AN UPDATE ON THE SPACE LAUNCH SYSTEM AND ORION: MONITORING THE DEVELOPMENT OF THE NATION'S DEEP SPACE EXPLORATION CAPABILITIES

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

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CONTENTS

December 10, 2014

AN UPDATE ON THE SPACE LAUNCH SYSTEM AND ORION: MONITORING THE DEVELOPMENT OF THE NATION'S DEEP SPACE EXPLORATION CAPABILITIES

WEDNESDAY, DECEMBER 10, 2014

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

The Subcommittee met, pursuant to call, at 10:03 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
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Subcommittee on Space

An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities

Wednesday, December 10, 2014
10:00 a.m. to 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Bill Gerstenmaier, *Associate Administrator for Human Exploration and Operations Mission Directorate, NASA*

Cristina Chaplain, *Director, Acquisition and Sourcing Management, Government Accountability Office*

U.S. House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Space

An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities

CHARTER

Wednesday, December 10, 2014
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The Space Subcommittee will hold a hearing titled *An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities* at 10:00 a.m. on Wednesday, December 10th. This hearing will examine the progress, challenges, and future opportunities for the Space Launch System (SLS) and Orion Multipurpose Crew Vehicle (Orion).

Witnesses

- **Bill Gerstenmaier** – Associate Administrator for Human Exploration and Operations Mission Directorate, NASA
- **Cristina Chaplain** - Director, Acquisition and Sourcing Management, Government Accountability Office
- **The Honorable David Radzanowski or designee (invited)** - Chief Financial Officer, NASA

Background

Following the Space Shuttle *Columbia* accident and the subsequent investigation into its cause, President George W. Bush announced a new "Vision for Space Exploration" in January 2004, to reinvigorate and redirect NASA's human exploration program. The policy outlined the next major steps for NASA with the International Space Station, missions to return to the Moon, and onward to Mars and beyond. NASA was directed to "implement an integrated, long-term robotic and human exploration program structured with measurable milestones and executed on the basis of available resources, accumulated experience, and technology readiness."[1] The Constellation Program—comprised of the Orion Crew Exploration Vehicle, Ares I crew launch vehicle, Ares V heavy-lift launch vehicle, along with new space suits and the Altair lunar lander--was born out of the Vision for Space Exploration. The Constellation Program began with NASA's budget request for fiscal year 2005 and development of these systems continued until Fiscal Year 2010 (FY10).

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[1] National Aeronautics and Space Administration-*The Vision for Space Exploration, February 2004.* Retrieved at http://www.nasa.gov/pdf/55583main_vision_space_exploration2.pdf

President Barack Obama proposed to cancel the Constellation program as part of his FY 2011 budget request released in February 2010. The President proposed to cancel a return mission to the Moon in favor of a trip to an asteroid and then to orbit Mars. The President articulated the outline of his plans for NASA in a speech at Kennedy Space Center in April 2010, with continued development of the Orion crew vehicle. Later that year, Congress authorized some of the changes to the human exploration program, mandating continued development of the Orion Multipurpose Crew Vehicle and heavy-lift Space Launch System.

Budget

The Exploration Systems Development program within the Human Exploration and Operations Mission Directorate is responsible for the design, construction, and integration of the next step in human exploration beyond low-Earth orbit. The FY2014 omnibus appropriation (P.L. 113-76) required a minimum of $1.6 billion for SLS vehicle development, which is a $230 million increase over FY2013. Additionally, the omnibus appropriation includes $1.197 billion for the Orion crew vehicle, which is roughly the same amount the program has received for the last two fiscal years.

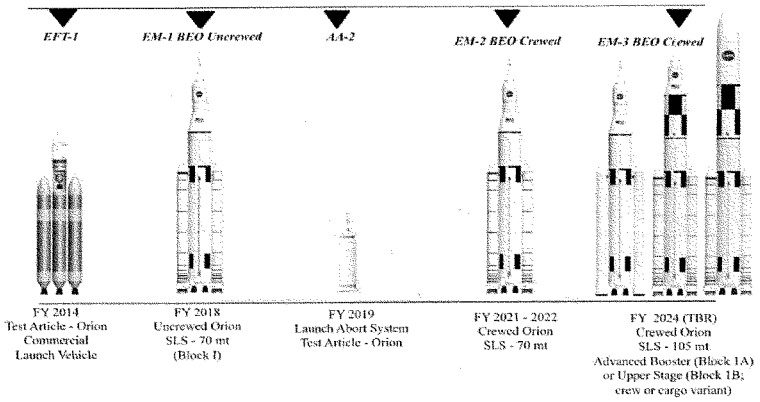
Each year, the President's Budget has consistently requested less money for Exploration Systems despite the insistence of Congress that these programs be a priority. Most recently, the President's budget for FY2015 included a request to reduce the exploration systems programs (SLS and Orion) by over $330 million[2] compared to the FY2014 enacted appropriation.

	Actual	Enacted	Request	FY14 Vs	Notional			
Budget Authority ($ in millions)	2013	2014	FY15	FY15	2016	2017	2018	2019
Exploration	3,705.5	4,113.2	3,976.0	(137.2)	4,079.9	4,049.4	4,107.7	3,673.4
Exploration Systems Dev	2,883.8	3,115.2	2,784.4	(330.8)	2,863.3	2,905.9	2,982.1	3,106.6
Orion Crew Capsule	1,113.8	1,197.0	1,052.8	(144.2)	1,096.3	1,119.8	1,122.9	1,126.7
Space Launch System	1,414.9	1,600.0	1,380.3	(219.7)	1,356.9	1,353.8	1,418.0	1,526.9
Exploration Ground Systems	355.1	318.2	351.3	33.1	410.1	432.3	441.2	453.0

Schedule

The first test flight of the new SLS/Orion program was conducted on December 5, 2014. The Orion was launched atop a United Launch Alliance Delta IV Heavy Rocket from Cape Canaveral Air Force Station. The mission was conducted for NASA by Lockheed Martin under a commercial launch license. The Exploration Flight Test-1 (EFT-1) was meant to validate various systems including Orion's heat shield, avionics, and parachutes used for landing. In FY 2018 NASA plans to launch the SLS for the first time with an uncrewed Orion to a circumlunar orbit. This flight, Exploration Mission-1 (EM-1) will demonstrate the integrated capability of both systems. The Exploration Mission-2 (EM-2)–planned for 2021—would launch an Orion and SLS with as many as four astronauts.

[2] President's Budget Request for NASA, Fiscal year 2015, accessed at http://www.nasa.gov/sites/default/files/files/508_2015_Budget_Estimates.pdf



NASA Authorization

The NASA Authorization Act of 2010 (the Act) directed the Administration to develop a heavy-lift launch capability and a next generation exploration vehicle. Specifically, Congress directed that:

> *It is the policy of the United States that NASA develop a Space Launch System as a follow-on to the Space Shuttle that can access cis-lunar space and the regions of space beyond low-Earth orbit in order to enable the United States to participate in global efforts to access and develop this increasingly strategic region.*[3]

Additionally, the Act required the continued development of the Orion:

> *The Administrator shall continue the development of a multi-purpose crew vehicle to be available as soon as practicable, and no later than for use with the Space Launch System. The vehicle shall continue to advance development of the human safety features, designs, and systems in the Orion project.*[4]

[3] NASA Authorization Act of 2010, Section 303(a). Retrieved at https://www.congress.gov/111/plaws/publ267/PLAW-111publ267.pdf
[4] NASA Authorization Act of 2010, Section 302(a). Retrieved at https://www.congress.gov/111/plaws/publ267/PLAW-111publ267.pdf

Last June, the House passed the NASA Authorization Act of 2014 by a vote of 401-2. This strong bipartisan bill included an endorsement of the continued development of the SLS and Orion. In particular, Congress directed that:

> *...the Administrator shall make the expeditious development, test, and achievement of operational readiness of the Space Launch System and the Orion crew capsule the highest priority of the exploration program.*[5]

The Space Launch System (SLS)

The SLS is the nation's next generation human exploration launch vehicle. At its most capable, the SLS will have the ability to lift 130 tons into low-Earth orbit. The NASA Authorization Act of 2010 explicitly included this minimum capability requirement.[6] Last June, NASA and Boeing definitized the contract for the SLS core stages that will be built and delivered for both the FY 2018 EM-1 test flight and the 2021 EM-2 flight. The value of the contract is $2.8 billion over six years. The work under this contract includes two SLS cores, including hydrogen and oxygen tanks as well as avionics.

Major projects at NASA go through a system of "key decision points" or "KDPs." As the program progresses, the agency evaluates its progress and determines whether it is prepared to proceed to the next phase. Last August, NASA completed Key Decision Point-C (KDP-C) for the SLS program. This KDP is significant in the planning process for both the agency and outside stakeholders because it is the point at which NASA formally establishes a cost and schedule baseline for the program.

In the case of the SLS, NASA determined that if the program receives $7 billion over the next three years, there is a 70 percent probability it will launch EM-1 by 2018.[7] This would roughly translate into $1.75 billion a year between fiscal year 2014 through fiscal year 2018. This is the first time that NASA has publicly acknowledged that EM-1 may not be ready to launch in 2017 as the agency had previously claimed in the President's budget requests.

The KDP-C agency baseline is somewhat in conflict with statements made by the NASA Administrator about the funding necessary to keep the program on schedule. In testimony before the House Committee on Science, Space, and Technology on April 24, 2013, Administrator Bolden testified on the topic of SLS funding reductions, saying:

> *"If I added $300 million to the SLS program, you wouldn't know it."*[8]

In that same hearing, in reference to the President's budget request, when asked about reductions to the program, he added:

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[5] NASA Authorization Act of 2014, Section 203 (c). Retrieved at https://www.congress.gov/113/bills/hr4412/BILLS-113hr4412rfs2.pdf

[6] NASA Authorization Act of 2010, Section 303(c). Retrieved at https://www.congress.gov/111/plaws/publ267/PLAW-111publ267.pdf

[7] "NASA Completes Key Review of World's Most Powerful Rocket in Support of Journey to Mars," retrieved at http://www.nasa.gov/press/2014/august/nasa-completes-key-review-of-world-s-most-powerful-rocket-in-support-of-journey-to/#.VINC8sknrWg

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

"We have asked for, and I think Bill Gerstenmaier, the head of the Human Exploration Operations Mission Directorate, has stated over and over that this is the amount of money that we need to deliver SLS on the date and time that we said, 2017 for the inaugural mission..."[9]

Following this hearing, the members of the Committee submitted additional questions for the record to follow up on these statements. In response to a related question from Space Subcommittee Chairman Palazzo, he stated:

"The FY2014 President's Budget Request....provides the necessary funding profile required to keep SLS, Orion, and EGS moving forward to achieve EFT-1 in 2014, EM-1 in 2017, and EM-2 in 2021."[10]

Despite these statements, the Government Accountability Office (GAO) recently noted: "According to the program's risk analysis...the agency's current funding plan for SLS may be $400 million short of what the program needs to launch by 2017."[11]

Orion Multipurpose Crew Vehicle (Orion)

The Orion is NASA's next generation human exploration vehicle. It will have the capability to carry astronauts to the Moon and Mars and will be the first deep space human exploration vehicle to launch since the Apollo program.

Orion consists of a crew module, service module, stage adapter, and launch abort system. The crew module is 16 ½ feet in diameter and nearly 11 feet in length with a mass of about 19,000 lbs. It is approximately 50 percent larger (by volume) than the Apollo capsule. The crew module can carry a crew of four for up to 21 days in space. There are other configurations of crew that would allow longer or shorter durations based on mission profile and crew needs. Additional habitation modules will need to be developed in the future for larger crews as NASA carries out longer-duration missions.

On December 5, 2014, Lockheed Martin launched the Orion on a United Launch Alliance Delta-IV Heavy launch vehicle under an FAA licensed commercial space launch. This test, dubbed EFT-1, was meant to provide engineers with data about systems critical to crew safety such as heat shield performance, separation events, avionics and software performance, attitude control and guidance, parachute deployment, and recovery operations to validate designs of the spacecraft before it begins carrying humans to new destinations in deep space. Under the terms of its contract with NASA, Lockheed Martin is required to provide a preliminary report with flight data within 90 days of the test.

EFT-1 is the first in a series of test flights for Orion and SLS. The next test, Exploration Mission-1 (EM-1), is scheduled for no later than 2018 and will include the first launch of the SLS with the Orion. Like EFT-1, EM-1 will not be crewed, but will test critical life support systems. The final test, Exploration Mission-2 (EM-2), will launch in 2021 and will include the

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[9] *Ibid.*

[10] Answers to Questions for the Record from NASA Administrator Charles F. Bolden regarding House Committee on Science Space and Technology Hearing Titled "An Overview of the National Aeronautics and Space Administration Budget for Fiscal Year 2014," October 28, 2013.

[11] Space Launch System - Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability. Government Accountability Office, Retrieved at http://www.gao.gov/products/GAO-14-631

SLS and Orion. It will have at least two crewmembers aboard. That flight will take astronauts to lunar orbit and back and will be the first time humans have been to the Moon since Apollo.

Despite a near-flawless EFT-1 mission, the Orion program has not been without its challenges. In an interview recently published in *Space News*, Orion Program Manager Mark Geyer was quoted as saying, "We're struggling to make December 2017, and I have a lot of challenges to make that date."[12] The reasons for this, as reported, included technical and schedule delays with various components of Orion including the heat shield and service module, which is being developed in coordination with European partners. Last January, the Director-General of the European Space Agency Jean-Jacques Dordain stated: "I have committed to NASA that the PDR [Preliminary Design Review] will not cause a delay in the delivery of the service module."[13]

Further complicating potential schedule delays, the President's budget request for the Orion is consistently lower than NASA's own cost estimates to maintain mission milestones. In the FY13, FY14, and FY15 budget requests, the Administration asked for reductions of $175.1 million, $87 million, and $144.2 million respectively.[14] Had Congress agreed to the requests compared to the enacted appropriation, the Orion program would have incurred over $400 million in reductions, and would likely face longer potential delays.

Key Questions

1. What are the true funding needs and schedule expectations for the development of the SLS and Orion Programs?
2. How can NASA, the Administration, and Congress mitigate the risks to these programs and ensure their timely and sustainable development?
3. What impact has NASA's treatment of termination liability had on the development of the SLS and Orion programs?
4. How has NASA's direction to manage the SLS and Orion programs based on the President's budget request rather than Continuing Resolution levels, which are higher, impacted the programs?
5. How does management of these programs compare to management of other large-scale development programs within the federal government?
6. How does the budget formulation process at NASA, including procedures and standard practices for producing funding requests for large-scale programs, differ from that of other agencies?
7. What did NASA learn from the commercial test launch of the Orion in EFT-1 and what do the preliminary findings and data demonstrate?
8. What is NASA's progress towards meeting key schedule milestones including a flight test of the SLS in fiscal year 2018?

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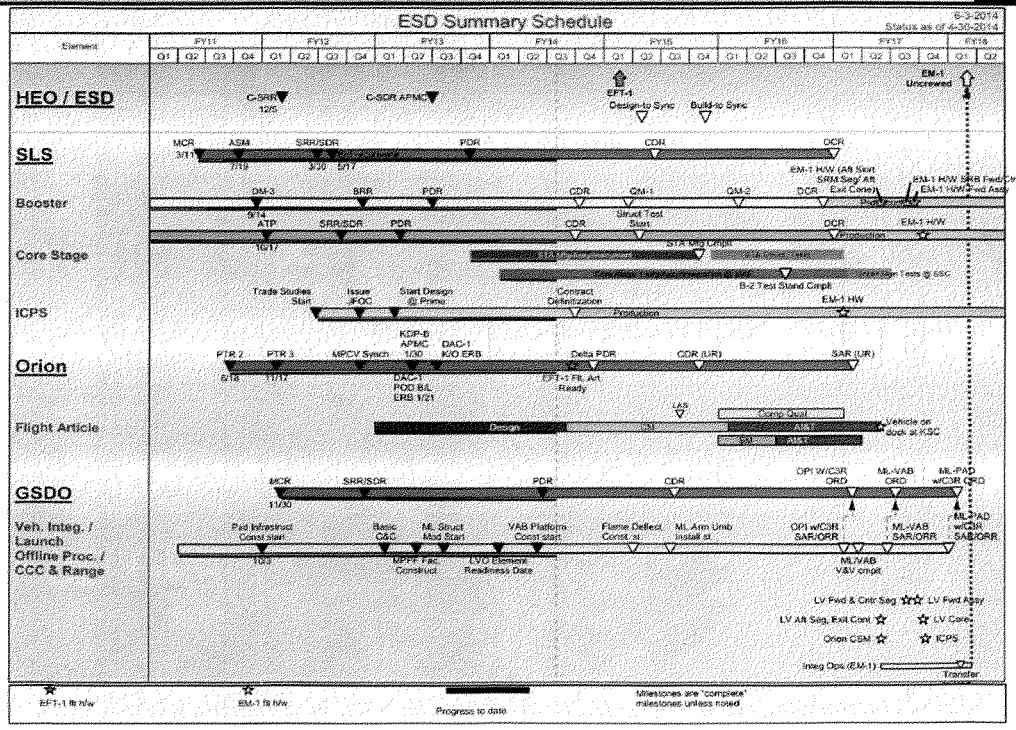
[12] "NASA Officials: Orion 'Challenged' To Make 2017 Launch Date," Space News, August 11, 2014. http://www.spacenews.com/article/features/41554news-from-aiaa-space-2014-nasa-officials-orion-%E2%80%98challenged%E2%80%99-to-make-2017

[13] Peter De Selding, "ESA Promises NASA that Orion Service Module Delay Won't Hold up 2017 Launch," Space News, January 17, 2014. Accessed at http://www.spacenews.com/article/civil-space/39138esa-promises-nasa-that-orion-service-module-delay-won%E2%80%99t-hold-up-2017-launch

[14] President's Budget Requests for Fiscal Year 2013, Fiscal Year 2014, and Fiscal Year 2015.

APPENDIX I – Note: this schedule predates the completion of KDP-C

ESD Summary Schedule



Chairman PALAZZO. The Subcommittee on Space will come to order.

Good morning. Welcome to today's hearing titled "An Update on the Space Launch System and Orion: Monitoring the Development of the nation's Deep Space Exploration Capabilities. In front of you are packets containing the written testimony, biography, and truth-in-testimony disclosure for today's witnesses.

I recognize myself for five minutes for an opening statement.

I would like to welcome everyone to our hearing and particularly our witnesses. Thank you for your appearance here today.

Anyone who pays attention to the media at all is no doubt aware of the spectacular launch of the Orion crew vehicle last week. I want to congratulate Mr. Gerstenmaier and his entire team at NASA, as well as the teams at Lockheed Martin and United Launch Alliance for an outstanding test flight.

While we will hear today about the preliminary results from this test, the scientists and engineers at NASA will continue to analyze the data for quite some time. I look forward to hearing more about the progress of this analysis in the future.

The successful test launch of Orion demonstrates that we are on the right track for sending humans back to the Moon and Mars within our lifetimes. Across the nation, people were watching with the same hope and pride that all Americans had in the early days of our space program. In my Congressional District children were bussed to Stennis Space Center to watch a live feed of the launch. Events like this are what we need to inspire the next generation of astronauts and engineers, and SLS is a giant leap forward in making America the leader in space once again. The tremendous ongoing work at NASA and our industry partners is beginning to produce tangible results. The nation can be proud of what was accomplished last week. It was certainly a job well done.

The purpose of our hearing today is to examine the challenges and opportunities facing the Space Launch System and Orion programs. It is no secret that this Committee is concerned that the support within NASA for the SLS and Orion is not matched by the Administration. While this lack of commitment is somewhat puzzling, it is not at all surprising. The President has made clear that he does not believe space exploration is a priority for the nation and has allowed political appointees within the Administration to manipulate the course of our human space flight program. These decisions should be made by the scientists, engineers, and program managers that have decades of experience in human space flight.

As everyone here knows, this is not an easy field; we cannot ramp up capability or prepare for these missions overnight. Space exploration requires a dedication to advanced preparation and research, and this Committee and this Congress are dedicated to supporting that requirement.

The Administration has consistently requested large reductions for these programs despite the insistence of Congress that they be priorities. Most recently, the President's budget for Fiscal Year 2015 included a request to reduce these programs by over $330 million compared to the Fiscal Year 2014 enacted appropriation. Additionally, in the 2013, 2014, 2015 budget requests, the Administration asked for reductions of $175.1 million, $87 million, and $144

million respectively for the Orion program relative to the enacted appropriations.

Had Congress agreed to the requests, Orion and the SLS would have incurred hundreds of millions of dollars in reductions and would likely face significant delays and mass layoffs. Thankfully, Congress listened to the program managers and industry partners to ensure these programs were appropriately funded.

Congress has once again demonstrated support for the SLS and Orion by providing funding well above the President's budget request in the Omnibus for Fiscal Year 2015. While these priority programs may not enjoy support within the Administration, they certainly do from Congress. Let me be very clear, on my watch Congress will not agree to gutting the SLS program; not now and not any time in the foreseeable future.

The human exploration program at NASA has been plagued with instability from constantly changing requirements, budgets, and missions. We cannot change our program of record every time there is a new president. This committee is consistent and unwavering in its commitment to human exploration, a tradition that I appreciate and am confident will continue into the future.

