 76:

The President's FY 2016 budget request supports a balanced portfolio that will allow NASA to continue to lead the world in space through a balanced program of exploration, science, technology, and aeronautics research.

QUESTION 77:

Please explain why a balanced science portfolio that equally funds Earth Science, Planetary Science, Astrophysics and Heliophysics is not in the best interests of the agency and the Nation.

ANSWER 77:

NASA's Science program is an integrated endeavor that recognizes and leverages the fact that the universe and all of its parts are inextricably linked. The FY 2016 President's 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 2016 President's request takes into account, balances, 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 we learn about Earth's complex system, as well as remote sensing technologies that we develop and test for Earth observations from space, are often used on planetary missions to expand our understanding of other worlds and identify the best target locations for finding life elsewhere in the universe (i.e., how to look for life on Mars, on Europa, or on exoplanets orbiting other stars). Similarly, study of phenomena occurring in the universe and of the physical principles that governs them, helps us achieve a better understanding of how all of the elements of our solar system originated and have changed over time.

QUESTION 78:

Please explain why Earth Science should receive a disproportionate amount of funding by the

SMD?

ANSWER 78:

The FY 2016 President's budget request contains sustained and substantial investment in varied space science endeavors undertaken by NASA's SMD. SMD's diverse missions advance understanding of our home planet as well as our solar system and other galaxies by making observations that can only be made from the vantage point of space.

The budget request demonstrates the important role that NASA Earth Science plays in the Nation's Science priorities (including those recognized in the NRC Decadal Survey) and the Administration's confidence in NASA's ability to effectively implement missions. Earth is a complex, dynamic planet and is where we live; study of Earth requires a constellation of Earth-orbiting satellites and airborne instruments to provide a suite of global observations continuously over the long-term. Data also is made available rapidly (often in near-real time), and thus is often used by other federal agencies with "operational missions" to improve their operational products, such as weather predictions and disaster response planning and execution. Demonstration of this commitment is seen in the FY 2016 President's request for the Sustainable Land Imaging program and a suite of atmospheric and radiation measurements.

Overall, Earth Science's fraction of NASA's funding in the President's FY 2016 request continues to be similar to that of recent years, and – as noted in the 2007 Decadal Survey – below the fractional level through the decade of the 1990s.

QUESTION 79:

Please provide an analysis of the impact of the proposed cuts in the President's Budget Request for FY 2016 on NASA's centers, contractor operations, and research enterprise. This analysis should include:

- a. The number of contractor layoffs or civil servant layoffs and reassignments that would result from the SLS reduction of \$344M.

ANSWER 79a:

When tasks related to EM-1 are completed within SLS and Orion, the workforce can progress to EM-2. The annual program execution is planned to the appropriated levels, in which the workforce costs must fit. For the Orion contracts, workforce would be reassigned from Orion to other projects as needed. As engineers and technicians move from design to production, work on various elements of SLS will be adjusted to match the progress being made to build the rocket. NASA's contractors size their workforce as they determine necessary for performance of their contracts.

QUESTION 79b:

The number of contractor layoffs or civil servant layoffs and reassignments that would result

from the Orion reduction of \$98M.

ANSWER 79b:

Please see response to Question #79a, above.

QUESTION 79c:

The additional content that could be added to the SLS program if the Administration's cuts were replaced.

ANSWER 79c:

In the past, NASA has used additional funding to get ahead on procurements, address high-risk items, and add reserves to manage unknown-unknowns as they arise.

QUESTION 79d:

The additional risk that could be drawn-down on the SLS program if the Administration's cuts were replaced.

ANSWER 79d:

Orion would use additional funds to address technical risk to the EM-1 and EM-2 flights, respectively, as well as to improve schedule confidence. SLS would likewise use any additional resources primarily to reduce risk with respect to the EM-1 mission, while continuing where possible to mature the SLS Block 1B architecture with an Exploration Upper Stage (EUS).

QUESTION 79e:

The additional content that could be added to the Orion program if the Administration's cuts were replaced.

ANSWER 79e:

Please see response to Question #79c, above.

QUESTION 79f:

The additional risk that could be drawn-down on the Orion Program if the Administration's cuts were replaced.

ANSWER 79f:

Please see response to Question #79d, above.

QUESTION 79g:

The length of schedule delays for SLS and Orion associated with the reductions, including the delay from 2017 to 2018 that resulted from completing a Joint Confidence Level with the Administration's lower budget assumptions.

ANSWER 79g:

SLS and Orion are progressing along an efficient path for completion of detailed design and for manufacturing, assembly and testing. The President's Budget supported the original 2017 JCL estimates. The integrated launch date for EM-1 has not yet been determined; it is to be determined after all three programs complete their Critical Design Reviews (CDRs) at the end of this calendar year. We have identified our Agency Baseline Commitment for the SLS and EGS which supports a launch capability readiness date of November 2018 at 70 percent and 80 percent (JCL, respectively, to the EM-1 launch readiness date. The FY 2016 President's budget request provides the funding level needed to keep SLS, Orion, and EGS on track for the first integrated launch of EM-1.

QUESTION 79h:

The number of contractor layoffs or reassignments as well as the number of civil servant reassignments that would result from the Planetary Science reduction of \$77M. This should include the number of Scientists, Engineers, and Technicians broken out individually.