While this hearing is certainly an opportunity for us to celebrate the great progress of the SLS and Orion programs, particularly last week's test flight, the Committee has ongoing concerns about the challenges facing these vital programs. In a letter to the NASA Administrator, Chairman Smith and I expressed our concerns for potential delays of Exploration Mission-1 that had been slated for 2017 and is now potentially delayed to as late as Fiscal Year 2018. The Administration's letter back to the Committee was strangely unresponsive and did not inspire a lot of confidence in NASA's ability to meet the original timelines laid out. Congress needs answers to these questions. At the very least, we need to know, what are the true funding needs and schedule expectations for the development of the SLS and Orion Programs, and is NASA on track to meet these expectations?

In addition to consistently submitting insufficient funding requests, the Administration also appears to be limiting the usefulness of funding it does receive. For example, the Administration's treatment of termination liability prevents hundreds of millions of dollars from being used for meaningful development work. Also, the Committee has learned that the Administration has given direction to the SLS and Orion programs to plan spending rates consistent with the President's budget request instead of the higher continuing resolution level. Combined, these efforts are undermining the successful development of these national priority programs.

In a recent report titled "Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability," the Government Accountability Office highlighted technical and schedule risks that NASA had not previously brought to the attention of the Committee. Specifically, GAO states that "According to the program's risk analysis, the agency's current funding plan for SLS may be $400 million short of what the program needs to launch by 2017." It was surprising for the Committee to hear about this shortfall since the Administrator had pre-

viously testified that "If we added $300 million to the SLS program, you wouldn't know it."

It is not unreasonable for Congress to expect the Administration to be straightforward about the risks and costs associated with national priority programs. As we look to continue pushing towards Mars, we must talk honestly and realistically about these programs and what we can accomplish with them. We want to be partners moving forward, not competitors; unfortunately, the Administration has simply not allowed for that cooperation.

The test last week of Orion was an important milestone in the future of America's space program. It was a fully commercial mission licensed by the Federal Aviation Administration and conducted by the private sector. In the future, Orion and SLS will serve as the tip of the spear for our nation's space exploration program.

Recently, some have argued that the government shouldn't be involved in space exploration at all and suggest that the private sector alone is capable of leading us into the cosmos. I certainly hope that this will someday be possible, but right now, space exploration requires government support. This is a worthwhile investment for the taxpayer. It inspires the next generation of explorers to pursue science, technology, engineering, and math; advances U.S. soft power and international relations; reinforces our aerospace industrial base; increases economic competitiveness; and advances our national security interests. Orion and SLS, the vanguard of our nation's space program, are key to advancing these interests.

I look forward to hearing from Mr. Gerstenmaier and Ms. Chaplain today about the challenges and opportunities facing these important programs.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
CHAIRMAN STEVEN M. PALAZZO

Good morning, I would like to welcome everyone to our hearing and particularly our witnesses. Thank you for your appearance here today.

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Let me be very clear, on my watch Congress will not agree to gutting the SLS program; not now and not anytime in the foreseeable future.

The human exploration program at NASA has been plagued with instability from constantly changing requirements, budgets, and missions. We cannot change our program of record every time there is a new president. This committee is consistent and unwavering in its commitment to human exploration, a tradition that I appreciate and am confident will continue into the future.

While this hearing is certainly an opportunity for us to celebrate the great progress of the SLS and Orion programs, particularly last week's test flight, the Committee has ongoing concerns about the challenges facing these vital programs. In a letter to the NASA Administrator, Chairman Smith and I expressed our concerns for potential delays of Exploration Mission-1 that had been slated for 2017 and is now potentially delayed to as late as fiscal year 2018. The administration's letter back to the Committee was strangely unresponsive and did not inspire a lot of confidence in NASA's ability to meet the original timelines laid out. Congress needs answers to these questions. At the very least, we need to know, what are the true funding needs and schedule expectations for the development of the SLS and Orion Programs and is NASA on track to meet these expectations?

In addition to consistently submitting insufficient funding requests, the Administration also appears to be limiting the usefulness of funding it does receive. For example, the Administration's treatment of termination liability prevents hundreds of millions of dollars from being used for meaningful development work. Similarly, the committee has learned that the Administration has given direction to the SLS and Orion programs to plan spending rates consistent with the President's Budget Request instead of the higher Continuing Resolution level. Combined, these efforts are undermining the successful development of these national priority programs.

In a recent report titled *Space Launch System–Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability*, the Government Accountability Office highlighted technical and schedule risks that NASA had not previously brought to the attention of the Committee. Specifically, GAO states that quote "According to the program's risk analysis . . . the agency's current funding plan for SLS may be $400 million short of what the program needs to launch by 2017." It was surprising for the Committee to hear about this shortfall since the Administrator had previously testifiedthat quote "If we added $300 million to the SLS program, you wouldn't know it."

It is not unreasonable for Congress to expect the Administration to be straight forward about the risks and costs associated with national priority programs. As we look to continue pushing towards Mars, we must talk honestly and realistically about these programs and what we can accomplish with them. We want to be partners moving forward, not competitors; unfortunately the Administration has simply not allowed for that cooperation. The test last week of Orion was an important milestone in the future of America's space program. It was a fully commercial mission licensed by the Federal Aviation Administration and conducted by the private sector. In the future, Orion and SLS will serve as the tip of the spear for our nation's space exploration program.

Recently, some have argued that the government shouldn't be involved in space exploration at all and suggest that the private sector alone is capable of leading us into the cosmos. I certainly hope that this will someday be possible, but right now, space exploration requires government support.

This is a worthwhile investment for the taxpayer. It inspires the next generation of explorers to pursue science, technology, engineering, and math; advances U.S. soft power and international relations; reinforces our aerospace industrial base; increases economic competitiveness; and advances our national security interests. Orion and SLS—the vanguard of our nation's space program—are key to advancing these interests. I look forward to hearing from Mr. Gerstenmaier and Ms. Chaplain today about the challenges and opportunities facing these important programs.

Chairman PALAZZO. I now recognize the Ranking Member from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and good morning and welcome to our witnesses.

I want to join Chairman Palazzo in congratulating NASA, Lockheed, United Launch Alliance, and the entire government and contractor team on successfully conducting the Exploration Flight Test, EFT–1, of the Orion capsule last week. I think it was truly exciting and I know that around the country and around the world there were many of us looking on television for the first time in a long time at a U.S. space program that really is very forward-looking. The flight subjected Orion and its systems to the rigors of outer space beyond low Earth orbit to test key systems, verify the Orion design, reduce technical risks, and test recoverability operations.

Mr. Chairman, I believe that this test flight shows Americans that tangible progress is in fact being made on returning humans to exploration beyond our Earth's neighborhood and a goal that this Committee and the Congress as a whole have embraced through multiple NASA Authorization Acts, despite some of the challenges that the Chairman laid out.

I would also note that I think we were in this hearing room just three years ago wondering whether Orion was really going to be possible or not and I think that we have addressed that question in what is a remarkably short period of time. And so while I look forward to looking at the challenges and taking on some of those challenges, I don't want us to lose sight of the fact that we have great capacity and that the American people can get greatly excited by that and I think then lead those of us who are the policymakers to do the right thing when it comes to robustly funding our exploration program.

The development of the Space Launch System, SLS, and the Orion crew vehicle are necessary next steps in reaching our goals for human space exploration, including the long-term goal of sending humans to the surface of Mars, as stated in our bipartisan House-passed NASA Authorization Act of 2014. And so I also thank you, Mr. Chairman, for holding this hearing so we can obtain an update on the status of the SLS and Orion programs.

And it was indeed just those three years ago that we sat in this room and we were pressing NASA for a decision on a final design of the SLS rocket. There was great debate between the Administration and this Committee and the Congress, and I think today we are going to hear of the program's approval to enter into the full-scale development, as some of us had envisioned. This is indeed a

significant accomplishment, even in the midst of major challenges, especially those related to constrained budgets. Very often Congress has been supportive of SLS/Orion and has appropriated funding above the President's request, as the Chairman has indicated.

I don't know that I necessarily share the Chairman's view about where all the faults lie. However, the programs have been challenged by the flat funding levels provided for SLS and Orion over the past years, a situation that departs significantly from the typical funding growth profiles of major development programs, and that is why we have recognized the critical need to authorize a robust top-line funding level for NASA in the 2013 Democratic NASA authorization bill that included healthy increases for the exploration program.

The National Academies Committee in fact recently released its report on human space exploration and also recognized that sending humans to the surface of Mars would include and require sustained increases. They said, "Increasing NASA's budget to allow increasing the human spaceflight budget by five percent per year would enable pathways with potentially viable mission rates greatly reducing technical, cost, and schedule risk."

And so, Mr. Chairman, we can work together to overcome these challenges. And as we work over this next Congress to reauthorize NASA, I look forward to working with you to ensure that this Committee authorizes the appropriations that the SLS and Orion programs require to achieve the expeditious development and testing of these vehicles for their use at the earliest possible date and that we obtain a human exploration roadmap to focus the SLS and Orion systems on long-term mission goals. And because when I see the excitement of the EFT–1 test flight, as demonstrated by the flight's coverage as a leading media story—I think in fact it did lead the broadcast news—I am reminded that the SLS and Orion programs really do belong to the American public and that they will in fact embrace them. We need to honor this thirst for exploration.

And finally, though the 113th Congress is rapidly drawing to a close, I encourage our colleagues in the Senate to seek quick passage of the House-passed NASA Authorization Act of 2014 so that NASA and its industry contractors, all of them, have the direction and stability needed to plan for continued progress.

And then finally, I will just reiterate what I have said many times before and that is we cannot have one set of goals for NASA and for our human exploration programs and then not match those goals with the resources that are required to commit to the work on a timely basis. It is unfair to the agency, it is unfair to contractors, and it is a false expectation for the public.

And with that I yield back and I look forward to hearing the testimony today.

[The prepared statement of Ms. Edwards follows:]

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

Good morning and welcome to our witnesses. First, I want to join Chairman Palazzo in congratulating NASA, Lockheed Martin, United Launch Alliance, and the

entire government and contractor team on successfully conducting the Exploration Flight Test—EFT-1—of the Orion capsule last week.

The flight subjected Orion and its systems to the rigors of outer space beyond low Earth orbit to test key systems, verify the Orion design, reduce technical risks, and test recoverability operations. Mr. Chairman, this test flight shows Americans that tangible progress is being made on returning humans to exploration beyond our Earth's neighborhood, a goal that this Committee and the Congress as a whole have embraced through multiple NASA Authorization Acts.

The development of the Space Launch System-SLS-and the Orion crew vehicle are necessary next steps in reaching our goals for human space exploration, including the long-term goal of sending humans to the surface of Mars as stated in our bipartisan House-passed NASA Authorization Act of 2014. So I thank you, Mr. Chairman, for holding this hearing to obtain an update on the status of the SLS and Orion programs.

It was only three years ago that we sat in this room pressing NASA for a decision on a final design for the SLS rocket, and today we'll hear of the program's approval to enter into full scale development. That's a significant accomplishment, even in the midst of major challenges, especially those related to constrained budgets.

Congress has been supportive of SLS and Orion and has appropriated funding above the President's requests. However, the programs have been challenged by the flat funding levels provided for SLS and Orion over the past years, a situation that departs significantly from the typical funding growth profiles of major development programs.

That's why we recognized the critical need to authorize a robust top-line funding level for NASA in the 2013 Democratic NASA Authorization bill that included healthy increases for the exploration program. The National Academies committee that recently released its report on human space exploration also recognized that sending humans to the surface of Mars would require sustained increases. They said, "Increasing NASA's budget to allow increasing the human spaceflight budget by five percent per year would enable pathways with potentially viable mission rates, greatly reducing technical, cost, and schedule risk."

Mr. Chairman, we can work together to overcome these challenges. As we work to reauthorize NASA during the next Congress, I look forward to working with you to ensure that this Committee authorizes the appropriations that the SLS and Orion programs require to achieve the expeditious development and testing of these vehicles for their use at the earliest possible date, and that we obtain a human exploration roadmap to focus the SLS and Orion systems on long-term mission goals.

Because, when I see the excitement of the EFT-1 test flight as demonstrated by the flight's coverage as a leading media story, I'm reminded that the SLS and Orion programs belong to the American public. We need to honor their thirst for exploration.

And, finally, though the 113th Congress is rapidly drawing to a close, I encourage our colleagues in the Senate to seek quick passage of the House-passed 2014 NASA Authorization Act so that NASA and its industry contractors have the direction and stability needed to plan for continued progress.

Thank you and I yield back.

Chairman PALAZZO. Thank you, Ms. Edwards.

I now recognize the Chairman of the full Committee, Chairman Smith.

Chairman SMITH. Thank you, Mr. Chairman.

And first, I want to congratulate Bill Gerstenmaier and those at NASA and also at Lockheed Martin, and United Launch Alliance, who I see represented in the room today, on a spectacular flight test last week of the Orion crew vehicle. I know a lot of hard work went into making that test flight successful.

At a fundamental level, space exploration—the mission of NASA—is about inspiration. This inspiration fuels our desire to push the boundaries of what is possible and to reach beyond our own pale blue dot. The successful Orion launch last week is one step in a long journey.

The purpose of today's hearing is simple: We wish to send a loud and clear message that space exploration is NASA's number one priority, and last week's test flight demonstrated many firsts. We

are also here to ensure the next steps in this long journey are on track and will be just as successful.

There is bipartisan support within Congress that NASA stay on track with the Orion crew vehicle and Space Launch System, including the omnibus appropriations bill that we plan to vote on tomorrow. The Orion and SLS are essential elements for astronauts to eventually travel beyond low Earth orbit.

The omnibus appropriations bill made public last night is the latest example of Congressional support for these programs. Funded well above the President's budget request, the SLS and Orion are receiving the resources they need to ensure their success.

Fortune favors the bold. Last week's test flight was necessary to answer the naysayers and critics who claim that America's best days on the frontier of space are behind us. Last week's mission answered those critics. The Apollo program demonstrated that we could reach the moon. And Orion and SLS will ensure that America continues a sustained series of missions as a space-faring nation for decades to come. The technologies that are developed for these programs exemplify our greatest breakthroughs and demonstrate American ingenuity. We must continue to push forward.

Great nations do great things. Everyone in today's hearing wants to ensure that the first flag flying on the surface of Mars is planted by an American astronaut. And they will have arrived there onboard an Orion crew vehicle, propelled by the Space Launch System. Let's work together to make that happen.

Thank you, Mr. Chairman. I yield back.

[The prepared statement of Mr. Smith follows:]

PREPARED STATEMENT OF COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
CHAIRMAN LAMAR SMITH

First I want to congratulate Bill Gerstenmaier and those at NASA, Lockheed Martin, and United Launch Alliance on a spectacular flight test last week of the Orion crew vehicle. I know a lot of hard work went into making that test flight happen.

At a fundamental level, space exploration—the mission of NASA—is about inspiration. This inspiration fuels our desire to push the boundaries of what is possible and to reach beyond our own pale blue dot. The successful Orion launch last week is one step in a long journey.

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And they will have arrived there onboard an Orion crew vehicle, propelled by the Space Launch System.

Let's work together to make that happen.

Chairman PALAZZO. Thank you, Mr. Chairman.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

Before I introduce our witnesses, I would be remiss if I did not point out that we are missing one this morning, NASA Chief Financial Officer David Radzanowski. The CFO or his designee was invited to participate in today's hearing to answer questions regarding NASA's budget development and guidance. Unfortunately, despite numerous invitations and attempts to secure his attendance, the Administration refused to make him available.

Mr. Radzanowski holds a Senate-confirmed position at NASA and is obliged to testify before the agency's oversight committees. We are aware of the many demands on his schedule, and for that reason the Committee was willing to allow any other employee from the CFO's office to appear. Unfortunately, NASA prohibited any other CFO representative from appearing today. This is unfortunate because Mr. Gerstenmaier may not be the appropriate person at NASA to explain many of the policies and practices being advanced by the CFO's office. I look forward to Mr. Radzanowski's appearance before the Committee in the near future to answer our questions.

At this time I would like to introduce our witnesses. Our first witness today is Mr. Bill Gerstenmaier. Mr. Gerstenmaier started his work with NASA in 1977 as a researcher on aeronautics. Today, he is the Associate Administrator for the Human Exploration and Operations Mission Directorate at NASA headquarters here in Washington, D.C. Mr. Gerstenmaier has received many awards for his work on space exploration, including the distinguished Executive Presidential Rank Award, the National Space Club von Braun Award, the Space Transportation Leadership Award, and several NASA awards. He received a bachelor of science in aeronautical engineering from Purdue University and a master of science degree in mechanical engineering from the University of Toledo.

Our second witness, Ms. Cristina Chaplain, has been a U.S. Government Accountability Office employee for 23 years and currently serves as Director of Acquisition and Sourcing Management at GAO. In this capacity she is responsible for GAO assessments of military space acquisitions and NASA. She has led reviews of the Space Launch System, the International Space Station, and the James Webb Space Telescope, among others. Prior to her current position, Ms. Chaplain worked with GAO's Financial Management Information Technology Teams. She received her bachelor's in international relations from Boston University and a master's degree in journalism from Columbia University.

Thanks again to our witnesses for being here today.

As our witnesses should know, spoken testimony is limited to five minutes each, after which members of the committee will have five minutes each to ask questions.

I now recognize Mr. Gerstenmaier for five minutes to present his testimony.

TESTIMONY OF MR. BILL GERSTENMAIER, ASSOCIATE ADMINISTRATOR FOR HUMAN EXPLORATION AND OPERATIONS MISSION DIRECTORATE, NASA

Mr. GERSTENMAIER. Thank you very much for having me here. I would like to again thank you on behalf of the entire team that works in the exploration program and I would like to start off my testimony with some videos and pictures that we provided earlier. These videos and images capture the work that has been accomplished in the exploration program. And I will narrate some of the video as it is shown. So if we could start the video, please.

[Video shown.]

Mr. GERSTENMAIER. Again, the program is made up of three major components, ground systems operations down in Florida, which is preparing a launch site. These are the images that you are seeing here on the screen. Again, the purpose of this video is to show how much work is actually being accomplished, kind of behind the scenes.

You can see the launch of the EFT–1 but you don't often get a chance to see all the work that is occurring at the various field centers and the various areas that are making these things happen.

This is the Delta IV. There are some Delta IV images showing up down at the Kennedy Space Center. This is the fabrication and manufacturing of the Orion capsule that was launched on EFT test flight. Again, you get to see the technicians, the folks at the various centers working to make all this activity happen. It is not only in Florida, but it is also in Houston, where the control center team got to monitor the capsule, actually send some commands to the capsule. There was a team in Florida that also monitored the launch, so they got to participate in that activity and participate in the Orion capsule activity.

Again, you can see the capsule coming together. Some of the hardware came from the Marshall Space Flight Center that was actually manufactured. The interface between the Delta IV rocket, and the Orion capsule came from the Marshall Space Flight Center. So again, I would say this is an entire NASA team coming together to make this happen.

This is some work at the—again in Florida preparing for the capsule, and also down at MAF, at the Michoud Assembly Facility, where the SLS will be put together. I think you were there for the Vertical Assembly Weld Center that got put together that will manufacture the large external tanks. That activity is occurring. There are several sections all ready to be test-welded next January, this—in about a month; that has moved forward. Also, the test was—a substantial amount of test occurred before the test to make sure the parachute systems would work.

We are preparing for the future exploration activities to look at the Asteroid Redirect Mission, and now you can see some of the work of actually, you know, transporting the capsule out to the launch pad to be integrated eventually with the Delta IV rocket.

So again, I think the important message and takeaway from all these images is there is a tremendous amount of work going on. It

is being accomplished pretty much on schedule. There are challenges to this work; it is not easy work. The teams are very dedicated. They are working very hard to make this—things occur and I think the results of the test flight show evidence that we are making significant and substantial progress as we move forward.

[Video shown.]

The next video that is getting queued up now is the actual video from the test flight. Many of you got to either see it in person or you got to see it on television. Again, I will describe some of the activities that occurred there. And again, the point here is that this test flight didn't come about just as a happenstance. There was lots of preparation before. We did many drop tests to the parachute systems; we did many recovery activities. We have done the abort system testing down at White Sands earlier again to verify and make sure that when we took this test we were ready to go do this test.

So we didn't have all the questions answered. There was still significant risk with this test. There were still things that we could not test in any other environment other than a test flight, but this test flight confirmed that those other pieces, at least at first look, fit well and we understand the data and things look very good from an overall standpoint.

Again, a lot of folks got to witness this. This was exciting to see people show up in Florida to be there. As you talked about in some of your opening remarks, the encouragement to the science, technology, engineering, and math students is really strong. To interact with many of the students down in Florida was really exciting for me to see their enthusiasm to move forward.

This is the actual launch activity. That umbilical up at the top was unique to Orion. That was added by United Launch Alliance just specifically for this flight. That umbilical did not exist before this flight on the Delta IV launch. Again, the launch went extremely well. The vehicle gave us a great ride to space, ejected the capsule exactly where it needed to be. The upper stage did all of its activities to accelerate the vehicle to the right entry conditions. All of that worked extremely well and went really, really flawlessly.

In terms of kind of first results from the test, nothing major was really learned. One of the video processing units had to be recycled, most likely caused by a radiation event, so we got to understand the radiation environment that the capsule will fly through. The heat shield looks in very good shape. As we returned, we removed some plugs from the heat shield out in California yesterday. The capsule is about ready to get on the truck to head towards Florida for a more detailed evaluation and all the data has come off the capsule.

The images at apogee are pretty impressive when you look at the small Earth and you see the horizon. I think what was more important was that when you see it through a window where someday a crew will be, it makes that tie between a human spaceflight and the robotic spaceflight even stronger.

This is the capsule again successfully floating in the water that—we expected to see five airbags deployed. In this situation we see two. There is something that didn't work in that system. We know

the pyros fired, we know the pressure came out of the system, and we will understand what occurred.

But again, overall, just a tremendous testimony to the work that the program has put together and I look forward to your questions as we move forward in this activity. So thank you.

[The prepared statement of Mr. Gerstenmaier follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
December 10, 2014

Statement of
William H. Gerstenmaier
Associate Administrator for Human Exploration and Operations
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, thank you for this opportunity to testify before you about the progress we are making in developing NASA's next generation of human deep-space exploration vehicles: the Orion crew vehicle and the heavy-lift Space Launch System (SLS).

Orion and SLS are part of a larger exploration architecture that will enable multiple missions and destinations over the next few decades, including human missions to asteroids and Mars. Affordable manufacturing and operating costs will be important to the sustainability of SLS and Orion. NASA's near-term strategy for exploration has several interlocking components: using the unique environment of the International Space Station (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 low-Earth orbit (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; and moving outward to deep space with Orion and the SLS to take us there.

Orion and the SLS are foundational capabilities for the implementation of our integrated human and robotic exploration strategy. We will travel beyond LEO to the proving ground of cis-lunar space where we will expand and test our capabilities with a series of crewed missions with SLS and Orion, including a mission to rendezvous with a redirected asteroid in lunar orbit. The Orion and SLS systems are designed to allow us to build the skills and capabilities necessary for deep-space human exploration in the proving ground of space around the Moon. 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, allowing us to access many other destinations and ultimately pioneer Mars. We are laying the groundwork for extending human presence in the solar system. Conceived in coordination with our international partners, this strategy maintains America's role as the world's leader and foundational partner in space exploration.

Exploration Flight Test-1

Last week's successful Exploration Flight Test-1 (EFT-1) is a critical milestone on our journey to Mars and serves as the pathfinder to validate approaches to space systems development. The test demonstrated spacecraft post-landing recovery procedures and the launch vehicle adapter, which will also be used on

the uncrewed Exploration Mission-1 (EM-1) in FY 2018, and the crewed Exploration Mission-2 (EM-2) in FY 2021-2022. EFT-1 tested the Orion heat shield at about 85 percent of lunar re-entry velocity, protecting the vehicle from temperatures near 4,000 degrees Fahrenheit. Data collected during the EFT-1 flight test will reduce or eliminate 13 of the top 17 risk drivers for the first crewed flight (EM-2). The flight test also demonstrated nearly 50 percent of the design, development, test, and evaluation (DDT&E) required for EM-2, and included about 50 percent of the software needed for the first crewed mission. Not only did EFT-1 test hardware and software, but it also tested key processes which will be needed for EM-2.

Orion and SLS: Traveling Beyond LEO

The dedicated NASA-industry team, working across the nation utilizing all of the NASA Centers and our primary industry partners, Lockheed Martin, Boeing, ATK, and Aerojet-Rocketdyne, is making excellent progress toward developing the next capabilities for human and robotic space exploration missions beyond LEO. The first uncrewed launch of Orion on SLS on EM-1 is slated for FY 2018, and the first crewed launch of Orion and SLS on EM-2 for FY 2021-2022. Both Orion and SLS are being designed to enable multiple missions and destinations rather than being optimized for one particular mission or architecture. Early missions will use cis-lunar space as a proving ground to test out capabilities and operations needed for missions to Mars in a safe and sustainable manner. One early demonstration mission in cis-lunar space will be to rendezvous with and return samples from a near-Earth asteroid. SLS is evolvable to provide progressively greater lift capability, and, with Orion, will enable humankind to successfully navigate the proving ground of deep space, ultimately sending humans to a variety of destinations in the solar system, including Mars.

The Orion spacecraft will be capable of taking humans farther into space than ever before, to multiple destinations as needed, and sustaining them in this challenging environment for longer than ever before. The Orion spacecraft includes both crew and service modules, and a Launch Abort System that will provide for improved crew abort capability. Orion can fly a crew of up to four for 21 days. Orion has a focused and rigorous step-wise test campaign to validate these capabilities in the challenging deep-space environment.

In 2014, in addition to completing the first Orion capsule for flight on EFT-1, the program has begun manufacturing components for EM-1, forging elements for the primary structure, building avionics kits, and procuring parts with a long lead time. In addition, the program continues to work with the European Space Agency as it develops the Orion service module for EM-1.

In FY 2015, the program will focus on preparing for Orion's first exploration mission, EM-1. EM-1 is an uncrewed test flight to lunar orbit, and will be the first pairing of Orion with the Space Launch System. The multi-day flight will provide the program with data, which, combined with data gained from EFT-1, will validate spacecraft design and operations. The Orion program will continue fabricating the crew module primary structure, and start to assemble secondary structures and mechanisms such as propulsion systems, and environmental control and life support. It will also complete its series of parachute tests and begin testing spacecraft avionics. Finally, the program will complete key programmatic reviews, ensuring Orion's readiness to progress to the next phase of the development life-cycle, at which point, the Agency commitment to cost and schedule milestones will be established.

The SLS is a heavy-lift, exploration-class launch vehicle that will transport Orion, as well as cargo and other systems, with a range of lift capabilities from 70 metric tons to LEO, evolving to 105 metric tons and eventually up to 130 metric tons, based on future mission requirements. The evolution of the SLS lift

capability fulfills specific, important roles within the exploration architecture, with the 130-metric-ton vehicle enabling future crewed missions to the Mars vicinity.

In 2014, NASA has made significant strides in SLS development. With the conclusion of negotiations for the Stages and Interim Cryogenic Propulsion Stage contracts in June and October 2014, respectively, all major elements for the SLS Block 1 are on contract. For the SLS Block 1 configuration to be flown on EM-1, the program successfully cleared the Agency's Key Decision Point C (KDP-C) milestone in August 2014, marking the transition from program formulation into development. This milestone provides a development cost baseline for the 70-metric ton version of the SLS of $7.021 billion from February 2014 through the first launch and a launch readiness schedule based on an initial SLS flight no later than November 2018. The establishment of this Agency commitment to cost and schedule for SLS at the 70-percent confidence level represents the Agency's formal SLS launch readiness commitment, established after a thorough Agency review process, and addresses Government Accountability Office (GAO) recommendations about matching resources to program requirements. NASA continues to hold the SLS program to an internal launch readiness planning schedule that is earlier than the commitment date. NASA is in the process of updating this internal planning schedule based on a better understanding of work and budget phasing. The appropriations that SLS has received to date have enabled the program to effectively manage risks to the internal planning date.

Both the Core Stage and Booster elements completed their Critical Design Reviews (CDRs) in July and August 2014, respectively, which keeps the program on track for the program-level CDR in 2015. Preparation for next year's CDR has been supported by a wide range of important hardware testing across NASA, including the last buffet wind tunnel test at Langley Research Center, testing of the Core Stage flight computers during the spring, and acoustic model testing of SLS during launch at Marshall Space Flight Center (MSFC) throughout the year.

Production of the first pieces of test and actual EM-1 flight hardware is also underway. The structural rings and engine barrel section for the EM-1 Core Stage are being welded at the Michoud Assembly Facility (MAF), and the first complete verification tank has been completed. NASA is utilizing new, state-of-the-art welding tools to increase the efficiency of Core Stage manufacturing compared to processes used to build Space Shuttle External Tanks. The largest of these tools, the Vertical Assembly Center (VAC) tool, was activated at MAF in Louisiana in July 2014, and the first full-duration test weld on the VAC took place in September 2014. The VAC is the final of six major weld tools at MAF that will produce the SLS Core Stage structure using less than half the labor of Space Shuttle External Tank production. The VAC is scheduled to be validated for flight welds by February 2015 and to be ready to support flight hardware manufacturing. Other major SLS facility work in 2014 includes the new structural test stands at MSFC, which broke ground in August 2014, and the B-2 test stand at the Stennis Space Center (SSC), which, through the use of an innovative Center contracting vehicle, continues to run on schedule and on cost in preparation for the start of Core Stage testing in FY 2017.

Progress continues on the other elements of SLS as well, reflecting both the challenges of advanced spaceflight hardware and the resiliency and innovation of the Government and contractor teams to overcome these challenges. The first SLS flight hardware, the Multipurpose Crew Vehicle Stage Adaptor (MSA), was completed in May 2014 for flight on EFT-1. At SSC, preparations continue to install and test an RS-25 engine in the A-1 test stand, the first time one of these engines (previously known as the Space Shuttle Main Engine) has been tested in over five years. The first hotfire of the RS-25 should take place in early 2015. For the Booster element, a complex chemical and mechanical interaction between the propellant and a new case liner resulted in unexpected voids that posed a testing risk; through an intensive focused effort by the team, new production processes were introduced and a new aft segment, PSA-2, is void-free and ready to support Qualification Motor 1 (QM-1) testing in Spring 2015. SLS remains on track for its program CDR next year.

The Ground Systems Development and Operations (GSDO) team at Kennedy Space Center (KSC) continues to make significant progress on the necessary Exploration Ground Systems (EGS) infrastructure design, development, and refurbishment to support SLS and Orion. KSC also is providing valuable operations expertise to the SLS and Orion teams to address operational issues in the design in order to help reduce eventual production and operations costs. This is a key aspect of assuring long-term sustainability for deep-space human exploration. In 2014, construction of new platforms in the Vehicle Assembly Building at KSC will enable SLS and Orion stacking and preflight processing as planned. Refurbishment and upgrades to a crawler-transporter, which will accommodate up to the 130-metric-ton version of SLS – a vehicle more powerful than the Saturn V – are being performed to support the FY 2018 EM-1 flight of SLS and Orion.

Orion, SLS, and EGS teams are using the latest in systems and manufacturing technology with the intent of developing the safe, affordable, and sustainable systems this country needs to extend human presence to Mars. For example, the Orion team is using time-triggered Ethernet and is taking advantage of the standards for this technology that are used in the automotive industry. Both Orion and SLS are utilizing friction-stir welding (including on large structures, such as the SLS Core Stage), culminating in the most advanced and largest friction-stir weld machine in the world. The EGS team has stripped out the old copper cables from Pad 39B and replaced them with the latest in fiber optics. These are three simple examples of how NASA's Exploration Systems are utilizing and advancing the latest in technology.

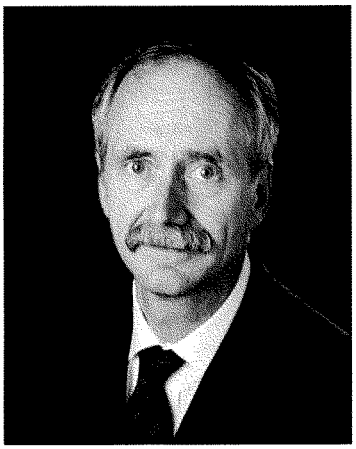
In developing the Orion, SLS, and EGS, NASA is seeking to build a sustainable national capability for the long-term human exploration of space. NASA is keeping each element of the program – SLS, ground systems, and Orion – moving at its best possible speed toward the first integrated launch, optimizing each element effort's schedule while being aware of the overall plan. This is best achieved when each element 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, the workforce can progress to EM-2. NASA is on a solid path toward an integrated mission and making progress in all three programs every day.

The evolving capabilities of these systems will provide the nation with flexibility over the long term to achieve a variety of goals. As we move further into the solar system to establish footholds in a variety of locations, having such flexibility will be important, as future missions can be built on what our astronauts and robotic probes learn in successive expeditions.

Conclusion

NASA's exploration strategy is designed to pioneer multiple destinations in the solar system. Over time, we will move beyond conducting limited-duration forays and begin to lay the groundwork to establish outposts in cis-lunar space. From there, we can expand human presence in the solar system and to the surface of Mars, and utilize *in situ* resources as we extend the reach of humanity. The key to realizing this goal will be to channel all of the factors that have enabled our space achievements to date in a way that will ensure a sustainable foundation on which future generations can continue to build. With the continued support of Congress, this long-term effort will expand the sphere of human life and activity, and draw upon the pioneering spirit and ingenuity, in the face of the seemingly impossible, that have helped make the United States the exceptional nation that it is.

Mr. Chairman, thank you for the opportunity to appear before you today to provide you with a status of our progress on Orion and SLS. NASA has a robust strategy that extends human presence into the solar system in an affordable and sustainable manner, and Orion and SLS are key initial steps in that strategy. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.



WILLIAM H. GERSTENMAIER
ASSOCIATE ADMINISTRATOR FOR
HUMAN EXPLORATION AND OPERATIONS

William H. Gerstenmaier is the associate administrator for the Human Exploration and Operations Directorate at NASA Headquarters in Washington, DC. In this position, Mr. Gerstenmaier provides strategic direction for all aspects of NASA's human exploration of space and cross-agency space support functions of space communications and space launch vehicles. He provides programmatic direction for the continued operation and utilization of the International Space Station, development of the Space Launch System and Orion spacecraft, and is providing strategic guidance and direction for the commercial crew and cargo programs that will provide logistics and crew transportation for the International Space Station.

Mr. Gerstenmaier began his NASA career in 1977 at the then Lewis Research Center in Cleveland, Ohio, performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

Beginning in 1988, Mr. Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at the Johnson Space Center. He was responsible for all aspects of OMV operations at Johnson, including development of a ground control center and training facility for OMV, operations support to vehicle development, and personnel and procedures development to support OMV operations. Subsequently he headed the Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division. He was responsible for resolving technical assembly issues and developing assembly strategies.

Mr. Gerstenmaier also served as Shuttle/Mir Program operations manager. In this role, he was the primary interface to the Russian Space Agency for operational issues, negotiating all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations in Russia, from January through September 1996 including responsibility for daily activities, as well as the health and safety of the NASA crewmember on space station Mir. He scheduled science activities, public affairs activities, monitored Mir systems, and communicated with the NASA astronaut on Mir.

In 1998, Mr. Gerstenmaier was named manager, Space Shuttle Program Integration, responsible for the overall management, integration, and operations of the Space Shuttle Program. This included development and operations of all Space Shuttle elements, including the orbiter, external tank, solid rocket boosters, and Space Shuttle main engines, as well as the facilities required to support ground processing and flight operations.

In December 2000, Mr. Gerstenmaier was named deputy manager, International Space Station Program and two years later became manager. He was responsibility for the day-to-day management, development, integration, and operation of the International Space Station. This included the design, manufacture, testing, and delivery of complex space flight hardware and software, and for its integration with the elements from the International Partners into a fully functional and operating International Space Station.

Named associate administrator for the Space Operations Directorate in 2005, Mr. Gerstenmaier directed the safe completion of the last 21 Space Shuttle missions that witnessed assembly complete of the

International Space Station. During this time, he provided programmatic direction for the integration and operation of the International Space Station, space communications, and space launch vehicles.

Gerstenmaier received a bachelor of science in aeronautical engineering from Purdue University in 1977 and a master of science degree in mechanical engineering from the University of Toledo in 1981. In 1992 and 1993, he completed course work for a doctorate in dynamics and control with emphasis in propulsion at Purdue University.

Gerstenmaier is the recipient of numerous awards, including three NASA Certificates of Commendation, two NASA Exceptional Service Medals, a Senior NASA Outstanding Leadership Medal, the Meritorious Executive Presidential Rank Award, and Distinguish Executive Presidential Rank Award. He also was honored with an Outstanding Aerospace Engineer Award from Purdue University. Additionally, he was twice honored by Aviation Week and Space Technology for outstanding achievement in the field of space. His other awards include: the AIAA International Cooperation Award; the National Space Club Astronautics Engineer Award; National Space Club Von Braun Award; the Federation of Galaxy Explorers Space Leadership Award; AIAA International Award; the AIAA Fellow; Purdue University Distinguished Alumni Award; and Honored at Purdue as an Old Master in the Old Masters Program; recipient of the Rotary National Award for Space Achievement's National Space Trophy; Space Transportation Leadership Award; the AIAA von Braun Award for Excellence in Space Program Management; and the AIAA von Karman Lectureship in Astronautics.

He is married to the former Marsha Ann Johnson. They have two children.

April 2012

Chairman PALAZZO. Thank you.

I now recognize Ms. Chaplain for five minutes to present her testimony.

TESTIMONY OF MS. CRISTINA CHAPLAIN, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, GOVERNMENT ACCOUNTABILITY OFFICE

Ms. CHAPLAIN. Chairman Palazzo, Ranking Member Edwards, Chairman Smith, and the Members of the Subcommittee, before I begin I would like to congratulate NASA on the successful test. It indeed does help demonstrate the design and technologies for the Orion and it is an important event.

As you know, we have recently reviewed preliminary cost estimates for the systems being discussed today. We performed an in-depth review of the Space Launch System and we have been covering the Orion program through our annual assessment of NASA's major programs. In conducting this work, at the time we reviewed SLS, the program was approaching a critical milestone known as KDP–C where it makes formal commitments to the Congress in the form of costs and schedule baselines. This gate represents the point at which a program begins full-scale efforts to fabricate the space system and the point at which technical and/or funding problems can have widespread effects. We found that SLS was generally doing a good job at maturing design, keeping requirements stable, and putting a high priority on quality. The program is also acting to manage costs. However, it did take longer than recommended to definitize contracts, which can create conditions for cost growth.

The program still faced inherent technical design and engineering risks, as all space programs do, but it was actively managing them in a transparent fashion. However, the program still faced a resource gap in that the agency's funding plan for SLS was insufficient to match requirements to resources for the December 2017 flight test at the high confidence level. The agency's options were largely limited to increasing program funding, delaying the schedule, or accepting a reduced confidence level for the initial flight test.

The SLS program calculated the risk associated with insufficient funding through 2017 as 90 percent likely to occur. Further, it indicated the insufficient budget could push the December 2017 launch date out six months and add some 400 million to the overall cost of development. After our report was issued when NASA established formal baselines for SLS, NASA committed to a launch readiness date of 2018 so that it could have more confidence in meeting this date. In our opinion, this was a good step as NASA still has low confidence, 30 percent, that it can meet the earlier date.

Going forward, we have short- and long-term concerns about NASA's human space exploration programs. In the short-term, the programs are entering the most risky phases of development. There are still technical hurdles to overcome, particularly with the Orion spacecraft, which is addressing challenges with the parachute system and the heat shield, among others. There is also still considerable development and testing ahead for Orion in terms of the human support systems.

Meanwhile, SLS is continuing to pursue the earlier launch date of December 2017. While NASA's urgency is understandable, the schedule for achieving the earlier date mostly with respect to the core stage is very aggressive. There is little room to address problems. Moreover, it does not appear that Orion and the ground system can achieve the earlier date.

In the long-term we have concerns about the cost estimating for human space exploration programs. NASA has only produced estimates for SLS in the ground system through the first flight test and for Orion through the second flight test. There would still be significant development ahead for SLS after the first flight and significant operations and sustainment costs for all three programs.

Moreover, there is still uncertainty about missions that will be undertaken after the second test. Without knowing the missions formally, NASA is limited in its ability to plan for the future and is at risk for making choices today that will not make sense later. Affordability for the long-haul is a real issue and one that this Subcommittee has already had hearings on, but to garner the long-term commitment from the Congress and taxpayers that is needed to make this program a success, we need transparent and realistic estimates about the resources that will be needed to achieve the Nation's goals for human space exploration.

Thank you. This concludes my statement. I am happy to answer any questions you have.

[The prepared statement of Ms. Chaplain follows:]

United States Government Accountability Office

Testimony before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

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NASA

Human Space Exploration Programs Face Challenges

Statement of Cristina T. Chaplain
Director, Acquisition and Sourcing Management

GAO Highlights

Highlights of GAO-15-248T, a testimony before the Subcommittee on Space, Committee on Science, Space, and Technology, House of Representatives

December 10, 2014

NASA

Human Space Exploration Programs Face Challenges

Why GAO Did This Study

NASA is undertaking a trio of closely related programs to continue human space exploration beyond low-Earth orbit: the SLS vehicle; the Orion capsule, which will launch atop the SLS and carry astronauts; and GSDO, the supporting ground systems. As a whole, the efforts represent NASA's largest exploration investment over the next decade, approaching $23 billion, to demonstrate initial capabilities.

In May 2014, GAO found that NASA's preliminary life-cycle cost estimates for human exploration were incomplete and recommended that NASA establish life-cycle cost and schedule baselines for each upgraded block of SLS, Orion, and GSDO; NASA partially concurred. In July 2014, GAO issued a report on SLS's progress toward its first test flight and recommended that NASA match SLS's resources to its requirements and define specific missions beyond the second test flight, among other actions. NASA concurred with these recommendations.

This testimony is based on GAO's May 2014 report (GAO-14-385), July 2014 report (GAO-14-631), and ongoing audit work related to SLS and Orion. It discusses NASA's efforts to match resources to requirements for the SLS program and developmental challenges facing the SLS and Orion programs. To conduct this work, GAO reviewed relevant design, development, cost, and schedule documents and interviewed program officials.