ANSWER 79h:

There are no delays to NASA's Planetary Science missions, instrument development or grants process associated with the President's budget request for FY 2016. There are two missions in extended operations that would be terminated: Opportunity and LRO. The FY 2016 request provides the necessary funding for all other activities contained within the budget proposal. NASA has also provided the committee with a notional analysis of any additional funding beyond the President's request, at the level proposed by the House authorization bill, per a previous request.

QUESTION 79i:

The length of schedule delays for Planetary Science missions as well as the delays to instrument development associated with the reduction of \$77M from the Planetary Science budget.

ANSWER 79i:

Please see response to Question #79h, above.

QUESTION 79j:

The number (and dollar amount) of grants that would not be issued or delayed as a result of the Planetary Science reduction of \$77M.

ANSWER 79j:

Please see response to Question #79h, above.

QUESTION 79k:

The number (and amount) of grants that would not be issued or delayed as a result of the education reduction of \$30M.

ANSWER 79k:

Requested FY 2016 Space Grant (SG) funds will be allocated so that each of the 52 grants likely would receive funding. No new grants would be issued by SG in FY 2016. Funding for any new, multi-year contract initially awarded with FY 2015 funds to evaluate SG would be deferred until after FY 2016.

EPSCoR grants that were not already fully funded in the 26 jurisdictions would be funded first, and an estimated 4 or 5 new grants each valued at \$750,000 could be made (compared to prior years' averages of 12 new grants).

MUREP would not issue any new competitive grants, but would distribute newly appropriated MUREP funds among the approximately 45 multi-year grants made in previous years.

SEAP estimates it would not issue six (6) new competitive grants based on proposals expected to be submitted in late 2015 (each grant estimated value is \$300,000 or \$1,250,000 total) to youth-serving or other informal education institutions and would delay funding to approximately one (1) multi-year grant supporting internships at NASA Centers.

QUESTION 80:

Additionally, please provide the Committee with a detailed accounting of the resources NASA plans to receive from other agencies to fund the development of the following instruments and

missions that were either previously funded by other agencies, or are currently the responsibility of other agencies:

- a. Landsat-9 (\$78.9M requested by NASA in FY 2016 request);
- b. Radiation Budget Instrument (RBI) (\$45.3M requested by NASA in FY 2016 request);
- c. Total and Spectral Solar Irradiance Sensor (TSIS-1) and TSIS-2 (\$17M total requested by NASA in FY 2016 request);
- d. Altimetry Follow-on (AFO) (\$35.9M requested by NASA in FY 2016 request); and
- e. Ozone Mapping and Profiler Suite-Limb (OMPS-Limb) (\$5.7M requested by NASA in FY 2016 request).

ANSWER 80a-80e:

Under the budget proposal, no funding would be transferred from other agencies to NASA for these purposes. The President's budget request contains the necessary funding for NASA to carry out the missions described in the question. As a clarification, acquisition of the space segment for Landsat-9 was not previously the responsibility of any agency other than NASA.

Additionally, several of the measurements that NASA has recently taken over from NOAA were originally developed, demonstrated, and initiated by NASA missions several years ago. For example, Topex/Poseidon, a joint NASA-CNES mission, was the forerunner for the Jason altimetry mission. The first Clouds and the Earth's Radiant Energy System (CERES) instruments (the predecessor instrument to NASA's current Radiation Budget Instrument) were launched on the NASA-Japanese Tropical Rainfall Mapping Mission (TRMM) and NASA's Earth Observing System (EOS) missions. Thus, NASA not only has the expertise but also the heritage and experience with developing these types of instruments.

QUESTION 81:

For each of the instruments and missions listed in item five, please also identify the corresponding reduction in funding from the other government agency so that the Committee can confirm that this was a transfer of funding rather than added content that allowed funding for work at other agencies at the expense of NASA's top-line.

ANSWER 81:

As stated in the previous answer, the President's budget request contains the necessary funding for NASA to carry out the missions described.

QUESTION 82:

Please provide an analysis of:

- a. When the last funded Planetary Science mission to the outer solar system is scheduled to launch;

ANSWER 82a:

The last funded outer planets mission was Juno, which was funded under New Frontiers, was launched in 2011 and is on its way to Jupiter; it is scheduled to enter into orbit around Jupiter in July 2016. NASA has partnered with ESA on three instruments on the ESA JUICE mission, which is scheduled to launch to Jupiter in 2022. NASA is also preparing to enter formulation for a mission to Europa, one of the moons of Jupiter. No specific launch date has yet been identified.

QUESTION 82b:

How budget reductions in FY10-FY15 have negatively impact NASA's Planetary Science missions to the outer solar system;

ANSWER 82b:

NASA has conducted a robust exploration of Saturn with the Cassini mission, and recently flew by the never-before-explored Pluto system. Both of these missions have made, and will continue to make, exciting scientific discoveries. In addition, NASA has invested in developing concepts and technologies for the next high-priority outer planets mission to Europa, and is now ready to begin formal formulation on a Europa mission.

QUESTION 82c:

How additional Planetary Science funding under the NASA Authorization Act for 2016 and 2017 would positively impact current and planned planetary science missions to the outer solar system?

ANSWER 82c:

NASA has provided the committee with a notional analysis of any additional funding beyond the President's request, at the level proposed by the House authorization bill, per a previous request.

QUESTION 82d:

The effect of additional Planetary Science, Astrobiology, and Exploration funding under the NASA Authorization Act for 2016 and 2017 on NASA centers, contractor operations, and research enterprise. This analysis should include:

- i. The number of additional hires for contractors and civil servants and
- ii. The additional research activities that this funding would allow.

ANSWER 82d-i & 82d-ii:

Since much of planetary science activities are competitively awarded, it is difficult to analyze the impact of potential increases in research or competed missions. Extension of the Opportunity rover will primarily increase staffing at Joint Propulsion Laboratory (JPL), funding of LRO will increase funding at Goddard Spaceflight Center, and additional funding for the Europa mission will increase staffing at JPL, and to a lesser extent at the Applied Physics Laboratory (APL).

QUESTION 82e:

How NASA's current planned Planetary Science missions do not fulfill the recommendations of the 2013 NRC Planetary Science Decadal.

ANSWER 82e:

NASA's current and planned Planetary Science missions do fulfill the top priorities laid out by the 2013 Planetary Science decadal survey. These missions include Mars 2020, Europa, OSIRIS-REx, Juno, and New Horizons. NASA's Planetary Science Division also continues to maintain funding to the Research and Analysis portfolio as well as the technology development programs, per recommendations in the latest decadal survey.

**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 2016"*

Questions for the record, The Honorable Charles F. Bolden Jr., Administrator,
National Aeronautics and Space Administration (NASA)

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

QUESTION 1:

What is the basis of NASA's Earth Science budget request for FY 2016, and what will be the impact if it is not fully funded?

ANSWER 1:

The President's FY16 budget for Earth Science funds NASA's continuing, essential role in advancing the Nation's Earth Science priorities, specifically including those recognized in the National Research Council (NRC) Decadal Survey. The budget request demonstrates the Administration's confidence in NASA's ability to effectively implement spaceborne Earth observation missions. The President's FY 16 budget requested additional funds to address a "multi-decadal sustainable land imaging program" and to transfer to NASA from NOAA responsibility for all non-defense satellite Earth observation programs other than weather satellites.

In response to Congressionally proposed cuts to authorized levels, NASA developed and evaluated approaches to address these cuts using specific constraints. The scenarios attempt to define an overall NASA Earth Science program that maximizes the contribution to science and applications development, and that is as responsive as possible to Decadal Survey recommendations, within the budget constraints set by the authorization levels – constraints that involve reductions of 25-40 percent from the funding levels proposed in the President's FY16 budget. In these scenarios, NASA attempted to maintain a balance between flights and mission-enabling portions of the Earth science portfolio as called for in the Decadal Survey, while also attempting to maintain a balanced cadence of large, medium, and small Earth science missions. Nevertheless, proposed reductions this large require widespread and draconian cuts. For example, NASA would likely be unable to maintain the cadence for Venture-class missions within a balanced-but-over-constrained program. Further, while some missions nearing launch would experience smaller cuts, to avoid stretching them out, missions recommended in the most recent Decadal Survey would likely be either eliminated or significantly delayed.

QUESTION 2:

What is the basis of NASA's Space Technology budget request for FY 2016, and what will be the impact if it is not fully funded?

ANSWER 2:

The President's FY16 budget for Space Technology funds NASA's ongoing role in developing and demonstrating new capabilities in spacecraft operation, particularly those prioritized by the National Research Council from the NASA Technology Roadmaps. The budget request demonstrates the Administration's commitment to investing in the research that will support our nation's future economic growth and sustain NASA's ability to explore the solar system.

At the levels in the FY 2016 House Commerce, Justice, Science appropriations bill, a reduction of \$99.5M from the Budget proposal of \$724.8M, NASA would have to significantly delay the development and demonstration of technologies required to enable the capabilities and systems for future exploration and science missions. While the funding proposed is a \$29M increase over the FY 2015 enacted level, the legislation and report include programmatic direction totaling \$45M, and NASA's Space Technology Mission Directorate (STMD) would therefore face decreased buying power in FY 2016 due to mandated increases for SBIR/STTR (approximately \$10M over FY 2015 level). At the proposed funding level in H.R. 2039, the directorate would face significant challenges in maintaining planned project milestones and deliverables for content already underway.

In order to preserve the 2016 launch readiness for the Green Propellant Infusion Mission and Deep Space Atomic Clock, NASA would most likely be forced to significantly reduce procurement funding for the Laser Communications Relay Demonstration and/or the Solar Electric Propulsion projects, resulting in disruption of current project schedules and re-phasing of critical technical milestones due to delayed flight hardware development. Space Technology would continue to prioritize projects in the current portfolio, including four Small Spacecraft Technology demonstrations set to launch in 2016 and projects with existing commitments to customers and stakeholders. However, Space Technology would most likely be forced to delay development of Deep Space Optical Communications (DSOC) flight hardware, planned for a potential flight demonstration on a Discovery 2014 mission. This would cause impacts to the missions that proposed incorporating the DSOC system and the Agency would lose an opportunity to demonstrate this enabling technology for future human and robotic deep space missions. In addition, Space Technology would likely have to delay technologies – coronagraph and starshade – needed to support direct detection of habitable exo-planets and the development of advanced composite technologies, which could improve the performance and reduce the manufacturing costs of future evolved SLS and Orion systems. These trade-offs could delay availability of these technologies for exploration and science missions by up to a decade. Even more critical, Space Technology would likely be unable to initiate new technology development activities (including tipping point technologies important to the aerospace industry) until completion of the existing portfolio, resulting in a two to three year gap in significant new in-space demonstrations of enabling technologies for human exploration and science missions. In addition to the above, FY 2016 Early Stage awards planned for academia would see a 40 percent reduction from the planning level, which would limit the ability to support the new In-Space Manufacturing and Resource Utilization Virtual Institute (in partnership with the Human Exploration and Operations Missions Directorate). NASA's budget request for Space Technology is an investment for the future. It enables a new

class of NASA missions beyond low-Earth Orbit, delivers innovative solutions that dramatically improve technological capabilities for NASA and the Nation, develops technologies and capabilities that make NASA's missions more affordable and more reliable, invests in the economy by creating markets and spurring innovation for traditional and emerging aerospace business, and engages the brightest minds from academia in solving NASA's toughest technological challenges. Investments in Space Technology are a value to NASA and a value to the Nation.