View GAO-15-248T. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

In 2014, GAO reported on a number of issues related to the National Aeronautics and Space Administration's (NASA) human exploration programs: the Space Launch System (SLS) vehicle, the Orion Multi-Purpose Crew Vehicle (Orion), and the Ground Systems Development and Operations (GSDO). For example, in July 2014, GAO found that NASA had not matched resources to requirements for the SLS program and was pursuing an aggressive development schedule—a situation compounded by the agency's reluctance to request funding commensurate with the program's needs. In August 2014, NASA established formal cost and schedule baselines for the SLS program at the agency-required 70 percent joint cost and schedule confidence level (JCL), which satisfied one recommendation from GAO's July 2014 report. The JCL is a calculation NASA uses to estimate the probable success of a program meeting its cost and schedule targets. To satisfy the 70 percent JCL requirement, the SLS program delayed its committed launch readiness date for its first test flight from December 2017 to November 2018. The program is still pursuing December 2017 as an internal goal, or target date, for the test flight, even though NASA calculated the JCL associated with launching SLS on this date at 30 percent. Moreover, neither the Orion nor GSDO program expects to be ready for the December 2017 launch date. With these programs likely unable to meet the December 2017 date, NASA risks exhausting limited human exploration resources to achieve an accelerated SLS program schedule when those resources may be needed to resolve challenges on other human exploration programs.

NASA's Target and Baseline Launch Readiness Dates and Associated Confidence Levels for Human Space Exploration Programs

	Target date	Confidence level for target date	Committed date	Confidence level for committed date
Space Launch System	December 2017	30%	November 2018	70%
Ground Systems Development and Operations	June 2018	30%	November 2018	80%
Orion Multi-Purpose Crew Vehicle[a]	TBD	TBD	TBD	TBD

Source: GAO analysis of NASA data. | GAO-15-248T

[a]Orion has yet to establish formal cost and schedule baseline commitments.

In addition, GAO's ongoing work has found that the Orion program is facing significant technical and funding issues. Orion just completed its first test flight, and data from this flight is required to address several risks that must be resolved before the second test flight in 2021 because they represent risks to crew safety. For example, during parachute testing, NASA discovered that when only two of the three main parachutes are deployed, they begin to swing past each other creating a "pendulum" effect. This effect could cause the capsule to increase speed and to hit the water at an angle that may damage the capsule, thereby endangering the crew. In addition, data from the test is necessary to inform NASA's design solution to address heat shield cracking issues, which NASA has been working to resolve since August 2013. The heat shield is integral to crew safety during re-entry.

Contents

Chairman Palazzo, Ranking Member Edwards, and Members of the Subcommittee:

I am pleased to be here today to discuss our work on the Space Launch System (SLS) and National Aeronautics and Space Administration's (NASA) other human exploration programs. SLS is NASA's first exploration-class launch vehicle in over 40 years. It is being developed to launch astronauts and carry cargo into space, beyond low-Earth orbit. SLS progress cannot be fully discussed without considering the progress of the Orion Multi-Purpose Crew Vehicle (Orion) and Ground Systems Development and Operations (GSDO) programs. The Orion program is developing a capsule that will launch atop the SLS and carry the astronauts, and the GSDO program is developing systems and infrastructure to support such activities as assembly, test, and launch of the SLS and Orion. As a whole, these efforts may cost nearly $23 billion to demonstrate initial capabilities, including the first planned SLS flight in 2018, the ground systems for that effort, and the first two Orion flights currently planned for fiscal years 2018 and 2021. This amount represents a significant portion of NASA's planned budget for major projects during that period and also a significant portion of government-wide launch-related research and development funding. As we have reported, any cost or schedule overrun on NASA's largest, most complex projects—including SLS, Orion, and GSDO—could have a ripple effect on the portfolio and has the potential to postpone, or even cancel altogether, projects in earlier development stages.[1] Given the expensive nature of developing space systems for human exploration, in today's constrained government budget environment, it is essential that NASA manage the acquisition of these systems as efficiently and effectively as possible.

GAO has designated NASA's management of acquisitions as a high-risk area for more than two decades in view of persistent cost growth and schedule slippage in the majority of its major projects. NASA's attempts to develop systems capable of transporting humans to space since the development of the Space Shuttle have been unsuccessful. For example, prior development programs, the most recent being the Constellation program, were canceled in the face of acquisition problems and funding-related issues. While the agency has made progress in recent years in

[1]GAO, *NASA: Assessment of Large Scale Projects*, GAO-14-338SP (Washington, D.C.: Apr. 15, 2014).

reducing risk on smaller-scale, less complex projects, demonstrating that this progress can be translated to larger, more complex projects, such as SLS and Orion, is more challenging yet exceedingly important.

We recently issued two reports on NASA's current human exploration program.[2] In addition, we regularly review SLS and Orion as part of our annual review of major NASA programs and projects.[3] My remarks today are based on these reports and our ongoing work. Specifically, I will discuss NASA's efforts to establish baselines for the SLS program based on matching cost and schedule resources to requirements, developmental challenges facing the SLS and Orion programs, and shortcomings in NASA's planning and cost estimates for the SLS, Orion, and GSDO programs. To conduct this work, we reviewed relevant design, development, cost, and schedule documents; interviewed program officials; and evaluated SLS and Orion program actions using acquisition and cost estimating best practices. More information on our scope and methodology is available in our related GAO products.

The work that supports this statement was performed in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Summary

In 2014, we found that NASA had not matched cost and schedule resources to requirements for the SLS program and was pursuing an aggressive development schedule. This situation, in turn, was compounded by the agency's reluctance to request funding in line with

[2]GAO, *Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability*, GAO-14-631 (Washington, D.C.; July 23, 2014); and *NASA: Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs*, GAO-14-385 (Washington, D.C.: May 8, 2014) .

[3]The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009 required GAO to prepare project status reports on selected large-scale NASA programs, projects, or activities. 155 Cong. Rec. H1653, 1824-25 (daily ed., Feb. 23, 2009).

the program's needs. In addition, we found that the agency's preliminary life-cycle cost estimates for human exploration were incomplete. Based on these findings, in July 2014, we recommended, among other things, that NASA develop baselines for SLS that match cost and schedule resources to requirements and result in a level of risk in line with its policies as well as develop improved life-cycle cost estimates. NASA concurred with our findings and recommendations. In August 2014, NASA completed the review of the SLS program that sets formal cost and schedule baselines and, in doing so, delayed the first test flight to relieve schedule pressure and allow additional time to address design challenges. However, some of the concerns we raised about the cost estimates, mission requirements, and long-term affordability remain. In addition, our ongoing work has found that the three human exploration programs are pursuing inconsistent and unrealistic schedule goals and that the Orion program is facing significant technical and funding issues that may affect NASA's overall schedule for its human exploration programs.

Background

The National Aeronautics and Space Administration Authorization Act of 2010 directed NASA to, among another things, develop a Space Launch System as a follow-on to the Space Shuttle and as a key component in expanding human presence beyond low-Earth orbit. To that end, NASA plans to incrementally develop three progressively more capable SLS launch vehicles—70-, 105-, and 130-metric ton (mt) variants. When complete, the 130-mt vehicle is expected to have more launch capability than the Saturn V vehicle, which was used for Apollo missions, and be significantly more capable than any recent or current launch vehicle. The act also directed NASA to prioritize the core elements of SLS with the goal of operational capability not later than December 2016.[4] NASA negotiated an extension of that date, to December 2017, based on the agency's initial assessment of the tasks associated with developing the new launch vehicle, and has subsequently committed to a launch readiness date of November 2018.

In 2011, NASA formally established the SLS program. To fulfill the direction of the 2010 act, the agency plans to develop the three SLS launch vehicle capabilities, complemented by Orion, to transport humans

[4]Pub. L. No. 111-267, §§ 302(c)(2), 303(a)(2) (codified at 42 U.S.C. §§ 18322, 18323).

and cargo into space. The first version of the SLS that NASA is developing is a 70-mt launch vehicle known as Block I. NASA has committed to conduct two test flights of the Block I vehicle—the first in 2018 and the second in 2021. The vehicle is scheduled to fly an uncrewed Orion some 70,000 kilometers beyond the moon during the first test flight, known as Exploration Mission-1 (EM-1), and to fly a second mission known as Exploration Mission-2 (EM-2) beyond the moon to further test performance with a crewed Orion vehicle. After 2021, NASA intends to build 105- and 130-mt launch vehicles, known respectively as Block IA/B and Block II, which it expects to use as the backbone of manned spaceflight for decades.[5] NASA anticipates using the Block IA/B vehicles for destinations such as near-Earth asteroids and LaGrange points and the Block II vehicles for eventual Mars missions.[6]

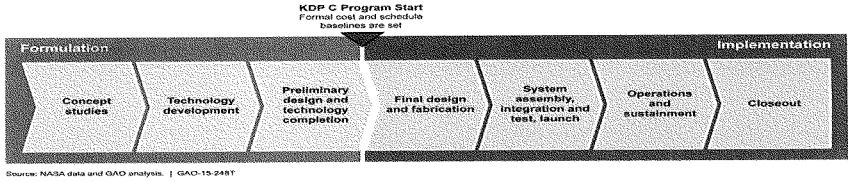
Space launch vehicle development efforts are high risk from technical, programmatic, and oversight perspectives. The technical risk is inherent for a variety of reasons including the environment in which they must operate, complexity of technologies and designs, and limited room for error in the fabrication and integration process. Managing the development process is complex for reasons that go well beyond technology and design. For instance, at the strategic level, because launch vehicle programs can span many years and be very costly, programs often face difficulties securing and sustaining funding commitments and support. At the program level, if the lines of communication between engineers, managers, and senior leaders are not clear, risks that pose significant threats could go unrecognized and unmitigated. If there are pressures to deliver a capability within a short period of time, programs may be incentivized to overlap development and production activities or delete tests, which could result in late discovery of significant technical problems that require more money and ultimately much more time to address. For these reasons, it is imperative that launch vehicle development efforts adopt disciplined practices and lessons learned from past programs.

[5]NASA plans for SLS Block IA to utilize advanced boosters, Block IB an exploration upper stage, and Block II the advanced boosters and exploration upper stage. The agency has not yet determined whether it will first develop the Block IA or Block IB variant.

[6]In a two-body system, such as Earth and the sun, there are points nearby where a third object can be positioned and remain in place relative to the other two objects. These are known as Lagrange points.

Best practices for acquisition programs indicate that establishing baselines that match cost and schedule resources to requirements and rationally balancing cost, schedule, and performance is a key step in establishing a successful acquisition program.[7] Our work has also shown that validating this match before committing resources to development helps to mitigate the risks inherent in NASA's programs.[8] We have reported that within NASA's acquisition life cycle, resources should be matched to requirements at key decision point (KDP)-C, the review that commits the program to formal cost and schedule baselines and marks the transition from the formulation phase into the implementation phase, as seen in figure 1 below.[9] The SLS program completed its KDP-C review in August 2014, GSDO completed its KDP-C review in September 2014, and the KDP-C review for Orion is currently scheduled for May 2015.

Figure 1: Key Decision Point (KDP)-C in NASA Development Life Cycle



Source: NASA data and GAO analysis. | GAO-15-248T

[7]GAO-04-386SP and GAO-01-288.

[8]GAO, *Defense Acquisitions: Key Decisions to Be Made on Future Combat System*, GAO-07-376 (Washington, D.C.: Mar. 15, 2007); *Defense Acquisitions: Improved Business Case Key for Future Combat System's Success*, GAO-06-564T (Washington, D.C.: Apr. 4, 2006); *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes*, GAO-06-218 (Washington, D.C.: Dec. 21, 2005); and *NASA's Space Vision: Business Case for Prometheus 1 Needed to Ensure Requirements Match Available Resources*, GAO-05-242 (Washington, D.C.: Feb. 28, 2005).

[9]GAO, GAO-06-218 and *NASA: Agency Has Taken Steps Toward Making Sound Investment Decisions for Ares I but Still Faces Challenging Knowledge Gaps*, GAO-08-51 (Washington, D.C.: Oct. 31, 2007).

NASA Delayed SLS Launch Date to Better Match Resources to Requirements

NASA has taken positive steps to address specific concerns we raised in July 2014 regarding aggressive schedules and insufficient funding by establishing the SLS program's committed launch readiness date as November 2018—almost a year later than originally planned. Specifically, we reported in July 2014 that NASA had yet to establish baselines that matched the SLS program's cost and schedule resources with the requirement to develop the SLS and launch the first flight test in December 2017 at the required confidence level of 70 percent.[10] NASA policy generally requires a 70 percent joint confidence level—a calculation NASA uses to estimate the probable success of a program meeting its cost and schedule targets—for a program to proceed with final design and fabrication. At the time of our July 2014 report, NASA had delayed its review to formally commit the agency to cost and schedule baselines for SLS from October 2013, as the agency considered future funding plans for the program. At that time, the agency's funding plan for SLS was insufficient to match requirements to resources for the December 2017 flight test at the 70 percent joint confidence level and the agency's options for matching resources to requirements were largely limited to increasing program funding, delaying the schedule, or accepting a reduced confidence level for the initial flight test. We have previously reported that it is important for NASA to budget projects to appropriate confidence levels, as past studies have linked cost growth to insufficient reserves, poorly phased funding profiles, and more generally, optimistic estimating practices.

We found that NASA's proposed funding levels had affected the SLS program's ability to match requirements to resources since its inception. NASA has requested relatively consistent amounts of funding of about $1.4 billion each year since 2012. According to agency officials, the program has taken steps to operate within that flat funding profile, including streamlining program office operations and asking each contractor to identify efficiencies in its production processes. Even so,

[10]NASA's procedural requirements require Mission Directorates to plan and budget programs and projects with an estimated life-cycle cost greater than $250 million based on a 70 percent Joint Cost and Schedule Confidence Level (JCL), or at a different level as approved by the Decision Authority, which for SLS is the NASA Associate Administrator. Any JCL approved by the Decision Authority at less than 70 percent must be justified and documented. The JCL is a quantitative probability analysis that requires the project to combine its cost, schedule, and risks into a complete quantitative picture to help assess whether the project will be successfully completed within cost and on schedule. NPR 7120.5E, §§2.4.4, 2.4.4.1, 2.4.3.2 (Aug. 14, 2012).

according to the program's own analysis, going into the agency review to formally set baselines, SLS's top risk was that the current planned budget through 2017 would be insufficient to allow the SLS as designed to meet the EM-1 flight date. The SLS program office calculated the risk associated with insufficient funding through 2017 as 90 percent likely to occur; furthermore, it indicated the insufficient budget could push the December 2017 launch date out 6 months and add some $400 million to the overall cost of SLS development. The cost risk was considerably greater than $400 million in the past, but according to program officials they were able to reduce the affect due to receiving more funding than requested in fiscal years 2013 and 2014. Similarly, our ongoing work on human exploration programs has found that the Orion program is currently tracking a funding risk that the program could require an additional $560 to $840 million to meet the December 2017 EM-1 flight date. However, the agency has yet to complete the review that sets formal cost or schedule baselines for the Orion program. At this time, we have not conducted enough in-depth work on the GSDO program to comment on any specific risks the program is tracking.

In our July 2014 report we recommended, among other things, that NASA develop baselines for SLS based on matching cost and schedule resources to requirements that would result in a level of risk commensurate with its policies. NASA concurred with our findings and recommendations. In August 2014, NASA established formal cost and schedule baselines for the SLS program at the 70 percent joint confidence level for a committed launch readiness date of November 2018. Nevertheless, the program plans to continue to pursue an initial capability of SLS by December 2017 as an internal goal and has calculated a joint cost and schedule confidence level of 30 percent associated with that date.

As illustrated by table 1 below, the SLS and GSDO programs are pursuing ambitious and varying target dates for the EM-1 test flight. In addition, the Orion program is currently tracking and reporting to December 2017. The agency acknowledges differences in the target dates the programs are pursuing and has indicated that it will develop an integrated target launch date after all three systems hold their individual critical design reviews.

Table 1: NASA's Target and Baseline Launch Readiness Dates and Associated Confidence Levels for Human Spaceflight Programs

	Target date	Confidence level for target date	Committed date	Confidence level for committed date
Space Launch System	December 2017	30%	November 2018	70%
Ground Systems Development and Operations	June 2018	30%	November 2018	80%
Orion Multi-Purpose Crew Vehicle[a]	TBD	TBD	TBD	TBD

Source: GAO analysis of NASA data. | GAO-15-248T

[a]Orion has not yet established formal cost and schedule baseline commitments.

The SLS program has assigned a low confidence level—30 percent—associated with meeting the program's internal target date of December 2017. Even if SLS does meet that goal, however, it is unlikely that both Orion and GSDO will achieve launch readiness by that point. For example, the GSDO program only has a 30 percent confidence level associated with a later June 2018 date. Additionally, the Orion program is currently behind its planned schedule and is facing significant technical risks and officials indicated that the program will not achieve launch readiness by December 2017. The Orion program has submitted a schedule to NASA headquarters that indicates the program is now developing plans for a September 2018 EM-1 launch, though that date is preliminary until the program establishes official cost and schedule baselines now planned for May 2015. With the Orion and GSDO programs likely unable to meet the December 2017 date, NASA risks exhausting limited human exploration resources to achieve an aggressive SLS program schedule when those resources may be needed to resolve other issues within the human exploration effort. In other work, we have reported that in pursuing internal schedule goals, some programs have exhausted cost reserves, which has resulted in the need for additional funding to support the agency baseline commitment date once the target date is not achieved.[11]

NASA's urgency to complete development and demonstrate a human launch capability as soon as possible is understandable. The United States has lacked the ability to launch humans into space since the last flight of the Space Shuttle in July 2011 and the initial goal from Congress was that NASA demonstrate a new human launch capability by 2016. Also, the SLS and GSDO programs have already slipped their committed

[11]GAO-14-338SP

launch readiness dates to November 2018, and Orion appears likely to follow suit. While these delays were appropriate actions on the agency's part to reduce risk, their compounding effect could have impacts on the first crewed flight—EM-2—currently scheduled for 2021.

NASA's SLS and Orion Programs Are Making Progress, but the Orion Program Is Facing Technical Challenges

We reported in July 2014 that NASA's metrics indicated the SLS program was on track to meet many of its design goals for demonstrating the initial capability of SLS. However, we found that the development of the core stage—SLS's fuel tank and structural backbone—represents the critical path of activities that must be completed to maintain the program's schedule as a whole. The core stage development had an aggressive schedule in order to meet the planned December 2017 first test flight. For example, the core stage had threats of nearly 5 months to its schedule due to difficulty acquiring liquid oxygen fuel lines capable of meeting SLS operational requirements. The aggressiveness of, and therefore the risk associated with the core stage schedule was reduced when the agency delayed its commitment for initial capability of SLS until November 2018. With SLS continuing to pursue a target date of December 2017, however, the aggressive core stage schedule remains a risk. Further, we reported that the program faced challenges integrating heritage hardware, which was designed for less stressful operational environments, into the SLS design. We found that these issues were not significant schedule drivers for the program as each had, and continues to have, significant amounts of schedule reserve to both the target and agency baseline commitment dates for launch readiness.

The Orion program just completed its first experimental test flight—EFT-1. This flight tested Orion systems critical to crew safety, such as heat shield performance, separation events, avionics and software performance, attitude control and guidance, parachute deployment, and recovery operations. According to NASA, the data gathered during the flight will influence design decisions and validate existing computer models. Data from this flight are required to address several significant risks that the Orion program is currently tracking that must be addressed before humans can be flown on Orion. Specifically, our ongoing work indicates that the Orion program passed its preliminary design review—a review that evaluates the adequacy of cost schedule and technical baselines and whether the program is ready to move forward—in August 2014 by meeting the minimum standards for all 10 success criteria. For 7 of the 10 success criteria, however, review officials highlighted known issues that could compromise Orion's success. Specifically, the review officials noted concerns about several unresolved design risks, including technical

challenges with the parachute system and heat shield. For example, during parachute testing, NASA discovered that when only two of the three main parachutes are deployed, they begin to swing past each other creating a "pendulum" effect. This effect could cause the capsule to increase speed and to hit the water at an angle that may damage the capsule thereby endangering the crew. Further, NASA faces choices between differing design solutions to resolve cracking issues discovered during manufacturing of the heat shield that protects the capsule during re-entry. Program officials plan to make a decision prior to the program's critical design review, based on additional testing and analysis, about how to resolve these risks with a goal of limiting design changes to the capsule's structure. Both the parachute and heat shield challenges must be resolved before EM-2 because each represents a significant risk to crew safety. Significant cost and schedule impacts could result if a redesign is required to address any of these unresolved design risks.