QUESTION 3:

For commercial crew, what recourse does the government have if contractors cannot complete the Commercial Crew Transportation Capability (CCtCap) milestones under the budget established in the firm fixed-price contract?

ANSWER 3:

NASA has carefully evaluated the prices the companies proposed to ensure that it is possible to execute the contract at these prices. Our policy is to identify performance issues early, and take proactive steps to ensure that the contractor is successful in accomplishing the contract. Additionally, the use of interim financing milestones will provide early warning that a company is having difficulty meeting the requirements. If a company does have difficulty meeting a requirement, NASA can either work with the company, providing our technical expertise to assist in overcoming technical obstacles, or cease financial payments. The Government may terminate the contract for Default if a contractor fails to perform in accordance with the terms of the contract. In short, the contractors are obligated to complete the milestones under the budget established. If the contractors don't complete the milestones, they don't get paid.

QUESTION 4:

For how long does NASA anticipate requiring Russian Soyuz crew transportation services following the certification of commercial crew transportation services? What other ISS-related Russian services does NASA anticipate requiring through 2020?

ANSWER 4:

Based on current commercial crew schedules and consistent with the President's Budget Requests, NASA does not anticipate needing to purchase any additional Soyuz seats for routine crew transfer. The Agency may utilize procured seats as a backup transportation option to ensure proper launch cadence or to augment future ISS operations and research.

NASA and Roscosmos are mutually reliant on one another for the life of the ISS. NASA will continue to need Russia-unique critical capabilities not currently available elsewhere, such as: propellant and propulsion systems for desaturation of the rate gyros, reboost, phasing burns and debris avoidance maneuvers; redundant life support for U.S. systems; sustaining engineering for the Russian-built, U.S.-owned Functional Cargo Block (FCB); goods and services related to

Russian Segment systems training for on-orbit ISS operations; supplies and sustaining engineering on the Russian-built toilet in the non-Russian segment; and potential de-orbit assistance. Roscosmos will continue to need NASA capabilities including: electrical power for Russian core systems and payloads; redundant life support for Russian systems; attitude control; communications downlink telemetry and commanding to augment limited Russian ground site coverage; and training for non-Russian Segment operations.

QUESTION 5:

Recently, NASA announced its decision, characterized as Option B for the Asteroid Redirect Mission, to send a Solar Electric Propulsion spacecraft to an asteroid, grab a boulder from the asteroid, and transfer the boulder to a distant retrograde lunar orbit. The preliminary cost estimate that NASA discussed in its announcement was \$1.25B, not including the cost of the launch vehicle. What specific analysis has NASA done to determine that the proposed ARM does the most to advance the long-term goal of sending human to Mars, as compared to using it for other activities needed to prepare for Mars? What analysis has NASA done to validate the \$1.25B cost estimate? Please provide these analyses to the Committee.

ANSWER 5:

NASA's approach to human missions to Mars is to utilize a building block approach for the developments and vehicles that are required. The initial building blocks include the International Space Station and the Space Launch System (SLS) and the Orion crew vehicle, the latter two of which are under development. The crewed mission to the asteroid boulder provides significant building blocks for Extra-Vehicular Activity (EVA), including sample collection and return, rendezvous and docking hardware and sensors, deep-space navigation, and the operational techniques required for deep-space navigation and the trajectory maneuvers. The Asteroid Redirect Mission (ARM) leverages the ongoing development of advanced solar electric propulsion technologies, common rendezvous and docking systems, and advanced technologies for EVA.

By doing this, ARM provides another set of capability building blocks that enable system reuse, extensibility, and economies of scale with commercial industry in the sustainability principles for pioneering space. The capabilities used on ARM can be utilized to position habitation capabilities, landers, and other elements in Mars orbit prior to the crewed mission.

NASA compared the cost of the ARM mission while leveraging the ongoing developments across the Agency with other preliminary estimates of a habitation capability in cis-lunar space in order to determine the most cost-effective approach to exploration. NASA has determined that both deep-space habitation capabilities and solar electric propulsion are key building blocks for missions to Mars. NASA is currently studying habitation concepts with the NextSTEP BAA and within our advanced architecture teams. The ARM robotic mission is in the formulation phase and delivers an efficient early technology development demonstration, enables an early test mission for Orion and SLS, and also provides necessary longer-term capability development. NASA will continue to develop and update exploration plans and will continue to brief the Committee on those plans as they evolve.

As part of the Mission Concept Review (MCR), NASA performed cost assessments to determine

if the proposed robotic spacecraft development budget of \$1.25B was reasonable at the stage of pre-phase A formulation. Alternative analysis performed using more traditional Class A-type robotic missions modeling showed the ARM pre-formulation cost estimate was credible for a technology demonstration mission. In addition, since the advanced solar electric propulsion system is leveraged from systems now under development in NASA, cost risk in technology development has been retired. NASA can share these assessments with the Committee at the Committee's convenience.

QUESTION 6:

The Mars 2020 mission will include a caching system for collecting samples from Mars, which responds, in part, to the top priority of the last National Academies Planetary Science Decadal Survey. What is the status of NASA's plans for the robotic mission to retrieve those cached samples and return them to Earth, which was part of a recommended Mars Sample Return campaign? When will NASA begin work on a robotic sample return mission?

ANSWER 6:

NASA recognizes the scientific importance of collecting and studying samples from Mars, which is why the Science Mission Directorate is working diligently to ensure a successful Mars 2020 mission with an effective sample caching system. The viability and significance of specific Martian materials will be better understood once samples have been acquired and investigated by future missions. 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.

QUESTION 7:

According to a 2015 NASA Inspector General report, the Deep Space Network, which is over 30 years old, is an aging infrastructure. In FY 2009, NASA developed a plan to achieve savings from the network that would be applied to upgrading the DSN. Unfortunately, sequestration and other cuts have led to delayed upgrades and either canceled or caused work to be replanned. Further cuts will increase the risks of not meeting the demands on DSN or not adequately protecting the system from, for example, cyber attack.

- a. What is NASA's plan under the FY 2016 budget request to address the NASA IG report recommendations on the DSN?

ANSWER 7a:

The NASA Associate Administrator for Human Exploration and Operations and the NASA Chief Information Officer provided a response to the 12 recommendations in the NASA IG report on March 24, 2015 (see attached). NASA concurred with all the recommendations. The recommendations with budget implications are still in work.

QUESTION 7b:

What contingencies are in place should the DSN suffer a major failure?

ANSWER 7b:

The Deep Space Network (DSN) has written procedures should failures occur. At the highest level, mission support would be offloaded to other antennas at a particular location, or to other antennas at other DSN sites. The NASA cross support agreement with the European Space Agency (ESA) would also be invoked, as necessary. This agreement allows NASA missions to coordinate the use of ESA assets on a non-reimbursable basis.

Also, the DSN has built in redundancies. While major failures might reduce capacity, they would not incapacitate the networks and all the capabilities. This means there could be a reduction in capacity that could be alleviated operationally through existing contracts and cross support agreements we have with our international partners.

QUESTION 8:

The FY 2016 request includes full funding for the SOFIA astrophysics observatory, which was proposed for mothballing in the FY 2015 request and which Congress reinstated in the FY 2015 enacted appropriation. I understand that SOFIA's initial science operations were planned to continue through the end of the decade. What is the justification for putting this mission through "senior review" before SOFIA has completed its initial science operations?

ANSWER 8:

NASA has decided not to include SOFIA in the 2016 Astrophysics Senior Review. SOFIA will have completed five years of full science operations in May 2019, so the SOFIA project will be included in the 2018 Astrophysics Senior Review, which covers FY19-FY20 funding. This five-year prime mission for SOFIA is consistent with that of other large observatories (e.g., Hubble, Chandra, and James Webb).

QUESTION 9:

The President's FY 2016 budget request includes an increase of \$10M for NASA's Near Earth Object activities (for a total request of \$50M). The program supports a Congressionally-mandated survey to detect, characterize, and catalogue potentially hazardous asteroids and also supports work related to the Asteroid Redirect Mission. A 2014 NASA Inspector General report found that, despite the increasing responsibilities, the NEO Program lacks a plan with integrated milestones, defined objectives, and cost and schedule estimates to help with monitoring progress in meeting program goals.

- a. In light of the further increase of \$10M requested for NASA's NEO

Program, what progress has NASA made in addressing the NASA IG's recommendations?

- b. What portion of the program's resources is devoted to the Asteroid Redirect Mission plans, and what portion is being used to meet the Congressionally-mandated survey requirements?

ANSWER 9a & b:

The Science Mission Directorate (SMD) has evaluated and concurred with comments on all of the NASA IG's recommendations regarding the NEO Program. The NEO Program has a well-defined objective of finding at least 90 percent of near-Earth asteroids of 140 meters and larger within the next 15 years. The program is a collection of many loosely-coupled projects (survey, data processing and analysis, and object characterization) that do not lend themselves to a monolithic program schedule and plan. Much of the work is still of planetary science research in nature. However, this year, SMD established a formal program structure and planning for the NEO Program as well as increased the program management personnel for oversight of the many projects from one to four full-time equivalents.

None of the NEO Program funding is devoted to the Asteroid Redirect Mission. Potential candidates for this mission are a subset of the population of near-Earth asteroids that the NEO Program seeks to find in its primary mission. As our surveys find asteroids that might make good candidates for the Asteroid Redirect Mission, we further characterize them for our own NEO Program interests as well as for potential destinations for robotic or human spaceflight missions.

QUESTION 10:

Cyber threats are evolving globally, and NASA's ability to protect its information assets needs to evolve accordingly. Your 2016 Annual Performance Plan indicates that NASA is "transforming its cybersecurity capabilities and integrating cybersecurity as a vital part of its cultural identity." Please describe this transformation and specify how long it will take to improve the agency's capability to thwart sophisticated cyber attacks.

ANSWER 10:

NASA is in the process of improving our risk management frameworks to ensure alignment with Agency strategic goals and objectives. We continue actions to conduct comprehensive assessments to fully understand our cybersecurity risks. To protect the Agency against inevitable cyber security incidents or attacks on its Information Technology (IT) infrastructure and information we are taking deliberate action, in collaboration with internal and external partners to ensure that our networks, systems and associated components are consistently safeguarded,

assessed, and monitored. For this critical effort, the agency dedicated additional resources to implement new capabilities, processes, training and enhancements to core systems to address IT security concerns.