NASA's Human Exploration Programs' Long-Term Missions and Affordability Are Uncertain

NASA has yet to address our concerns regarding mission planning or life-cycle cost estimates. NASA has not yet defined specific mission requirements for any variant of the SLS. The two currently scheduled flights are developmental test flights designed to demonstrate and test the capabilities of the 70-mt launch vehicle and the capability of the core stage in particular. Office of Management and Budget guidance indicates that agencies should develop long-range objectives, supported by detailed budgets and plans that identify the agency's performance gaps and the resources needed to close them.[12] With mission requirements unspecified, NASA has not yet finalized plans for the next step in evolving the SLS and risks investing limited available resources in systems and designs that are not yet needed and missing opportunities to make early investments in developing systems that may be needed in the future. According to agency officials, beyond the two scheduled test flights, future mission destinations remain uncertain. In the absence of specific mission requirements, officials indicated the SLS program is developing current and future variants based on top-level requirements derived from NASA's Design Reference Architectures for conducting missions in line with the agency's strategic plan. NASA's 2014 strategic plan, for example, identifies sending humans to Mars as one of the agency's long-term

[12]Office of Management and Budget, *OMB Circular A-11, Supplement for Part 7: Capital Programming Guide* (Washington, D.C.: July 2013).

goals; in turn, the agency's Mars Design Reference Architecture indicates that multiple missions using a vehicle with a lift capability of about 130-mt will be necessary to support that goal. We recommended based on these findings that NASA define a range of possible missions beyond the second test flight and introduce increased competition in the acquisition of hardware needed for future variants to reduce long-term costs.[13] The agency concurred with our recommendations, but has not yet taken specific actions to address our concerns

The long-term affordability of the human exploration programs are also uncertain, as we found in May 2014, because NASA's cost estimates for the programs do not provide any information about the longer-term, life-cycle costs of developing, manufacturing, and operating the launch vehicles.[14] For example, as illustrated in table 2 below, NASA's baseline estimate for SLS does not cover program costs after EM-1 or costs to design, develop, build, and produce the 105- or 130-mt variants. Though the subsequent variants will evolve from the first variant, they each represent substantial, challenging development efforts and will require billions of more dollars to complete. For example, the 105-mt vehicle will require development of a new upper stage and upper stage engine or the development of advanced boosters, either of which will be significant efforts for the program.

[13]GAO-14-631

[14]The Orion program has not yet established formal cost and schedule baseline commitments.

Table 2: Costs Included in the Scope of Baseline or Preliminary Cost Estimate

	Agency baseline commitment (costs)	System development (including establishing manufacturing and test facilities)	Exploration Mission 1 (including 3 months of post-flight data analysis)	Exploration Mission 2 (including 3 months of post-flight data analysis)	Development of future vehicles	Future manufacturing, operations, and support costs
Space Launch System (SLS)	$9.7 billion	Yes	Yes	No	No	No
Ground Systems Development and Operations	$2.8 billion	Yes	Yes	No	No	No
Orion Multi-Purpose Crew Vehicle	TBD Preliminary range estimate of $8.5 billion to $10.3 billion	Yes	Yes	Yes	No	No

Source: GAO analysis of NASA data. | GAO-15-248T

Based on the tenets of widely accepted best practices for cost estimation, as well as NASA's own requirements and guidance regarding life-cycle costs, in May 2014 we recommended that NASA establish a separate cost and schedule baseline for the SLS program for work required to support EM-2.[15] Additionally, we recommended that NASA establish life-cycle cost and schedule baselines, or at least provide minimum and maximum ranges, for each upgraded block of SLS, Orion, and associated ground support. NASA partially concurred with our recommendations, stating that their current approach for establishing separate baselines and estimates for the SLS, Orion, and GSDO programs met the intent of our recommendations and agreed to report cost estimates for the future SLS capabilities annually via the agency budget submission until key requirements are defined and baselines can be established. We disagreed and stated that establishing cost and schedule baselines at the program level was unlikely to provide the detail necessary to monitor the progress of future blocks of SLS, each of which will in essence constitute a separate development project within the SLS program, and that budget requests neither offer all the same information as life-cycle cost estimates nor are necessarily linked to an established baseline that indicates how

[15]GAO-14-385.

much NASA expects to invest to develop, operate, and sustain a capability over the long term.

In conclusion, by delaying the committed launch readiness date and establishing funding levels at a 70 percent confidence level, NASA has improved the SLS program's overall risk posture. We are concerned, however, that the program continues to pursue the overly ambitious goal of a December 2017 launch date. It is important to note at this point that the SLS, Orion, and GSDO programs are intrinsically linked. None of the three can satisfy NASA's human exploration goals on its own, and cost overruns or delays in any single program, such as the significant funding and technical issues now facing the Orion program, will directly affect the others. Without a realistic integrated flight date guiding the efforts of all three programs, and meaningful reporting of progress, insight into the progress of NASA's human exploration portfolio and the agency's ability to make informed management decisions regarding the allocation of resources across the three programs is limited. Further, NASA's plans for human exploration beyond SLS's second flight in 2021 remain unclear. Until long-term missions are finalized, the agency will lack clear definition in its plans to move forward. This will in turn affect the agency's acquisition planning and any efforts to incorporate increased competition. Furthermore, without complete life-cycle cost estimates for all three programs, and their planned variants, the agency's ability to make important decisions about the affordability of the program in the context of the agency's overall budget and competing priorities is limited.

Chairman Palazzo, Ranking Member Edwards, and Members of the Subcommittee, this completes my prepared statement. I would be pleased to respond to any questions that you may have at this time.

GAO Contact and Staff Acknowledgments

GAO Contact	If you or your staff have any questions about this testimony, please contact Cristina T. Chaplain, Director, Acquisition and Sourcing Management at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this statement.
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NASA

Cristina T. Chaplain

Ms. Chaplain currently serves as a Director, Acquisition and Sourcing Management, at the U.S. Government Accountability Office. She has responsibility for GAO assessments of military space acquisitions, NASA, and the Missile Defense Agency. Among other topics, she has led reviews on the international space station, the Space Launch System, acquisition progress for major NASA projects, the James Webb telescope, commercial cargo and crew, NASA contract management, contract terminations and the evolved expendable launch vehicle. In addition to her work on space and missile system development, Ms. Chaplain has led a variety of DOD-wide contracting-related and best practice evaluations for the GAO. Before her current position, Ms. Chaplain worked with GAO's financial management and information technology teams. Ms. Chaplain has been with the GAO for 23 years. She received a bachelor's degree, magna cum laude, in International Relations from Boston University and a Masters Degree in Journalism from Columbia University.

Chairman PALAZZO. I thank the witnesses for their testimony and reminding the Members that Committee rules limit questioning to five minutes, the Chair will at this point open the round of questions.

The Chair recognizes himself for five minutes.

Mr. Gerstenmaier, the written testimony provided by GAO and Ms. Chaplain states that GAO found that NASA's proposed funding levels had affected the SLS program's ability to match requirements to resources since its inception. GAO also reported that the SLS program is tracking a $400 million shortfall in funding as its most significant risk. NASA officials have testified multiple times before this committee that the President's budget request was sufficient to keep the SLS and Orion on budget and on schedule.

I realize this is a tough question for you to answer because you have to defend the President's budget request, but Congress is ultimately responsible for funding this program and ensuring taxpayer dollars are efficiently spent. But given that NASA has now delayed the initial launch of SLS due to funding pressure, what funding level would keep the 2017 date on track?

Mr. GERSTENMAIER. Again, I would say that the recent review we did, the programmatic review that Cristina talked about, we committed to a joint confidence level of 70 percent on a November of 2018 launch, and that is consistent with the budgets that we have submitted to Congress through the Administration. So that is a consistent plan.

We have been trying to work to an earlier schedule and that is based on the risk mitigation for the extra funding we have received from Congress, so we have kind of kept both plans in place so we take the funds that we are—have been given by Congress and use those in an effective manner in trying to hold the earliest launch date that we can potentially hold moving forward. We need to be aware of the concerns that GAO brought up and make sure that we don't overly pressure that schedule and try to work too fast and do things that end up in—wasting the funds or wasting of resources.

So our current planning we were holding December of 2017. I would say we have now moved off of that date. We will be somewhere in the 2018 time frame now with our current planning and that is just based on the reality of problems that have come along in the program and some uncertainty in funding. So we will move a little bit into—probably with our planning dates into I would say maybe June kind of time frame of 2018, and that is still ahead of our commitment consistent with the budget level in 20—of November of 2018 that is consistent with the President's budget request.

So I would say we are managing it in this kind of interesting environment where we get different funding levels. The teams are making tremendous technical progress. SLS is entering into probably one of the more critical phases where they actually go in to manufacture of hardware and we will see how that goes over the next couple of months here in January, February, and March. But again, I think we have been able to balance the budget needs that we have overall to try to deliver a program as effectively as we can for the Nation and for the Congress.

Chairman PALAZZO. Ms. Chaplain, GAO has noted in the past that the SLS and Orion programs do not have integrated schedules for development and launch. How is NASA currently managing the schedules for these two programs so that they will launch not just on time but at the same time?

Ms. CHAPLAIN. At present there are still different dates in the final launches and Orion is a TBD you could say right now because they are about to go into the process where they look at their resources, their schedules, and they set a launch date. At this time it does not look like they could make 2017 and 2018 is even a challenge in and of itself. So we look forward to seeing what that date really is and then how do the dates of the other programs align. It is important to plan to a single date as early as you can so you can align tasks appropriately to meet that date. You don't unnecessarily expend resources trying to meet dates that other people or other systems can't meet. So we will have to see what happens after this next KDP–C cycle for Orion and see how the dates shake out.

Chairman PALAZZO. I now recognize Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman. And again thank you for the testimony.

Mr. Gerstenmaier, We have all recognized that resources for Orion/SLS programs have been constrained and I think we can acknowledge as well that flat budgets are not optimum for carrying out major development programs like Orion and SLS, but I am impressed with how much progress has been made on these programs given these constraints. And as you know, the Committee has had the goal of having SLS and Orion operational at the earliest possible date. You indicated that—you have also indicated the slippage based on the budget constraints.

We are going to be authorizing NASA again—well, reauthorizing next year, so I want to understand what the additional progress could be made on the SLS and Orion programs if we were to authorize additional resources and whether or not the impact on the exploration program—whether there would be any impact if there were inflationary increases, as recommended by the National Academies' report of a five percent increase, say.

And would a sustained increase of this kind of magnitude be sufficient to accelerate the progress that you describe for projected launch dates for EM–1 and 2, or would it only be enough to reduce the risk of those dates being pushed even further to the right? I guess I am just trying to figure out what would get us back to a 2017 target. You seem to have indicated that it is not just resources but even Ms. Chaplain acknowledges that the 2018 dates are at risk as well because of the uncertainty around budget constraints.

Mr. GERSTENMAIER. Okay. And I think one thing that could be very helpful to us is to get some stability in understanding what the budget is. It is difficult for the programs to plan for potentially what could be a Congressional budget versus the Administration budget. To get some agreement between the Administration and Congress so we know what to plan for in terms of budget would be helpful to us overall, as well as the absolute level.

In terms of the technical work, again, I think we have really probably moved off of December 2017 when I look at the work so I don't think funding will pull us back to that date. I also respectfully have a difference of opinion with GAO. I think it is perfectly fine to complete one of these programs ahead of the others. They don't need to all sync up at exactly the same time. If you think about when you take a vehicle to launch down at the Kennedy Space Center, typically the rocket is ready to go well before the payload is; then the payload comes later. And I think it is actually to our advantage to have some difference in schedules between those. So I think SLS coming first, having the ground systems ready in Florida, and then Orion showing up at the third-place is perfectly fine. It is not going to waste resources on—if EM–1 is complete, if SLS is ready to go fly, we will beginning to work on the next core for the second flight of SLS so that workforce will transition immediately from the EM–1 activity to EM–2, so there is not a need to have all these programs synced up. So I think we needed to be careful and think about that. If we put that extra constraint in where I have to sync all these programs up and match all these schedules, I think that puts another burden and that can make an inefficiency.

So again, I think again from a technical standpoint we are probably in 2018 somewhere with SLS and the first part with the funding levels we have seen. We have made the commitment in the KDP–C activity to November of 2018, ground ops is in June 2018 with our commitment, and we are in the process of doing the Orion evaluation now to pick a date for Orion.

Ms. EDWARDS. Thank you. And, some have criticized the SLS and Orion program as kind of a rocket and spacecraft without a mission. We have set a long-term goal of a House-passed NASA Authorization Act of 2014 of sending humans to Mars and we need a roadmap from NASA of the best way to get there, and it seems to me that now is the time for that. What role do you see SLS and Orion have in reaching that goal and when will we have a strategy for getting there?

Mr. GERSTENMAIER. I think both SLS and Orion play a key role in that strategy you described. SLS is the heavy lift launch vehicle. It is the—we need that kind of ability to launch that much mass to go do a Mars class mission. Orion will have to return at velocity similar to what you saw in the flight test, actually higher from at least lunar return velocities, which most capsules have not. So those two components are really critical to our Mars strategy.

There are others that need to be added, a habitation module, and we are actually using the space station today to buy down risk on the human performance and how well systems work. So I think it was talked about, the life support system of Orion; it is actually being tested on space station today so we are actually getting a chance to see how the Amine Swingbed operations work onboard space stations. So we can use all these pieces to continue to advance us towards Mars but I don't think there is any question that these two pieces fit squarely in any plan for Mars activity.

Ms. EDWARDS. So we should just set aside that criticism, right?

Mr. GERSTENMAIER. Yes.

Ms. EDWARDS. Thank you.

Chairman PALAZZO. I now recognize Mr. Bridenstine from Oklahoma.

Mr. BRIDENSTINE. Thank you, Mr. Chairman, and thank you for your leadership on this very important committee. Thank you to our witnesses for providing testimony today. It is an honor to be with you and certainly to hear your testimony.

Gene Cernan was the last man to walk on the moon. He took off the moon December 17th, 1972, three years before I was born. He was a naval aviator, a naval officer. He was an aeronautical engineer, an electrical engineer, a fighter pilot, a test pilot, and an astronaut. He and so many others that accomplished that pinnacle feat never went back to the moon, and I think that is a tragedy and certainly something that this committee needs to be aware of. It hasn't happened in my lifetime. My parents remember exactly where they were the first time it happened with Neil Armstrong and Buzz Aldrin.

This committee, before I got here, and certainly Congress as a whole, commissioned a report that cost $3.2 million. They spent 18 months. It was a group of individuals led by Governor Mitch Daniels and they came up with a report that is called "Pathways to Exploration." And one thing that I thought was telling in this report is they talk about a horizon goal. What is the horizon goal for NASA? And their horizon goal, according to them, NASA's horizon goal ought to be Mars. And of course there are steppingstones, pathways to get to land a human on Mars and to bring humans home from Mars. And interestingly, he says, "The current program to develop launch vehicles for spacecraft for flight beyond LEO cannot provide the flight frequency required to maintain competence and safety." I am going to read that again: "cannot provide the flight frequency required to maintain competence and safety."

I took a trip down to Houston, I visited the Johnson Space Center, I talked to them about SLS. Of course everybody was looking forward to the first launch. It was going to be December of 2017; now we are hearing 2018. But what was interesting is what the follow-on launch after that was going to be. It was going to be a human launch that was going to be in 2021, and my initial reaction as a Navy pilot—remember, Gene Cernan and these guys inspired a guy like me. Even though I hadn't been born yet, I read about these folks. They became heroes of mine and inspired a guy like me to join the United States Navy to become a pilot. It was aspirational. This is the kind of benefit that this has to the United States of America.

And they said 2017 would be the first launch, 2018 could be what it slips to, and then ultimately we are going to launch man—a manned Orion mission in 2021. Now, it would appear that would have to slip as well. But my initial reaction was we are going to go four years without a launch and then we are going to put men in the vehicle and women in the vehicle and send them into space.

My question for you, Mr. Gerstenmaier—sorry, my name is Bridenstine so I live with the same problem—my question for you is do you agree with this assessment that the current program to develop launch vehicles and spacecraft for flight beyond LEO cannot provide the flight frequency required to maintain competence and safety? Do you agree with that?

Mr. GERSTENMAIER. We are looking very closely at those concerns. I am not—first of all, I would say that the fact that EM–1 has moved into '18 doesn't mean that EM–2 has moved also. We will continue to look at ways of holding that. We are trying to look at building a system that we can fly repeatedly and fly for reasonable cost and we still owe answers to GAO on those activities.

Our goal is, once we fly a crew in '21, we would like to fly roughly a flight rate of about once per year, and we are off analyzing that once-per-year flight rate to see if we can achieve that within our budgets and we think if that—does that provide enough frequency of flight that it answers those safety concerns, and we are off analyzing both of those activities right now. So our intent would be to take this period between the first un-crewed flight of Orion to deep space on the SLS and then the second flight with crew and then follow that with roughly one flight per year after that.

Mr. BRIDENSTINE. Do you agree that the horizon goal of the United States ought to be landing humans on Mars?

Mr. GERSTENMAIER. Yes. And the way we see it at NASA is we see three phases. There is what we call the Earth-reliant region, which is a station which we use today to test out systems like I described. We also understand how the human body performs in microgravity. We will do a one-year expedition next year with crew members to see that the human can tolerate the kind of duration in microgravity to go to Mars.

Then we see the next region of space, the proving-ground region of space that is around the moon. That is where we are now days away from return, we can test the systems, look at orbital mechanics, we can see deep space radiation, we can do rendezvous without communications to the ground, we can verify and validate the concepts that will be needed to take us eventually to Mars.

Then the last phase is Earth-independent or the Mars-ready phase, and that is this horizon goal you described. But we think we have at a macro level an orderly process beginning in low Earth orbit going to cislunar space and then eventually moving on to the Mars class mission.

Mr. BRIDENSTINE. And, Mr. Chairman, if you will entertain me for just a few seconds here, I would like to ask one last question, which is the report here that we commissioned, $3.2 million, 18 months, a lot of experts, they indicate that given our flat funding for the human spaceflight directorate that we are not going to accomplish that mission of getting to the Mars. Given where we are with flat funding, do you agree with that assessment?

Mr. GERSTENMAIER. We are going to need some funding level above flat funding.

Mr. BRIDENSTINE. Would you be willing to come back and provide us what kind of funding level is necessary in order to accomplish the objective?

Mr. GERSTENMAIER. We could—we can provide that and we can take that for the record and describe that to you. Again, it is going to be a function of the time frame and the time frame is driven not only by the funding requirement but it is also by have we gained enough experience in cislunar space, have we bought down enough technical risk, have we—are we ready to take that next step? So there are several components. It is more than just a budget discus-

sion; there is also the technical speed and the assurance of what we can learn during this period moving forward.

Mr. BRIDENSTINE. And that obviously would require more flight frequency than what we are currently getting?

Mr. GERSTENMAIER. Potentially, yes.

Chairman PALAZZO. The gentleman's time is expired. We may have a second round of questions——

Mr. BRIDENSTINE. Thank you, sir.

Chairman PALAZZO. —if the Member would like to—at this time I recognize Ms. Bonamici for five minutes or six or seven.

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

And thank you so much to the witnesses for being here today. It is really a pretty exciting time for the U.S. space program. I know that my colleagues and I all watched the Orion test launch with great interest.

And I want to also join my colleagues to congratulate NASA, Lockheed Martin, United Launch Alliance, and everyone who participated in this test flight. I heard from some of my constituents who really applauded this, saw this as a big step in our leadership in space, and that comes as welcome news as we are trying to inspire and spark interest in the next generation of young scientists.

In our previous Space Subcommittee hearings, we have talked about the challenge of communicating the importance of NASA's work and mission to our constituency who support the mission with their hard-earned tax dollars. And as Mr. Bridenstine was saying, we have a lot of people who are inspired looking back to the Apollo missions and the Moon landing, but that public outreach is really important. And I noticed that you gave us a publication here that has—"It Takes a Country" that talks about all the places across the country where the parts and pieces were supplied and purchased and that shows a broad range of States and businesses I am sure that participated in that. That kind of thing is important to convince our constituents of the importance economically as well.

I want to make sure Mr. Bridenstine saw the Congressmen On Board picture in this publication, too. We have some of our Congressmen pictured in there.

Also, I know that the budget challenges and the lack of certainty is very, very important and, Mr. Gerstenmaier, you talked about that need for stability and it is certainly something that we talk about here on a regular basis, that that certainty in decision-making is—and long-term thinking—is so important, especially more so for NASA than perhaps many of the other decisions that we make here. And also we know about the importance of safety. Acknowledging, as we all know, that space exploration involves risk, there are safety concerns and I know that NASA does a lot to address those.

So, Mr. Gerstenmaier, some have said that outfitting the Orion with the necessary life support equipment on the first crewed mission will cause the spacecraft to be overweight, so should we be concerned about that? What options does NASA have to mitigate this possibility?

Mr. GERSTENMAIER. And we—in the flight test we just flew, the next flight of Orion will be significantly lighter. We have done a major redesign of some of the structures to actually lower the

weight of Orion and that wasn't easy to make those changes but they have done that. We have also—are starting, as I described earlier, testing some of the life support systems on board space station so we will know how much they will actually weigh and some of those systems are in place.

So I think we have a sound approach to address the concerns that you raised. We know what it will take to add the life support system and we will make sure that it can be added and still not exceed the mission weight.

Ms. BONAMICI. Thank you. And then also, Mr. Gerstenmaier, I want to follow up on your response to Ms. Edwards' question. You know, we tend to focus on the SLS and Orion when we think of the exploration program, but I want to talk a little bit more about the ground infrastructure at the Space Center, which is also undergoing some significant development to support the SLS and Orion launches. I know there has been work on the mobile launcher, the tower, the vehicle assembly building, the Launch Pad 39B underway, so where does that ground infrastructure work stand relative to the progress being made on SLS and Orion? Are they in sync so that they will be ready at the same time?

Mr. GERSTENMAIER. Again, I think you saw in the video a lot of activity that is going on down in Florida. That work is in progress and we completed the KDP–C review for ground systems and it shows a 70 percent confidence level for that equipment to be ready in Florida to support a launch in June of 2018, so it is on schedule to move forward.