NASA's Office of the Chief Information Officer (OCIO), in conjunction with internal and external stakeholders, continues deliberate actions to ensure that agency policies are supported by vetted procedures. We are refining the management of our IT systems and the IT sensors across the corporate and mission networks to provide actionable intelligence. The enhanced awareness of our enterprise is enabling rapid risk-based decisions to protect our infrastructure and our information. Additionally - we are focused on user education via our IT security training, threat awareness sessions and phishing exercises.

Our continued efforts and collaboration with internal and external stakeholders (National Security Agency (NSA), Federal Bureau of Investigation (FBI) and Department of Homeland Security Continuous Diagnostics and Mitigation Program (DHS CDM Program) will lead to sustained enhancements in our IT Security posture over the next 2 years.

QUESTION 11:

What does NASA hope to learn from comparing Scott Kelly's vital signs to those of his twin brother, Mark, here on Earth in the first-ever experiment using identical twins?

ANSWER 11:

The investigations involving astronauts Scott and Mark Kelly who are identical twins will provide NASA with a genetic blueprint and broader insight into the subtle effects and changes that may occur during long-term (i.e. 1-year) spaceflight as compared to Earth-based environments. NASA and the National Space Biomedical Research Institute (NSBRI) will jointly manage this ambitious new undertaking.

The studies will focus on four areas: human physiology, behavioral health, microbiology/microbiome, and molecular or -omics studies. Human physiological investigations will look at how the spaceflight environment may induce changes in different organs like the heart, muscles or brain within the body. Behavioral health investigations will help characterize the effects spaceflight may have on perception and reasoning, decision making and alertness. The microbiology/microbiome investigations will explore the brothers' dietary differences and stressors to find out how both affect the organisms in the twins' guts. Lastly, but potentially opening a whole new realm of information about humans exposed to the spaceflight environment are the molecular or "-omics" studies (-omics refers to a system-level approach to studying molecular biology; examples include genomics, proteomics, and metabolomics). These studies will look at the way genes in the cells are turned on and off as a result of spaceflight; and how stressors like radiation, confinement and microgravity prompt changes in the proteins and metabolites gathered in biological samples like blood, saliva, urine and stool.

Although the investigations conducted on the Kelly brothers are not expected to provide definitive data about the effects of spaceflight on individuals — because there are only two subjects for data collection — they do serve as a demonstration project for future research initiatives. These investigations may identify changes to pursue in research of larger astronaut populations.

QUESTION 11a:

How will Scott Kelly's extended stay advance our confidence that a Mars human mission is possible?

ANSWER 11a:

The one-year mission will be a stepping stone to extended human exploration beyond low-Earth orbit. Data from the expedition will be used to determine whether there are ways to further reduce the risks on future long-duration missions to an asteroid and eventually Mars. Researchers expect the mission's investigations to provide data on biomedical, performance and behavioral changes and challenges astronauts may face when they embark on longer-duration missions, like those to an asteroid, Mars, or beyond. NASA and Roscosmos selected several collaborative investigations for this mission to evaluate the effects of long-duration spaceflight on humans. Each of the U.S. investigations will be grouped into one of seven categories: functional, behavioral health, visual impairment, metabolic, physical performance, microbial, and human factors.

QUESTION 11b:

What access will NASA have to the data collected on the Russian cosmonaut who is undergoing the same one-year mission?

ANSWER 11b:

NASA has established data sharing agreements with our Russian partners for joint U.S.-Russian investigations taking place aboard the ISS in the context of the year-long mission. Similar agreements are also nearly in place for data sharing between NASA and Russian researchers who are performing independent investigations on this mission that do not share crew members, but which have corresponding research objectives.

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 2016"*

Questions for the record, The Honorable Charles F. Bolden Jr., Administrator, National Aeronautics and
Space Administration (NASA)

Questions submitted by Rep. Eddie Bernice Johnson, Ranking Member, Full Committee

QUESTION 1:

It's been almost a year since the National Academies released its report, *"Pathways to Exploration: Rationales and Approaches for a US. Program of Human Space Exploration."* The committee, co-chaired by Governor Mitchell Daniels and Dr. Jonathan Lunine, took a serious look at the rationales and approaches that could be taken for sending humans to Mars. Their committee concluded that sending humans to Mars is a worthy goal for the nation. They also concluded that *"Increasing NASA's budget to allow increasing the human spaceflight budget by 5 percent per year would enable pathways with potentially viable mission rates, greatly reducing technical, cost, and schedule risk."* It is Congress's responsibility to provide NASA with the resources it needs to send humans to the surface of Mars and to support this commitment as a long-term goal. However, policymakers, the international community, industry, and the citizens need a roadmap. What has NASA done as a result of the National Academies report?

ANSWER 1:

NASA has been evolving its human exploration strategy over the past few years in accordance with the guidance and direction in the 2010 NASA Authorization Act, and this planning has continued during and after the development of the National Research Council (NRC) report. We engaged in dialog with this NRC committee during its lifetime, with standing NRC committees since, with our own NASA Advisory Council, and with our many partners and stakeholders. We continue to engage this community. As a result of this work, it has become clear that we need to define an approach to human space exploration that embraces Mars as a horizon destination, is sustainable over multiple decades, and is achievable within reasonable budget expectations. In dialog with those mentioned above and with our international and commercial partners, we have formulated and matured a set of principles for the overall Journey to Mars in keeping with these goals and constraints, and these have been met with broad consensus. NASA's exploration strategy is consistent with the Global Exploration Roadmap (GER), released by the International Space Exploration Coordination Group (ISECG).