It has challenges that need to be worked as well, and again I would stress I don't see that all these activities have to line up. Even if SLS is ready a little bit early and the ground system isn't fully there, it is still the right thing to do to move the rocket down to Florida and begin checking out umbilical interfaces to see how it is going to fit within the launch tower, to see how it will fit within the launch pad. That still fits from an overall schedule standpoint so there is not a disconnect in this schedule. Even though they don't—everything doesn't arrive at precisely the same time, it is perfectly appropriate to have one component arrive before.

Ms. BONAMICI. Thank you. And I am going to squeeze one more question in here.

As demonstrated by the House-passed NASA Authorization of 2014, there is a strong sentiment for NASA to have a policy on termination liability that really maximizes the use of appropriated funds to make progress in meeting those established technical goals and schedule milestones. How is NASA currently handling potential termination liability for SLS and Orion?

Mr. GERSTENMAIER. It is actually not a NASA policy. We believe it is part of the Anti-Defamation Act where the termination liability is required by all agencies to be handled in a similar manner to which the agency does. So, you know, that is where we are. So it is not unique to NASA and unique to what we have done in the past.

Ms. BONAMICI. Thank you very much and I am—yield back. Thank you, Mr. Chairman.

Chairman PALAZZO. I now recognize Mr. Rohrabacher from California.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman, and thank you for holding this hearing. It is vitally important that we have a responsible oversight of the various NASA projects that are the responsibility of this Subcommittee. Many of us were very skeptical about this SLS commitment when it was made. We said there would be funding problems; I had no idea the funding problems would come on so quickly. And, sir, you noted that you said the funding levels now are interesting. Interesting? They are not interesting; they are insufficient, insufficient to reach your goals. And why are they insufficient? Because we didn't have enough money for this project to begin with.

Am I correct in assuming that there are large commitments of finances that will be necessary to develop other technologies that are yet to be developed for this spacecraft, for the SLS to move forward on its mission to Mars? We don't even know if those expensive technology development projects will succeed. To say we have got the cart before the horse is an understatement. And there is an expense to that and I hope my colleagues on this Subcommittee understand that with a $10 billion—and that is a minimum expenditure that we are talking about here in developing this monstrous rocket project that won't have a real mission until we are ready to go to Mars, which could be two decades or three decades from now depending on if we can actually ever get over the technological hurdles that we haven't gotten over yet, that by doing that we have committed ourselves not to do a bunch of other things, not to identify all the near-Earth objects that could be hitting the Earth and murdering millions of people from some object hitting the Earth, much less setting up a system for how we can deflect a near-Earth object.

We are not going to have that because we are going to have a big, huge rocket that we can be so proud of that won't even have a mission for two decades. We are not going to be building ways to deflect those rockets. We are not going to be building a way and a technology developing a way, Mr. Chairman, to clear space debris. Space debris is going to end up strangling humankind's involvement in space in order to improve the condition of human beings, which is a good investment to make, not an investment in a huge rocket that doesn't have a mission for 20 years.

And we basically have canceled—just even recently we have canceled this solar cell project. We are not going to have a refueling system in space that could incredibly increase our abilities to do things in space, and basically we could be perfecting our ways of repairing satellites. All of these things are going to be defunded because we are spending billions of dollars on a rocket that may not fly to Mars two decades from now.

This is—I was going to say to say this is the cart before the horse is an understatement that I have ever heard and we are already having budget crisis talks about it right now because what you are telling us today is that things aren't going to work out with the budget that we have got. It is not just interesting; it is insufficient to achieve the goal. And even if we do then pump more money into the SLS project, we have pumped it into a project that is providing a rocket that will be useless to us for two decades as compared to all those other things that can be done in space.

Mr. Chairman, we need to be serious; we need to be responsible. We should not be blaming the people at NASA and our professionals and the executive branch. We made a wrong decision when we went down this road and I think that unfortunately the American people and the people of the world are going to pay for it not just out of their pockets with money but out of things that we could of been doing in space that would have been so beneficial to the human race.

With that, and I guess you have got 30 seconds to answer that, but go right ahead. Is there any refutation you have of that observation? Please feel free. My feelings won't be hurt.

Mr. GERSTENMAIER. My only comments would be we don't have very—we have—I can't think of any real major technical challenges in terms of SLS development.

Mr. ROHRABACHER. How about the radiation challenge with going to Mars?

Mr. GERSTENMAIER. That is——

Mr. ROHRABACHER. Have we met that?

Mr. GERSTENMAIER. We have not met that——

Mr. ROHRABACHER. Yeah, we have got a whole bunch of those type. I am not talking about the challenges of developing the SLS; I am talking about the challenges of once we have it and we have spent those billions of dollars whether it is going to be able to go to a mission which it is supposedly for. We don't even know how we are going to land on one of those moons on Mars yet, do we? We don't have the exact systems set up and how much that is going to cost us to develop it and how it is going to be put on the rocket. We have a list of these technological achievements that are necessary for this rocket to have been useful in any way and we are not even halfway there. Please feel free.

Mr. GERSTENMAIER. And then the only other thing I would add is we are doing some activities in the area as you described. On board space station we have a refueling demonstration——

Mr. ROHRABACHER. Um-hum.

Mr. GERSTENMAIER. —package on the board outside of space station where we have actually robotically serviced the outside of a satellite——

Mr. ROHRABACHER. Right.

Mr. GERSTENMAIER. —and we have transferred some propellant back and forth.

Mr. ROHRABACHER. Right.

Mr. GERSTENMAIER. We are also looking at cryogenic servicing on station.

Mr. ROHRABACHER. Right.

Mr. GERSTENMAIER. There is a package on board station——

Mr. ROHRABACHER. Those are the good things. Okay.

Mr. GERSTENMAIER. And then we also have solar electric propulsion and—as part of the Asteroid Redirect Mission and we are also looking at techniques where we can use a gravity tractor——

Mr. ROHRABACHER. So——

Mr. GERSTENMAIER. —to deflect some asteroids. So we are——

Mr. ROHRABACHER. They are wonderful but let me just note all of those projects were financed in budgets before the SLS became part of our budget. All of those things that you said we now are

testing, they were done in the research and development stage long before we started taking all of our money out to put it in one big rocket. And we don't even know, do we, whether we are going to have the money to finish all those projects that you just talked about in their development because this is how at $10 billion, and by all of the experience we have had, it is likely to go up to double that by the time we finish with this rocket. And I say finish, that is just when the rocket is ready to take off for the first time.

This was a rotten decision on the part of this committee. It is not your fault. You are good soldiers and you are doing your very best with what the Members of Congress are giving you. We have given you an undoable task and thank you very much for your hard work.

Chairman PALAZZO. I now recognize Mr. Posey.

Mr. POSEY. Thank you, Mr. Chairman. I am glad that didn't stop Apollo.

We are all excited about the Orion launch, Mr. Gerstenmaier, and I think we are seeing more public awareness of SLS now and that is something we all look forward to. Can you take a moment, following up on Congresswoman Bonamici's comments, to discuss the importance of another special aspect of the SLS program and that is the exploration ground systems. I am sure many folks are not up to speed on the importance of the ground systems aspects of the SLS.

Mr. GERSTENMAIER. Yeah, the ground systems team plays a critical role in the Space Launch System. They are working on the mobile launch platform to interface with the rocket to provide propellant to that to fuel the rocket and they will actually launch off it. They are also working on a launch pad; a significant amount of work has gone into the pad.

We have looked forward to trying to lower our operations costs so there are many activities on the launch pad. It is a clean pad which should help lower launch costs. We also have the firing room down at the Kennedy Space Center. That is going in place with a lot of software development activities there. We have also made the launch pad a multipurpose launch pad so it can not only support SLS but it can support other rockets so the fiber cables that run out to that launch pad can support multiple rockets launching off of that pad, which is a good thing. So there is a tremendous amount of work going on at the Kennedy Space Center.

The recovery activities that occurred for the EFT–1 flight, those were all managed at the Kennedy Space Flight Center by the ground systems folks that worked with the Navy and the Anchorage to pick up the capsules. So again, the ground support activities, and as you saw in the video, are absolutely critical to what we are doing with the heavy lift launch vehicle and the Orion processing and manufacturing.

Mr. POSEY. Thank you. Following up little bit, can you explain the thinking behind the President's budget request calling for funding increases for exploration ground system in the years 2016 to 2019 and what happens if these funding targets are not met?

Mr. GERSTENMAIER. Again, we need the funding levels that we have requested to meet the schedules that we have put forward or there will be slippages in activities, as I have described.

Mr. POSEY. Okay. Thank you, Mr. Chairman. I yield back.

Chairman PALAZZO. I now recognize Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

As you can discern from the comments of Representatives Donna Edwards and Dana Rohrabacher, the mission for SLS and Orion is a certainly a concern for this committee and for Congress as a whole. Mr. Gerstenmaier, it seems that you are uniquely situated as Associate Administrator for Human Exploration Operations to answer some of these questions about SLS's missions. It is one thing for us to test whether SLS and Orion components work; it is another thing to actually give SLS and Orion a substantive, a real mission such as going to the moon or Mars, capturing an asteroid, space station resupply if that is what is necessary, or whatever. In your opinion, what should SLS's first real mission be?

Mr. GERSTENMAIER. I think the SLS and Orion's first mission will be to this proving ground, this space that I described around the moon amid we call it cislunar space in the vicinity of the moon. That is a very necessary step for us to move forward as we push human presence into the solar system. So it is a place for us to hone skills, to understand techniques, to prepare, much as the early flights did in Mercury and Gemini to prepare for the Apollo activities. These flights around the moon will help us prepare to get ready to go do these Mars missions decades later. But the first flights will be to the vicinity of the moon. The rocket is capable of doing that. Orion is capable of doing that without any additions and we can learn the skills, bring our level of expertise up to where the risk is then appropriate to take bolder steps beyond the cislunar space.

Mr. BROOKS. For clarity, you are saying around the moon. Does that include landing on the moon or simply going around the moon?

Mr. GERSTENMAIER. We didn't—in our budget we don't have funding for landing on the moon; we just have in the vicinity of the moon. We use potentially the gravity of the moon to help with doing trajectory design as we would look for Mars. We have an international community that is very interested in potentially doing lunar activities and maybe we can partner with the international community if they choose to develop the lander. But in our concept we don't have funding in our plans for a lander to the moon.

Mr. BROOKS. Okay. After we go around the moon, what should be the second mission of SLS?

Mr. GERSTENMAIER. Again, I think it is going to take more than one mission around the moon it to build these skills that we need to——

Mr. BROOKS. Okay. After all the around-the-moon missions, what should be the second mission for SLS?

Mr. GERSTENMAIER. Then we are ready to start heading towards Mars, and whether we go to an asteroid as an intermediate destination or we go all the way to the vicinity of Mars and go to potentially a moon of Mars, those are things yet to be decided.

Mr. BROOKS. Can you please give me a timetable sequencing of what you believe is appropriate for NASA and SLS with respect to the missions you have just enumerated?

Mr. GERSTENMAIER. Again, we kind of think of them in broad terms so that the decade of the '20s to the '30s, that is this proving ground region that I described to you where we learn these capabilities between 2020 and 2030. But beyond 2030 we are ready to go do these other activities, to an asteroid potentially in its native orbit or potentially all the way to the moons of Mars or to Mars in that time frame.

Mr. BROOKS. So for clarity, for the next decade or two you are talking about circling the moon and then roughly two decades thereabouts in the 2030s you are talking about then we can think about going to Mars. Is that your testimony?

Mr. GERSTENMAIER. We need—it is not just circling the moon; we are actually doing activities around the moon with the intent that we are building the skills, understanding the hardware, understanding the techniques, understanding the environment that we are operating in that prepares us to go to distances as far as Mars with a reasonable risk assessment.

Mr. BROOKS. Is additional funding needed to speed up the mission platform that you have just expressed?

Mr. GERSTENMAIER. Additional funding can help with that activity.

Mr. BROOKS. How much additional funding would be required, by way of example, to speed up the Mars part of the mission scope to somewhere in the 2020s, around 2030?

Mr. GERSTENMAIER. Again, I think I would like to take that question for the record. It is more than just funding. It is not only funding but it is also how long it takes us to actually get proficient at these skills to go take that next step, and to give you a real answer I need to spend some time with our teams looking at how long we think those activities take and then back into the funding discussion that you have.

Mr. BROOKS. Well, I hope you can understand this Subcommittee's concerns when it took us less than a decade not only to go around the moon but to land on the moon under Apollo and with what I am hearing you testify to it is going to be 10 to 20 years to just go around the moon, not actually land on the moon. So those kinds of timing issues are of concern.

And, Mr. Chairman, if I could ask Ms. Chaplain a question, is that okay?

Chairman PALAZZO. That is okay.

Mr. BROOKS. Thank you.

Chairman PALAZZO. You may proceed.

Mr. BROOKS. At this past year's hearing on the President's Fiscal Year 2015 budget request for NASA, Administrator Bolden indicated that providing more funding for SLS would not be helpful for completing the first version of SLS by 2017. However, your testimony states that the "top risk" for meeting its deadline for EF–1 in December 2017 is insufficient funding. Would you please explain this discrepancy and would additional funding make meeting the 2017 test flight possible or at least more likely?

Ms. CHAPLAIN. So the cost risk we identified in our report comes from NASA's own documents and was also raised by their Standing Review Board so there was indeed a very high risk that there was not enough money to help meet the 2017 date.

That said, as Mr. Gerstenmaier has already testified, just putting in money now won't help you get there any quicker. There are a lot of sequential activities that are needed to get some of the critical path items done for SLS like the core stage. The money at this point would be helping out with reserve and possibly doing testing and some other activities that couldn't be done earlier in bringing them forward.

Mr. BROOKS. Thank you, Mr. Chairman, and thank you, Mr. Gerstenmaier and Ms. Chaplain.

Chairman PALAZZO. I now recognize Mr. Schweikert.

Mr. SCHWEIKERT. Thank you, Mr. Chairman.

Part of this is going to be a little bit of a follow-up on both what Dana and Congressman Brooks were—Ms. Chaplain, help me get my head a bit—from your report and I am assuming much of the—woven into your report was actually taken from the documents from NASA and others, and then when we start to look at timelines, any—and this—I will let you do it as a personal opinion because you have been doing this for a while. How short are we financially? And then I will go to Mr. Gerstenmaier and ask how short we are technologically.

But if I came to you and say, hey, here is the robustness of what we are trying to do, I am looking at, you know, a number of tables that have, you know, all these moving pieces and projects, and I came to you and said here is where we are over the next 20 years, here is what we are seeing Congress' appetite for funding, what is an honest number of shortfall?

Ms. CHAPLAIN. I think there are various numbers to pay attention to here. First are the kind of short-term numbers laid out in the documents for SLS and Orion. For SLS they ranged anywhere from 400 to 900 million, but with pushing out the date and doing some other things, those numbers have been reduced. There is still a funding risk for Orion that is considerably high——

Mr. SCHWEIKERT. Well—and—but—and I am actually after something for the robustness of the system. Is that just Orion itself? Is that also ground control, personnel costs? I mean every step you need to make this work instead of just this individual silo, has that been actually looked at through the totality of the system that is required?

Ms. CHAPLAIN. Right. So the problem we identified in a different report on cost estimating is we don't really know the total number now of how much it is going to cost to do everything we are looking for them to do. And second, we don't know really what the pathway is and that pathway has a big effect on numbers. Like Mr. Gerstenmaier mentioned a landing system. It is very costly. There is not money to do it right now. If you want to move things up, you have to pay for a landing system. How much is that? So it is very, very important to kind of layout the roadmap now and see all the different pieces that you need. We don't know that and we don't have cost estimates beyond the first test for some of the systems.

Mr. SCHWEIKERT. And, Ms. Chaplain, you understand sort of the—you know, when we are looking at CBO-type numbers, you know, we have here is our best guess, here is our optimistic, and here is when we are in trouble, I mean, sort of those variants. We understand for every step of technology, every additional incre-

mental piece of timeout, the variance grows because it is unknown. But we are trying in a number of discussions to get some idea of what the exposure is and are we about to cannibalize everything else?

Mr. Gerstenmaier, technologically if I came to you and said the goals that are here on the timeline over the next ten years, 20 years, where do we have things where we don't actually have the technology yet but we are working on it?

Mr. GERSTENMAIER. I would say the biggest technology areas that we need to work on are we need to work on radiation for the human being and look at radiation shielding. We can only shield so much and—but I think again that is a manageable risk, but will there ultimately be some risk associated with galactic cosmic radiation that we will have to deal with on humans.

The other big thing is if we are going to Mars, the entry, descent, and landing into the Mars—to the surface of Mars is a big technology leap. Today, we have landed Rovers on the order of one metric ton on the surface of Mars. For our human class mission we are going to have to land about 20 times that, at least 20 metric tons. We don't know exactly how to do that. We did some tests off the—in Hawaii to go look at some inflatable reentry heat shields. We are working on that technology.

And then kind of going back a little bit to the other questions about Mr. Brooks and why we are not sprinting to the moon like we did before, I am really building systems that are modern manufacturing, so the equipment we are putting in down at Stennis is going to allow us to have a system that can be reproduced and flown multiple times for minimum cost.

Mr. SCHWEIKERT. Okay.

Mr. GERSTENMAIER. So we are spending extra time, I would say, to prepare a system that is affordable in the long-term. GAO wants more details on that. We need to provide that information to them. But we are looking forward that we are not just building a single system that sprints to a destination. We are building an infrastructure that allows us to have sustained presence beyond low Earth orbit.

Mr. SCHWEIKERT. All right. Thank you.

Mr. Chairman, as you have had a number of conversations with staff and the rest of us, we still think there is so much variability, exposure, and costs, and we all know what is about to hit us in the entitlement crisis over the next decade cost-wise. What is going to happen to future Federal Government spending? Somewhere here we are going to have to have a much more robust and much more brutally honest—of what we have cash for and what we don't.

With that I yield back.

Chairman PALAZZO. At this time we will go into our second round of questions.

Mr. Gerstenmaier, when did NASA first begin tracking the $400 million risk identified by GAO?

Mr. GERSTENMAIER. Probably that got identified back in 2013, 2014 time frame. I would say if you asked my teams now, they would say that that $400 million risk, because of the appropriations we have received in 2014 and the pending bill that we saw last night, that $400 million risk will be retired.

Chairman PALAZZO. Well, you said in 2013, we had Administrator Bolden sitting where you are telling us that if we threw another 300 million at SLS and Orion, we wouldn't even notice it. I mean it wasn't needed at that time so you recognized this risk. If we would have—if you would have come to us, say, a year ago or when you first started tracking it—because it feels like we are just finding out about this risk, this 400 million since the GAO's report has come out. Has—and you are telling me NASA has known about this for a much longer period than that?

Mr. GERSTENMAIER. It was in their earlier reports that GAO picked up and it is one of many risks. We carry technical risks, programmatic risks, and budget risks. And it was again to meet a specific launch date and we—and again, we have moved the launch date, which gives us some margin as well and then we have also—we actually know what the budgets are now in 2014 and we will know what the budget is when it gets approved here in '15. Those remove that uncertainty and that lowers the level of the risk. So as we identify those, we carry those and bring those forward as soon as we can.

Chairman PALAZZO. And are you going to be matching your expenditure of funds based on Congress' budget or the President's request, which has been quite lower than what Congress has been appropriating for the past several years?

Mr. GERSTENMAIER. This is the dilemma we have, right. So the reality is the program plans to some variance between those two limits that you just described.

Chairman PALAZZO. And if we—if you would have come to us for, say, additional funding a year or two years ago, would you have been able to mitigate the risk or buy down the technical risk or would we still be having this same conversation that the test is going to slip to the right regardless of the amount of funding we may have been able to appropriate to the program?

Mr. GERSTENMAIER. That is a very difficult question to answer. And the other thing that is hard for me is that I look at human spaceflight as the total, which is SLS/Orion, also commercial crew, commercial cargo, and International Space Station. I see human spaceflight as really the combination of all those activities. We are using space station today to buy down a lot of risk for Mars so I have to look at a balancing across all those programs. I can't optimally find any one of those programs so I effectively balance across those in the risk and I try to weigh the budget and the technical risk associated with those programs to give what we think is the best approach to deliver hardware for the lowest cost for the Congress and the taxpayers.

Chairman PALAZZO. I now recognize Ms. Edwards.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you again for a second round of questions.

I want to go back to something that I raised earlier and it is regarding the recommendation by the National Academies about a five percent inflationary increase in the budget. And although I understand that for this specific purpose of looking at 2017 slippage to 2018, that that is not what we are talking about, but I want to know about the program and would it be useful for both the Administration to recommend and Congress to incorporate this mar-

gin that the National Academies has recommended so that we, over a period of time—that we are not looking at the questions that are being raised today? Just give us some guidance. Okay. Flip a coin. Yes, Ms. Chaplain.

Ms. CHAPLAIN. I would just add that is not the first time a recommendation like that has been made. It was made at the tail end of the Constellation program by the Augustine Commission and I think they recommended about three billion additional a year, which was pretty significant, and that was their view of what was needed over a number of different paths that you would take, not just the Constellation path. They mentioned a path similar to what is being done here.

Ms. EDWARDS. And that would provide a lot more stability than what we are seeing now, wouldn't it?

Ms. CHAPLAIN. Yes, and the other thing to remember is programs like this have spikes in terms of their funding needs so Constellation program itself, when that recommendation was made, was asking for about $3 billion a year but in their budget they went up to as much as $7 billion a year in terms of their needs. So there are spikes depending on what you are developing and when activities come up.

Ms. EDWARDS. I want to just ask really briefly in Department of Defense large-scale programs, they don't go through this. They say—they set out kind of a goal. It crosses Congresses. They know that there is a difference in these kind of large-scale development programs. Why is it that we are funding a scientific program that has a lot of uncertainties year by year and in some cases a few months by a few months? Don't we actually end up wasting way more money over the long term by doing that than just setting out a goal of making sure that we fund this program in the most robust way possible across Congresses so that the goal is achieved? Why aren't we—why isn't there modeling for these large-scale science programs the same way that there is that kind of modeling for defense programs? And has GAO ever analyzed that and what the impact would be to the success of the programs?

Ms. CHAPLAIN. We have never analyzed NASA funding compared to DOD funding but we do know when the funding stretched out, the problems you are describing do occur. It is not like all the DOD systems don't experience some kind of instability. It is rare when Congress is trying to give more money than what they are asking for. Sometimes there is the reverse case where Congress gives a little less. But with programs with a lot of schedule pressure and everybody recognizes——

Ms. EDWARDS. And experimentation?

Ms. CHAPLAIN. Yes, but programs where everybody recognizes a date is important to deliver, there tends to be more support funding-wise and it tends to be more stable.

Ms. EDWARDS. Mr. Gerstenmaier, do you have a comment about that?

Mr. GERSTENMAIER. No, I think again the discussion is good. Some understanding and stability in budget would be helpful. At least matching inflation would be helpful.

But again, I think the problem is we deal, as you describe very succinctly that—with essentially a year budget, sometimes months.

You know, we throw in furloughs and other things just to make—and those are real impacts to us. When we had—we stood down effectively for two weeks where we couldn't do any work on Orion during that time and how you plan for that in a programmatic sense is extremely difficult.

So it is a tribute to my teams to take this environment that is very dynamic and figure out a way to make as significant progress as we can, not waste funds, not use funds in an inappropriate manner, but it is difficult for the teams to do that but they have done a fairly good job, as we have seen through this activity. It could be eased if we got some more certainty.

Ms. EDWARDS. Well, Mr. Chairman, I really—I am on a mission that we have to think differently about the way that we do these large-scale programs. We faced it with James Webb. We are looking at it here with SLS/Orion. This is just really not smart, and at the end of the day, the technologies expire, the technologies change over a period of 10 or 20 years as we are stretching things out, and then it is like starting all over again. And I just think it is about the dumbest way to do science.

And with that I yield.

Chairman PALAZZO. Ms. Edwards, I think there are several people that would agree with you.

I now recognize Mr. Bridenstine.

Mr. BRIDENSTINE. Thank you, Mr. Chairman.

And, Ms. Edwards, I do agree with you and your comments are certainly well recognized on both sides of the aisle so thank you for that. And we would like to work with you on how we can remedy this.

I just had a quick question about the international implications of our direction for human spaceflight. The report that Ms. Edwards referenced from the National Academies indicated that if we were to do this Asteroid Redirect Mission, we would be not in alignment with the international community, most of which is focused on getting to the moon, namely the lunar surface and then on to Mars, and that this misalignment, according to the report, again headed by Governor Mitch Daniels, indicated that this misalignment could actually result in us spending a whole lot of money on dead-end technologies rather than actually accomplishing the objective of getting to the moon. Mr. Gerstenmaier, could you address that?

Mr. GERSTENMAIER. I would say the global exploration roadmap is the plan that the international partner community has agreed to, along with NASA, as the basic framework of how we want to head forward. I think in that roadmap Mars is a horizon destination, as we have described. The internationals, as the report describes, have a stronger interest in the moon. The Asteroid Redirect Mission places this asteroid in the vicinity of the moon, which is consistent with what the international partners would want to do. The SLS rocket, the Orion capsule, they fit very well in this lunar activity, in this proving ground I described, that the partners then have a desire to do lunar activities. We could very easily work with the partners and support that activity.

The Asteroid Redirect Mission also fits into the long-term goal of what we want to do. We believe for a Mars class mission we need

solar electric propulsion to move large masses to the vicinity of Mars. We are going to move essentially a 50 metric ton asteroid through space. That could be the same cargo we are delivering to Mars so that space tug that we are building for the Asteroid Redirect Mission is a piece of the tug that would be used for the human class missions to Mars so it fits in that other architecture moving forward.

So it is not a diversion, it is not—from our overall goal. So we look at each piece we are developing within human spaceflight. We look how it fits in terms of international partner needs, we look how it fits in our horizon goal of Mars needs, and we only move projects that we can continue to keep moving forward in that direction. We don't want to spend resources on items that are one-of-a-kind use——

Mr. BRIDENSTINE. Do you know——

Mr. GERSTENMAIER. —much as the report said.

Mr. BRIDENSTINE. Do you know offhand specifically which technologies they are talking about that would be dead-end technologies as we pursue this path?

Mr. GERSTENMAIER. I think we didn't have a chance to discuss with the Committees significantly how we were going to use this cargo capability for Mars. I think if we would have had a chance to describe that with them, they would not have seen that as a dead-end capability. And so we—I think we needed to have more dialogue with the Committee. We ran out of time towards the end. They didn't get a chance to see some of our latest thinking of how all these pieces fit together towards the ultimate Mars horizon goal.

Mr. BRIDENSTINE. Okay.

Mr. GERSTENMAIER. But I can't judge what their answer would have been.

Mr. BRIDENSTINE. Last question—we are down to about a minute-and-a-half—we noticed that the WARN Act—notices went out for the WARN Act recently associated with the SLS program. Can you explain why, given the fact that we are spending more money than expected and everybody seemed to be telling us that things were ahead of schedule and we are spending more than what was anticipated, why did these WARN Act notices go out?

Mr. GERSTENMAIER. One reason for the WARN Act was there is—again, they are issued by the contractors based on the activity and the direction we give them. There is a natural change in the development lifecycle of the SLS. We are essentially ramping down on the heavy design phase where there is a lot of engineering, a lot of drawing development, analysis kind of activities that now is terminating naturally.

Now we are getting ready to go manufacture so they are going to be buying long-lead items, large aluminum forgings. The work occurs down at the Michoud facility down off—by New Orleans to actually do manufacturing, so we are shifting from design to manufacturing, and during that shift, there is a natural ramp-down of the skills that the overall workforce will come up but it will come up in other areas and it will show up in materials. It will not show up in personnel. So this is a piece of that. Warren Act activity is supporting this natural progression from design to manufacturing.

Mr. BRIDENSTINE. Roger that. Mr. Chairman, I yield back.

Chairman PALAZZO. Thank you, Mr. Bridenstine.

Two stories below us is the House Armed Services Committee room and Mr. Bridenstine and I also serve on that same committee, and we have had testimony presented to us that the number one threat to America's national security is our national debt, and I am going to have to say that the number one threat to America maintaining its leadership in space is also going to be our national debt, and many Members on both sides of the aisle recognize that we have to address the pending fiscal problem that is going to be facing our Nation and hopefully we can overcome that.

Once again, Mr. Gerstenmaier, congratulations to you and your entire team at NASA, to Lockheed Martin and ULA for a very successful outstanding test flight.

And I want to thank the witnesses for their valuable testimony and the Members for their questions. The Members of the Committee may have additional questions for you and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments and written questions from Members.

The witnesses are excused and this hearing is adjourned. Thank you.

[Whereupon, at 10:30 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Bill Gerstenmaier

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities"

Questions for the record, Mr. Bill Gerstenmaier, Associate Administrator for Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration

Questions submitted by Rep. Chris Collins, Subcommittee on Space

QUESTION 1:

How does NASA expect to keep support from its supplier base when they continually make major program funding swings to these same suppliers?

ANSWER 1:

The dedicated NASA-industry team, working across the nation utilizing all of the NASA Centers and hundreds of contractors, is making progress toward developing the next capabilities for human and robotic space exploration missions beyond low-Earth orbit (LEO). In developing the Orion, the Space Launch System (SLS), and Exploration Ground Systems (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 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 element is allowed to progress on its own schedule, rather than being linked too tightly to the others. When tasks related to Exploration Mission-1 (EM-1) are completed, the workforce can progress to EM-2. NASA is on a solid path toward an integrated mission and making progress in all three programs every day.

QUESTION 2:

How does NASA expect Industry to acquire and retain America's brightest STEM graduates when high technology companies have a revolving door of staff due to program instability?

ANSWER 2:

Please see ANSWER to Question #1, above. NASA's exploration vehicles and supporting ground systems are being designed to support a variety of crewed missions into deep space in a manner that is sustainable in the long term. NASA and its contractor community offer recent graduates many unique experiences not available in other fields.

QUESTION 3:

How many changes will there be to flight critical hardware on the SLS Core Stage between first unmanned launch (EM-1) and the first manned launch (EM-1) due to the funding profile?

ANSWER 3:

Unless technical issues arise during EM-1, there should be no changes in SLS Core Stage flight critical hardware between EM-1 and EM-2. The EM-2 Core Stage is planned to be a duplicate of EM-1.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities"

Questions for the record, Mr. Bill Gerstenmaier, Associate Administrator for Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration

Questions submitted by Rep. Jim Bridenstine, Subcommittee on Space

QUESTION 1:

In your testimony, you included the moon, and cis-lunar space, as a necessary proving ground for getting to Mars. However, in 2010, President Obama seemed to emphatically oppose another moon landing, stating: "I just have to say pretty bluntly here: We've been there before." Does this difference of opinion between people like you, the experts at NASA, and the President and his administration hinder our efforts to advance a unified plan for our manned space exploration program?

ANSWER 1:

NASA has been executing an integrated human and robotic exploration strategy leading to the human exploration of Mars. NASA's exploration strategy is to move from today's Earth-reliant posture through the proving ground of cis-lunar space to an Earth-independent capability needed to extend human presence into the solar system and to the surface of Mars. This begins with research on the International Space Station (ISS), including the one-year crew increment that starts in March 2015. It continues with crewed Space Launch System (SLS) and Orion missions in cis-lunar space, including the rendezvous with the redirected asteroid. It will continue with new capabilities in deep space for habitation, in-space transportation, and joint science/exploration/technology missions to Mars. One such example is the Mars 2020 rover, which will conduct unprecedented science as well as exploration technology investigations to help plan for future human missions. NASA will build upon our increasingly advanced fleet of Mars robotic explorers that have dramatically improved our scientific knowledge and helped pave the way for astronauts to travel there. Lunar distant retrograde orbits offer an ideal proving ground for initial crewed operations. Given that the entry, descent, and landing, and ascent environment for Mars is so different from that of the Moon, a costly human landing on the lunar surface would provide limited applicability to a landing on Mars.

QUESTION 2:

I was pleased to hear you say Mars is and should be the horizon goal for the United States' manned space program. However, there is a sense that Mars is a goal to someday get to in the distant future, with the Moon and an Asteroid Redirect Mission as other goals in the interim. To me, there is a distinction between this philosophy

and a philosophy that labels Mars as the distinct target by a date certain, with the Moon and an ARM as steps toward that goal. Are there ways for NASA, perhaps with guidance from Congress, to be bolder in the vision to see a human on Mars within the next few decades?

ANSWER 2:

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 in a distant retrograde orbit around the Moon, in the mid-2020s. 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 a potential habitation module. 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 International Space Station [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.

QUESTION 3:

On the subject of Mars, and following up from my question in the hearing, can you please lay out the ideal budget and timeline that you see as necessary to provide adequate funding, development, and flight frequency to put an American on Mars as soon as technologically possible?

ANSWER 3:

Please see response to Question #2, above, for the timeframe for a human mission to Mars, the Asteroid Redirect Mission (ARM) in the mid-2020s, and factors informing NASA's decisions on specific future missions. In terms of flight frequency, NASA is working toward an SLS/Orion flight rate of at least one per year following EM-2, with a surge capability of three SLS flights per year. The actual cadence of missions beyond 2022 will be defined in the coming months and years based on mission needs and available resources. The outyear projections in the President's FY 2016 budget request set us on a course for achieving the goal of humans on Mars.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities"

Questions for the record, Mr. Bill Gerstenmaier, Associate Administrator for Human Exploration and Operations Mission Directorate, NASA

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

QUESTION 1:

What level of confidence does NASA have in the planned dates for the EM-1 and EM-2 test flights of no later than November 2018 and 2021, respectively?

ANSWER 1:

The FY 2016 President's Budget Request provides the funding level needed to keep the Space Launch System (SLS), Orion, and Exploration Ground Systems (EGS) on track. We have identified our Agency Baseline Commitments 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. The Agency will determine the Exploration Mission 1 (EM-1) integrated launch date after Orion, the Space Launch System (SLS), and Exploration Ground Systems (EGS) have completed their respective Critical Design Reviews (CDRs). The integrated launch date for Exploration Mission-1 (EM-1) is to be determined in December 2015. The first crewed mission (EM-2) is scheduled to launch in FY 2021-2022.

QUESTION 1a:

What single factor is most critical to preserving those launch dates?

ANSWER 1a:

Programmatic stability and funding at the level of the President's Budget Request are elements that support keeping NASA's exploration efforts on track.

QUESTION 1b:

Assuming funding levels consistent with the FY 2015 enacted appropriation, what adjustments are being made to prevent schedule slippage of EM-1?

ANSWER 1b:

Programmatic stability and funding at the level of the President's Budget Request are elements that support keeping NASA's exploration efforts on track.

QUESTION 2:

If additional resources above the FY 2015 enacted appropriation were made available for the SLS program in FY 2016, what would be the most effective use of those resources?

ANSWER 2:

Additional funding would not advance the schedule. If additional resources were made available for the SLS program in FY 2016, they would "buy down" schedule and provide additional budget margin to work potential future technical risks.

QUESTION 3:

Please explain, in simple terms, the strategy for initially developing an SLS capable of a 70 metric ton lift capacity and then following that with an SLS capable of lifting 105 to 130 metric tons.

a. Could NASA accomplish the same thing by sending more launchers but of lesser lift capacity, as some have suggested? If not, why not?

ANSWER 3a:

NASA's strategy for incrementally increasing the SLS lift capability is driven by the need for lift capacity in each exploration regime. Our analyses show the 105 metric ton (mt) configuration, with the addition of an upper stage, is sufficient for a variety of human and cargo missions in the proving ground of cis-lunar space. Once we are ready for missions to the vicinity of Mars, we plan to progress to the 130-mt configuration, which we plan to achieve through the addition of advanced rocket boosters to the SLS, plus an upper stage. Fewer launches of this version of the SLS would be required to launch missions to Mars. If smaller launch vehicles were used, NASA would need to launch more often and would need to break payloads up into smaller pieces for launch, increasing payload cost and the complexity of the overall architecture.

QUESTION 3b:

What are the pros and cons of this incremental development approach and to what extent has NASA used incremental development for previous programs?

ANSWER 3b:

The incremental development of SLS is a component of NASA's Journey to Mars strategy, and is similar to the approach used by Mercury, Gemini, and Apollo. Under these programs, NASA incrementally built up its capability to keep astronauts alive in space for increasing durations, expanded in-space activities to include rendezvous, docking and extravehicular activities, and ultimately landed Apollo crews on the Moon. With SLS and Orion, we will travel beyond low-Earth orbit (LEO) to the proving ground of cis-lunar space where we will expand and test our capabilities with a series of crewed missions with SLS and Orion, including a mission to

rendezvous with a redirected asteroid in lunar orbit. The Orion and SLS systems are designed to allow us to build the skills and capabilities necessary for deep-space human exploration in the proving ground of space around the Moon. 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, allowing us to access many other destinations and ultimately pioneer Mars.

QUESTION 4:

You discussed during the hearing that NASA would like to fly the SLS at "a flight rate of about once per year" and that NASA is analyzing the once-per-year rate to determine whether it addresses safety concerns regarding the SLS flight rate and can also be achieved within NASA's budgets. When will that analysis be complete? What budget levels does the analysis assume? Please provide a copy for the record once the analysis has been completed.

ANSWER 4:

NASA continues to conduct a detailed analysis; NASA needs to continue to scrub production and operations costs.

QUESTION 5:

Ms. Chaplain said during the hearing that it is "very, very important to kind of layout the roadmap now and see all the different pieces that you need. We don't know that and we don't have cost estimates beyond the first flight test for some of the systems." As you know, the House-passed NASA Authorization Act of 2014 includes language directing NASA to provide a human exploration roadmap to Congress. When will NASA provide such a roadmap to Congress?

ANSWER 5:

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 in a distant retrograde orbit around the Moon, in the mid-2020s. NASA's exploration strategy is to move from today's Earth-reliant posture through the proving ground of cis-lunar space to an Earth-independent capability needed to extend human presence into the solar system and to the surface of Mars. This begins with research on the International Space Station (ISS), including the one-year crew increment that starts in March 2015. It continues with crewed SLS and Orion missions in cis-lunar space, including the rendezvous with the redirected asteroid. It will continue with new capabilities in deep space for habitation, in-space transportation, and joint science/exploration/technology missions to Mars. One such example is the Mars 2020 rover, which will conduct unprecedented science as well as exploration technology investigations to help plan for future human missions. Specific future missions will depend on factors including the incremental evolution of SLS capability. These missions will be informed by potential partnering opportunities, the ability to leverage technology developments, and the ability to leverage possible *in situ* resources. NASA

will be prepared to update the Congress on our strategy in any timeframe specified by Congress.

QUESTION 5a:

How are NASA's human exploration strategy and roadmap addressing the National Academies' Pathways to Exploration report guidance, which indicates that NASA can sustain a human exploration program that pursues the horizon goal of a surface landing on Mars only "when that program has elements that are built in a logical sequence, and when it can fund a frequency of flights sufficiently high to ensure the maintenance of proficiency among ground personnel, mission controllers, and flight crews"?

ANSWER 5a:

As noted in the ANSWER to Question #5, NASA's strategy is based on a logical progression from low-Earth orbit through the proving ground of cis-lunar space, where we can prepare for the long-duration missions to Mars-vicinity distances. SLS is being designed to be capable of supporting a long term potential 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 and available resources.

QUESTION 6:

What would be the criteria for a NASA decision to use the SLS to launch a future robotic science mission? How would NASA evaluate the costs and benefits of using SLS as compared to other launch vehicles?

ANSWER 6:

NASA is primarily focused on developing the SLS launch vehicle and the Orion spacecraft to provide the United States with a human capability to explore space beyond Earth orbit by 2021. NASA acknowledges this capability will be a national asset, one that can be used to the benefit of other national interests.

Major, flagship-class science missions (the kind that could potentially be the primary spacecraft payload on SLS) are informed and prioritized through the NRC decadal planning process. At this point, the space science decadal surveys have not identified any science missions over the decadal timeframes that would require SLS.

QUESTION 7:

You said during the hearing that radiation shielding is a major technology requirement for NASA's work in mitigating the risks of human space travel to Mars. What are the priorities for research and technology development on radiation shielding? Is there a timeline for completing the research and technology development, and if so, could you please provide it?

ANSWER 7:

Space radiation exposure is one of many risks to astronauts engaged in deep-space exploration and poses significant health risks for crewmembers, including the possibility of developing cancer later in life and radiation sickness during the mission. Since radiation shielding is a primary mitigation against exposure, NASA has made significant investments in shielding research and technology development. For example, Human Exploration and Operations Mission Directorate (HEOMD) has just completed the first phase of a project to develop spacecraft storm shelters for exploration spacecraft that can be used to protect crew against Solar Particle Events. The concepts and prototypes developed under this project will be implemented during the development of deep-space exploration vehicles. There is radiation protection capability on the ISS today. Its effectiveness is being measured and results are being incorporated into planning for future exploration spacecraft.

The highest priority with respect to exploration spacecraft shielding is to optimize the shielding design and associated computational tools so that shielding implementation can provide maximum protection to crewmembers, while minimizing the overall shielding weight. To meet this goal, HEOMD and the Space Technology Mission Directorate are working together on a Thick Galactic Cosmic Rays Shielding Project. The Advanced Radiation Protection project will use the NASA Space Radiation Laboratory at Brookhaven National Laboratory to study how to optimize shielding for space exploration missions. Although concerns over radiation exposure of astronauts may not be completely resolved, NASA expects to have the issues of the uncertainty in spacecraft shielding design and astronaut exposure behind this shielding resolved in 2018.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

"An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities"

Questions for the record, Mr. William Gerstenmaier, Associate Administrator for Human Exploration and Operations, NASA

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

QUESTION 1:

You previously have said that NASA is working towards an internal planning date for SLS for EM-1 that differs from the agency baseline, how does that affect the schedule for the EM-1 Orion module?

ANSWER 1:

The Exploration Mission-1 (EM-1) Orion spacecraft schedule is not impacted by the Space Launch System (SLS) Agency schedule commitment established at Key Decision Point-C (KDP-C) or by the internal planning date for SLS. The fact that SLS and Exploration Ground Systems (EGS) are slightly ahead of Orion is encouraging in that Orion is required for the last of the integrated testing and for the launch.

QUESTION 1a:

Is the Orion program working towards an internal planning date that matches SLS or do they have different internal planning dates?

ANSWER 1a:

The Orion Program Agency schedule commitment will be established at KDP-C for the spacecraft, slated for the third quarter of FY 2015. The internal planning date is under review.

QUESTION 1b:

How do you determine what is an acceptable gap between delivery of the EM-1 Orion vehicle and the SLS? What planning tools do you have in place to assess this schedule difference?