Further, we have continued to refine an approach that builds up capability through which NASA and its partners extend our presence into the solar system. We cast this framework as moving from an "Earth-reliant" phase in which crew return is measured in hours, to a "Proving Ground" phase in which we test out and build up deep space capabilities in cis-lunar space where crew return times are measured in days, to an "Earth-independent" phase in which we can conduct missions to the vicinity or surface of Mars where crew return times are measured in months to

years. In the Earth-reliant phase, we are conducting human research on the International Space Station (ISS) according to a well-defined plan to develop the mitigations for the risks to humans of long-duration spaceflight beyond low Earth orbit (LEO). We are also using the ISS as a testbed to fill critical gaps in technologies we will need. For example, the environmental control and life support system that will be used for Mars missions will be tested on ISS. In parallel, we are working to facilitate the growth of the market for commercial LEO services that will free NASA up to move outward. We are building the Space Launch System (SLS) and Orion for missions in cis-lunar space, and are defining the test objectives to be met by the missions in this Proving Ground regime. We are currently studying approaches to achieving deep-space habitation capability in this region in collaboration with our partners. The Asteroid Redirect Mission (ARM) will advance the in-space propulsion and automated rendezvous and docking capabilities we will need for future Mars missions. Cis-lunar space will also be a staging area for both cargo and crewed missions to Mars. Robotic science missions at Mars today and going to Mars over the next decade are providing essential understanding of Mars atmospheric conditions, surface destinations, and resources; we are also conducting analyses of requirements for: crew and cargo transit systems; entry, descent and landing on Mars; *in situ* resource utilization for fuel, oxygen and food; surface power; and other elements of a humans-to-Mars architecture. The Space Technology Mission Directorate (STMD) is already supporting precursor development in many of these areas where long lead times and/or technical barriers could prevent immediate infusion into flight ready systems. For example, STMD programs are reducing packing volume of solar arrays, increasing power of electric propulsion systems, and advancing water processors and air revitalization systems so we can reduce reliance on Earth.

Building off of the successful radiation monitor already operating on the Curiosity rover, the next Mars rover planned for launch in 2020 will contribute to the preparation for human exploration of Mars by making significant progress towards addressing strategic knowledge gaps. Further, the Mars 2020 rover will potentially cache samples for possible return to Earth by future missions. In addition, the Mars Reconnaissance Orbiter is scanning the climate and surface of Mars and identifying the best possible landing sites for Mars 2020 and future missions. Simultaneously, the Mars Atmosphere and Volatile Evolution (MAVEN) mission is exploring the Red Planet's upper atmosphere, ionosphere and interactions with the sun and solar wind. Just as these rovers and orbiters help us answer the question of whether life ever existed on Mars in the past, they are also helping us to prepare to put human life on Mars in the future. One key to a sustainable program of space pioneering is to recognize what decisions need to be made and when. We have made decisions on: how to best use ISS (including the Administration's decision to extend ISS operations to at least 2024 in part to enable deep space exploration); development of SLS and Orion, including SLS' evolution pathway (pursuing an Exploration Upper Stage before advanced boosters based on cis-lunar mission capture); on sending Exploration Mission-1 (EM-1) to a distant retrograde orbit around the Moon because of its utility for future deep space missions; and on the utility of solar electric propulsion for moving large masses in deep space. We know the next set of decisions, to be made over the next few years, will include the areas of deep-space habitation and deep space transit capability, and on entry, descent and landing needs and technology pathways. Future decisions will include whether to send human missions to the moons of Mars before missions to the Mars surface, based on the degree to which the former is enabling of the latter.

But we do not need to make all these decisions today. In fact, it is better if we don't. We want to be able to take advantage of new scientific discoveries, new technology advances, and new commercial and international partnerships. Considering how each of these areas has advanced

over the past five years, it is easy to imagine they will change substantially over the next 5-10 years. Thus, as we pursue the development today of systems we know we will need for the proving ground phase, we can and should hold open some decisions for the Earth-independent phase where NASA and partner capabilities will evolve before we settle on the configuration of the first human mission to Mars.

QUESTION 1a:

What is the status of NASA's response to the panel's recommendations?

ANSWER 1a:

Please see response to Question #1, above.

QUESTION 1b:

Does NASA have plans to respond in writing to the panel's findings? If not, why not?

ANSWER 1b:

Please see response to Question #1, above.

QUESTION 1c:

Is NASA developing one or more pathways to Mars, consistent with the recommendations of the National Academies?

ANSWER 1c:

NASA is implementing the Journey to Mars through a pioneering approach that extends human presence into the solar system. The journey starts with research on ISS, including the current one-year mission, extends through missions of SLS/Orion in the proving ground of cis-lunar space, and builds toward an Earth-independent capability that enables human missions to Mars. See the answer to main part of Question #1, above.

QUESTION2:

The Space Subcommittee held a hearing in late February on NASA's Commercial Crew Program, and during that hearing, I was very troubled to learn of NASA's refusal to provide the Aerospace Safety Advisory Panel (ASAP) with key safety information about the program, despite the fact that ASAP has a Congressionally-chartered mission to advise you and the Congress on aerospace safety matters. To be specific, the Aeronautics Safety Advisory Panel (ASAP) said in its 2014 Annual Report, *"Over the last several years, the DCSD [--the Director of Commercial Spaceflight Development--] has responded to ASAP's requests for information related to the plans on how commercial programs would be certified or how confidence would be gained on the safety of operations with a seamless set of constraints as to why the information could not be shared."*

- a. What have you done to address this matter, and what will you be doing to ensure that ASAP has full and unfettered access to any information it needs to evaluate safety issues related to the Commercial Crew Program or other any other program for which it is assessing safety?

ANSWER 2a:

To protect the integrity of the procurement process, the agency controlled the release of data following the award of the initial Certification Products Contracts and after the award of the follow-on Commercial Crew Transportation Capability (CCtCap) contracts. The CCtCap procurement blackout and protest period caused the agency to extend data and product release restrictions to all parties for almost one year. Protecting the integrity of the procurement process ensured the best selection was made.

After the GAO protest findings were released in January 2015, NASA took immediate steps to inform its key stakeholders, Congress, the Aerospace Safety Advisory Panel (ASAP), and the public about Commercial Crew contract details, including the following.

- The CCtCap Source Selection Statement was posted on NASA's website.
- NASA provided detailed briefings to our Congressional oversight committees on the status and plans of the CCP, including in-depth descriptions of the CCtCap contracts.
- NASA provided two in-depth briefings to the ASAP. One on the status of the industry partners designs and technical risks and another on the overall progress of our industry partners and the CCP as a whole.
- NASA conducted a press conference regarding the CCtCap contracts, which included representatives from both industry partners.
- NASA has posted a public version of the CCtCap contracts on the NASA website.

Now that the constraints of the procurement process has been lifted, NASA plans to continue its information transparency initiatives. We are confident that this will provide all our oversight groups with sufficient insight into the human spaceflight programs at the agency.

QUESTION 2b:

Have you made any personnel reassignments in response to ASAP's concerns, and if not, why not?

ANSWER 2b:

The reduction in access to data was due primarily to the ongoing contract competition. The Procurement Integrity Act (41 U.S.C. 2102) prohibits disclosure of agency source selection information and proposal information during a procurement. During a protest, GAO issues a protective order pursuant to 4 C.F.R. part 21.4, which restricts access to all protest materials to only the individuals specifically authorized by GAO. Thus, there was no fault involved on the part of any individual; NASA was abiding by established procurement rules.

Appendix II

ADDITIONAL MATERIAL FOR THE RECORD

STATEMENT SUBMITTED BY FULL COMMITTEE RANKING MEMBER
EDDIE BERNICE JOHNSON

Good morning, and welcome Administrator Bolden. I look forward to your testimony, and I thank you for your continued service to this nation.

As the Chairman has indicated, we are here to review NASA's Fiscal Year 2016 budget request. Before I discuss specifics, I would like to say that I appreciate the President's commitment to NASA as expressed in this budget request, as well as his support for R&D overall. It is clear that he understands the importance of investing in our nation's R&D enterprise, of which NASA is a key component.

So while I may differ on some of the specific funding decisions reflected in this budget request, I think that NASA's overall request is a good starting point for our deliberations—and I hope that Congress will at least equal that budgetary top line, if not exceed it. Because the reality is that successive Congresses and Administrations have tasked NASA with a number of critically important endeavors, yet we have lagged in providing the resources needed to carry them out. The truth is that NASA's "buying power" has actually decreased by 15 percent from Fiscal Year 2005 to Fiscal Year 2013 and is expected to continue to decline if the budgetary outlook doesn't improve. Mr. Chairman, the hardworking women and men of NASA deserve better.

Let me cite an example. Just about a year ago, a distinguished panel of the National Academies completed its review of the nation's human space exploration program. The panel was headed by former governor and OMB Director Mitch Daniels, an individual well known for his fiscal conservatism. Which makes the panel's conclusions even more impressive, namely: America's human spaceflight program is worth continuing, Mars is the appropriate goal, the government needs to come to a consensus on a pathway to Mars—that is, a set of interim destinations and milestones—and it's going to require funding above constant dollars if NASA is to succeed.

That's pretty unambiguous advice.

So it came as a bit of a shock to me that the very next budget request for NASA to be submitted after the report's release would actually propose cutting the funding for the Space Launch System and Orion, two fundamental enabling elements of the human exploration program. It's directly counter to the National Academies' findings, and I think Congress needs to correct that.

Neither has NASA yet told us how it plans to get to Mars—what's the pathway or roadmap? NASA needs to look beyond just the next four or five years and lay out the milestones it needs to pursue to get humans on Mars. As the National Academies panel made clear, defining such a roadmap is not just for NASA's benefit. Congress and the American people will need to be confident that NASA has a well thought-out plan if we are going to be able to sustain support for such an ambitious undertaking over the coming years.

There are other examples in the budget request that I could cite as areas of concern: the cuts made to NASA's Education program, to Aeronautics, and to Planetary Science, among others. However,

I am sure we will discuss them further during the hearing, so I won't pursue them here. Instead, I will close by saying again what I have said many times already: NASA is a crown jewel of America's research and development enterprise. It advances knowledge, promotes technological innovation, projects a positive image of America throughout the world, and inspires. Its workforce is dedicated and accomplished. NASA deserves our support.

Thank you, and I yield back the remainder of my time.