ANSWER 1b:

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 element 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. NASA is on a solid path toward an integrated mission and making progress in all three programs every day. We will establish an integrated EM-1 launch date at the end of CY 2015 after all element Critical Design Reviews (CDRs) are complete.

QUESTION 2:

Administrator Bolden testified before the Committee in April of 2013 that, "If I added $300M to the SLS program, you wouldn't know it." The President's Budget Request for Fiscal Year 2015 included a reduction of $219M relative to the 2014 enacted appropriation of $1.6B. The KDP-C completed by NASA in August of this year calls for a slip of the EM-1 launch date to 2018 due to low levels of funding requested by the Administration.

a. Please explain why the Administration did not request funding levels that would have kept the 2017 launch of EM-1 on track.

ANSWER 2a:

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). 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 Joint Confidence Level (JCL), respectively, to the EM-1 launch readiness date. The baseline commitment date was not due to "low levels of funding requested by the Administration." NASA will establish an Orion launch capability readiness date as a product of its Key Decision Point-C review in the third quarter of FY 2015, though the formal baseline for Orion will be for development through EM-2. 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 3:

In the FY 2013, FY 2014, and FY 2015 budget requests, the Administration asked for reductions of $175.1M, $87M, and $144.2M respectively for the Orion program relative to the enacted appropriations for those years. According to program manager Mark Geyer, "We're struggling to make December 2017, and I have a lot of challenges to make that date."

a. If the program was facing schedule challenges, why would you seek to cut funding for the program?

ANSWER 3a:

The context of the quote above is that Orion is working technical, rather than budgetary, challenges. NASA did not seek to cut funding for Orion: 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. As noted in the response to Question #2a, above, NASA will establish an Orion launch capability readiness date as a product of its KDP-C review in the third quarter of FY 2015.

QUESTION 3b:

Can NASA keep the EM-1 launch date on schedule with these reductions to the program?

ANSWER 3b:

The FY 2016 President's Budget Request provides the funding level needed to keep the cost and schedule commitments made for SLS and EGS on track for their launch readiness for EM-1. As noted in the ANSWER to Question #2a, above, the integrated launch date for EM-1 is to be determined after all three programs complete their CDRs.

QUESTION 3c:

How much schedule margin is the EM-1 Orion module currently carrying and how would reductions of nearly $200M a year affect that margin?

ANSWER 3c:

NASA will be able to determine the schedule margin Orion is carrying for EM-1 once the launch date has been established after all three programs complete their CDRs. Reductions in appropriated funding levels below the FY 2016 President's Budget Request would impact our ability to maintain progress, while increasing the risk posture of the Program.

QUESTION 4:

The SLS and Orion programs are being developed independently and have different schedules for their various Key Decision Points. At what point will NASA develop an integrated schedule which includes agency baselines that are matched up for the EM-1 and EM-2 launches?

ANSWER 4:

As noted in the ANSWER to Question #2a, above, the integrated launch date for EM-1 is to be determined after all three programs complete their CDRs. The integrated launch date for EM-2 would be set following the EM-1 mission. Program baselines are based on when each program's capabilities are developed; the Orion

Program will have a baseline that is to the completion of development for the crew capability, which is the EM-2 flight.

QUESTION 5:

While the successful EFT-1 mission demonstrates important components of Orion, the test vehicle did not have all the systems necessary to safely fly crew and, according to the program manager, is challenged to meet the 2017 EM-1 flight test.

a. Is SLS development being slowed to match a potential Orion delay?

ANSWER 5a:

No; please see ANSWER to Question #1b.

QUESTION 5b:

If Orion was not ready for the 2017 EM-1 launch, how would NASA manage the different schedules to ensure a stable workforce and supplier base?

ANSWER 5b:

When tasks related to EM-1 are completed within each program, the workforce can progress to EM-2. Within Orion, the program's development phase runs through the EM-2 launch and therefore there is significant non-EM-1 work also proceeding in parallel leading up to EM-2, such as the Ascent Abort-2 flight.

QUESTION 5c:

Could some of these risks be mitigated by allowing program managers to plan to year-long funding levels consistent with continuing resolutions rather than the President's budget request?

ANSWER 5c:

The FY 2016 President's Budget Request provides the funding level needed to keep SLS, Orion, and EGS on track, and program managers are planning to the year-of-execution funding level. Aggressive planning helps maintain progress; however, it brings risks that if requested levels are not enacted, content would have to be cut.

QUESTION 6:

According to GAO, the Joint Confidence Level (JCL) for SLS meeting a launch readiness of November 2017 is 30 percent and the JCL for Ground Systems meeting a launch readiness date of June 2018 is 30 percent.

a. Given the low confidence levels, how can NASA plan to a date any earlier than the agency baseline established by the SLS KDP-C?

ANSWER 6a:

The integrated launch date for EM-1 is to be determined after all three programs complete their CDRs.

QUESTION 7:

NASA has experienced multiple delays to the RS-25 testing schedule at the Stennis Space Center. How have these delays impacted the overall schedule for EM-1?

a. How have proposed reductions to the SLS program, as requested by the Administration, affected the engine testing schedule?

ANSWER 7a:

The delays encountered with the RS-25 testing were related to technical issues and the availability of engine controllers. Given that the Liquid Engine project funding levels have been steady for several years, there has been no adverse effect of proposed or enacted funding levels. The most recent successful RS-25 hot fire test has shown that the new engine controller software works as designed. This test shows good progress to date.

QUESTION 7b:

Even though Congress has appropriated more money for SLS than the Administration has requested, has this reduction in requested funding affected the purchase of long-lead items or the planning and scheduling of tests?

ANSWER 7b:

There has been no reduction in funding. Congress has added funds above the President's request each year of the program.

QUESTION 8:

GAO's recent report states, "According to the program's risk analysis...the agency's current funding plan for SLS may be $400M short of what the program needs to launch by 2017."

a. How is NASA mitigating this risk and why hasn't NASA requested increased funding for the SLS program if it is tracking such a risk?

ANSWER 8a:

Based on FY 2015 appropriated levels, this risk was retired in December 2014.

QUESTION 8b:

Has the value of this risk changed since the release of the report? What is the current value of this risk?

ANSWER 8b:

Based on FY 2015 appropriated levels, this risk was retired in December 2014.

QUESTION 9:

One of the risks in the SLS Program identified by the NASA Advisory Council and the National Research Council is the low flight rate of the Space Launch System. How is NASA planning to mitigate the risks associated with the current planned flight rate?

ANSWER 9:

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 and available resources. NASA is presently examining the safety aspects of the SLS flight rate.

QUESTION 9a:

How would that be impacted by funding reductions as requested by the Administration?

ANSWER 9a: Please see ANSWER to Question #9, above.

QUESTION 10:

If NASA reverted to the manner in which it applied termination liability to contractors under the Constellation program (as well as how it treats the ISS program and JPL), how much more money would that allow the scientists and engineers to devote to development work? How would that impact schedule?

ANSWER 10:

NASA's policy for funding termination liability obligations has remained consistent for at least two decades. For nearly every incrementally funded contract, NASA manages termination liability by using standard Federal Acquisition Regulation (FAR) clauses (Limitation of Funds (LOF), FAR 52.232-22). These standard government-wide LOF clauses instruct contractors to consider any potential termination liability when notifying NASA when their anticipated costs approach the limit of an increment of funding.

In a few cases, NASA Program and Contract management personnel have elected to use a Special Termination Cost Clause (STCC), which allows contractors to exclude termination liability costs when calculating the anticipated date of reaching the limit of a funding increment. In the few cases NASA has used one of these clauses, NASA follows the direction given in multiple Comptroller General opinions that an Agency must obligate or reserve funds equal to the termination liability referenced in the STCC (*e.g.,* Comptroller General, *USAF B1-B Core Program*, B-238581 (1990), "In similar situations, we have held that the government has obligated the amount of the termination liability"). When NASA reserves these funds in accordance with this Comptroller General direction for the exclusive purpose of covering the STCC termination liability, the funds are no longer available for contract performance.

QUESTION 11:

What is the current value of termination liability on the SLS and Orion contracts and how does the value of those liabilities affect the scope of the work the contractors are able to fulfill?

ANSWER 11:

The FY 2015 value of Program Termination Liability is on the order of $420M for SLS and Orion. Each contractor identifies and manages its own resources and determines how much of the available funding on the contract to allocate to potential termination costs. The contractors are working to enable application of more of the contract funds for performance.

QUESTION 12:

One option for NASA to handle potential termination liability is to use the special termination cost clause in these contracts. This would effectively allow them to free up those funds for development work. Has NASA considered using this clause and if not can you explain why not?

ANSWER 12:

Please see ANSWER to question #10, above.

QUESTION 12a:

Could NASA use uncosted or unobligated funds from other programs within the same appropriations accounts to cover the highly unlikely event of a termination for convenience on these national priority programs?

ANSWER 12a:

Uncosted funds are already obligated on contracts, although not yet invoiced and paid because the work has not yet been completed, and therefore are not available to cover termination costs on different contracts. For nearly every incrementally funded contract, NASA manages termination liability by using standard Federal

Acquisition Regulation (FAR) clauses (Limitation of Funds (LOF), FAR 52.232-22). These standard government-wide LOF clauses instruct contractors to consider any potential termination liability when notifying NASA when their anticipated costs approach the limit of an increment of funding. Therefore, it is incumbent on our contractors to set the level of liability and NASA must obligate funds within the contract to cover the stated liability. Therefore, unobligated funds from other programs are not available to address termination liability on these contracts with LOF clauses. It should be noted that the LOF clause permits contractor discretion on how to manage the risk of termination within the obligated amounts on contract. Contractors could apply funds toward actual work and progress instead of holding them for potential termination liability if they so desired based on their risk assessment.

QUESTION 12b:

Is this how other mission directorates currently handle this unlikely possibility?

ANSWER 12b:

No. NASA's policy used by all Mission Directorates has been to use the Limitation of Funds clause (FAR 52.232-22) in incrementally funded, multiple year, cost-reimbursable contracts to require the contractor to manage standard termination liability. In a few cases, NASA has used special termination cost clauses, as discussed in the ANSWER to question #10 above, in which NASA agrees to cover termination costs that exceed the amount contractually obligated under the LoF clause.

QUESTION 13:

In your written testimony you discussed the development of an integrated human and robotic exploration strategy that involved international partners.

a. What process did you use for the coordination of these efforts?

ANSWER 13a:

NASA, in partnership with 11 other space agencies around the world, has developed a Global Exploration Roadmap (GER) to outline a potential coordinated international strategy for deep space exploration. There is global consensus of the value of human and robotic exploration -- with Mars as the ultimate destination -- as reflected in the August 2013 GER released by the space agencies participating in the International Space Exploration Coordination Group (ISECG).

QUESTION 13b:

How has the international community responded to NASA's plans to forgo returning to the Moon in favor of the Asteroid Redirect Mission?

ANSWER13b:

The GER demonstrates the important role of NASA's Asteroid Redirect Mission (ARM) in advancing the capabilities needed for exploring Mars and the economic and societal benefits to humans on Earth that such exploration missions can bring about. This GER defines common goals for missions to the Moon, cis-lunar space, and Mars. There is common agreement among these agencies that cis-lunar space is the next best destination given the resources available in these countries to commit to space exploration. The GER also reflects that NASA and our international partners share a common interest in advancing a unified strategy toward deep-space exploration, with robotic and human missions to destinations that include near-Earth asteroids, the Moon and Mars.

Orion and SLS have the potential to support international partner activities in the vicinity of the Moon. In addition, NASA has identified a number of areas where international collaboration on the ARM could provide mutual benefit. Examples could include:

- Data sharing and lessons learned analysis involving other asteroid/small body missions;
- Asteroid identification and characterization, both near term as NASA works to down-select candidate asteroid targets, and longer term to support preparation for the selected asteroid;
- Asteroid capture system contributions including both deployable structures and autonomous robotic manipulators;
- Rendezvous sensor contributions that could be used for a wide range of mission applications including automated rendezvous and docking and asteroid characterization and proximity operations; and,
- Secondary payload contributions to either the Asteroid Retrieval Vehicle or the SLS that could advance either science or future exploration capabilities.

QUESTION 13c:

Did NASA condition its participation in the International Space Exploration Coordination Group Report on the include of an Asteroid mission?

ANSWER 13c:

No.

QUESTION 13d:

What discussions have you personally had with your international counterparts and what have those discussions yielded for cooperation in future exploration missions?

ANSWER 13d:

NASA senior leadership has regular teleconferences and meetings with our international counterparts around the world to discuss opportunities for international cooperation. This cooperation in space exploration will build on the foundation of the International Space Station (ISS). Senior Agency Managers representing the space agencies in the International Space Exploration Coordination Group (ISECG) meet regularly to discuss how coordinated and integrated space exploration activities can advance the interests of all the agencies, including NASA's plans for ARM, cis-lunar space and human exploration of Mars.

As reflected in the GER, NASA's international partners have expressed interest in the potential for participation in the Agency's future exploration missions, for NASA participation in their missions and collaborative ventures. To wit, the Heads of the ISS partner agencies released a statement following their November 2014, meeting that "In reviewing the strong commitment that enabled 14 years of continuous human presence on ISS in low-Earth orbit, the agency leaders noted the stable, solid, and robust ISS partnership that will serve as the basis for working together in future human exploration. The heads reaffirmed the ISS is the foundation for human exploration beyond low-Earth orbit highlighting its technical, scientific, and developmental capabilities. The ISS partnership will continue to advance the use of the ISS for the benefit of humanity." The specific level of involvement, and details of contributions to be made, will be determined in the years ahead. The Europeans' provision of the service module for Orion is illustrative of a desire for, and by, the international community to work with NASA on human exploration.

QUESTION 14:

The House-passed NASA Authorization Act of 2014 includes a requirement for an exploration roadmap that defines the specific capabilities and technologies necessary to extend human presence to the surface of Mars and the sets and sequences of missions required to demonstrate such capabilities and technologies.

a. What is NASA currently doing to plan for future missions beyond 2021?

ANSWER 14a:

NASA has been executing an integrated human and robotic exploration strategy leading to the human exploration of Mars. The capabilities required for a human mission to Mars have been understood in coarse terms for some time. How these might be optimally sized and assembled in a total space exploration architecture is the subject of current study. The implementation steps and investments, partner approaches, and technical pathways to Mars are varied. NASA will ramp up its capabilities to reach – and operate at – a series of increasingly demanding environments, while advancing technological capabilities with each step forward. This will include early test and demonstration activities in cis-lunar space as called for in the NASA Authorization Act of 2010. The Agency is tightly coupling the

planning of its science and technology portfolios with this strategy where appropriate.

QUESTION 14b:

Does NASA have an integrated step-by-step mission plan for getting humans to Mars and if so, how was it developed?

ANSWER 14b:

NASA has a goal of a human mission to Mars in the 2030s. NASA's exploration strategy is to move from today's Earth-reliant posture through the proving ground of cis-lunar space to an Earth-independent capability needed to extend human presence into the solar system and to the surface of Mars. This begins with research on the International Space Station (ISS), including the one-year crew increment that starts in March 2015. It continues with crewed SLS and Orion missions in cis-lunar space, including the rendezvous with the redirected asteroid. It will continue with new capabilities in deep space for habitation, in-space transportation, and joint science/exploration/technology missions to Mars. One such example is the Mars 2020 rover, which will conduct unprecedented science as well as exploration technology investigations to help plan for future human missions. 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 in a distant retrograde orbit around the Moon. 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 module. It will also depend on partnering opportunities, 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 (including lessons learned from the one-year crew increment on 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 14c:

Does this plan include the notional costs?

ANSWER 14c:

Please see ANSWER to Question #14b, above.

QUESTION 15:

The SLS Contractors recently began the process of informing their employees of layoffs (presumably due to funding shortfalls in the program) despite continued increases in funding from Congress above the President's budget request. The SLS contract is managed at the Marshall Space Flight Center (MSFC).

a. When did the program office notify you of the FY 2015 spending problems, and the need to enact layoffs to remain within the anticipated budget?

ANSWER 15a:

Please see ANSWER below to Question #15c for information about the SLS workflow, including SLS Core Stage passing Critical Design Review in June 2014, as well as the limitations on the June 2014 definitization of the Core Stage contract.

QUESTION 15b:

For the past three years the program has had stable funding above the Administration requests, and is performing ahead of schedule, and meeting the cost commitments. Why is NASA now in a spending crisis and where is the money being spent?

ANSWER 15b:

NASA is not in a spending crisis. For information on the SLS workflow, please see ANSWER below to Question #15c.

QUESTION 15c:

What caused the funding shortfalls and layoffs? Did a technical issue arise that required additional funding or were these planned budget transfers and layoffs?

ANSWER 15c:

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. Boeing manages its workforce as it determines necessary for its performance of the contract. SLS Core Stage passed Critical Design Review (CDR) on schedule in June 2014, as a major milestone toward SLS program CDR scheduled for FY 2015. Passing CDR is normally a point in development where design work ramps down, and the initial stages development plan recognized a reduction in the stages staffing in FY 2015 due to program maturation from design into production.

In addition, contract definitization was concluded in June 2014 for Core Stage, which included all efforts and materials for two Core Stage production units. The contract content included accelerated Core Stage 2 production, and assumed synergy with Exploration Upper Stage development. Fiscal year funding phasing was not part of the definitized contract. NASA and Boeing assumptions for FY 2015 funding were not aligned, and NASA and Boeing are working together to identify priorities for, and impacts of, the available funding for Stages. NASA plans contract action to align the Boeing Stages contract to available funding and concomitant launch schedule. SLS remains on track for its program CDR this year and for a launch capability readiness date no later than November 2018.

QUESTION 16:

The House passed bipartisan NASA Authorization bill includes direction for NASA to work with the Secretary of Defense and the Director of National Intelligence, to prepare a report that addresses the effort and budget required to enable and utilize a cargo variant of the 130-ton Space Launch System configuration.

a. How could these types of partnerships help decrease operational costs associated with the SLS?

ANSWER 16a:

The Department of Defense and the Director of National Intelligence have not to date identified any requirement for the SLS.

QUESTION 16b:

Have you reached out to other stakeholders and mission directorates to find areas of compatibility that could increase the predicted flight rate of the SLS? If so, what have you learned?

ANSWER 16b:

NASA is primarily focused on developing the SLS launch vehicle and the Orion spacecraft to provide the United States with a human capability to explore space beyond Earth orbit by 2021.

In 2014, the U.S. Air Force submitted a report to Congress entitled, "DOD Utility Assessment of the NASA SLS." As noted in the report, the Department of Defense "does not have any current requirement for this [SLS] large payload space lift capacity."

QUESTION 17:

In GAO's May 2014 report, GAO recommended NASA establish life-cycle cost and schedule baselines for each stage of development of the SLS program leading to EM-2. NASA responded that while they partially agreed with GAO's recommendations, they felt their approach was adequate, and that any further cost estimates should be delineated by each of the subsequent year's presidential budget requests. Why would NASA rely on the President's budget request to determine the cost and schedule of SLS development, instead of implementing a multi-year strategy based on long-term cost and schedule baselines designed by NASA?

ANSWER 17:

Orion and SLS are designed to be part of an evolving set of capabilities for deep-space exploration. NASA is currently reviewing different component configurations and phasing plans that will enable these capabilities. While the different versions of SLS will employ some of the same hardware (e.g., the Core Stage), the flexibility of

this approach means that different mission sets will become available at different times. Thus, NASA has chosen to focus its cost commitments on the initial operational capability of SLS (EM-1) and Orion (EM-2). NASA will provide the Congress with insight into the costs of block upgrades of SLS and Orion beyond their initial capabilities as the plans for those are adopted. In this way, the total cost of SLS and Orion will be apparent to the Congress for each stage of evolution. SLS and Orion are elements of an evolving multi-decadal space exploration infrastructure, not discrete missions. NASA is focused on efficient development of initial SLS and Orion capabilities with emphasis on evolvability and on constraining long-term production and operations costs.

Material requested for the record on page 42, line 883, by Representative Bridenstine during the December 10, 2014, hearing at which Mr. William Gerstenmaier testified.

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 in a distant retrograde orbit around the Moon, in the mid-2020s. 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 a potential habitation module. These missions will be informed by potential partnering opportunities, 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 (including lessons learned from the International Space Station [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. The outyear projections in the President's FY 2016 budget request set us on a course for achieving the goal of humans on Mars.

Material requested for the record on page 58, line 1273, by Representative Brooks during the December 10, 2014, hearing at which Mr. William Gerstenmaier testified.

The timetable for a human Mars mission will be determined by a number of factors, of which funding is one. 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 in a distant retrograde orbit around the Moon, in the mid-2020s. 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 a potential habitation module. 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 International Space Station [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. The outyear projections in the President's FY 2016 budget request set us on a course for achieving the goal of humans on Mars

Responses by Ms. Cristina Chaplain
Questions from Chairman Steven Palazzo

1) **In your written testimony, you indicated that of the three human exploration projects, SLS, Orion, and GSDO, Orion may be facing the most significant technical and funding issues. Would you please expand on the nature of those issues?**

   a. **How would reductions in funding like those requested by the Administration affect these issues?**

      The Orion program's top risk has been insufficient funding to support the uncrewed exploration mission-1 (EM-1) launch, even though the program has not established cost or schedule baselines. Insufficient funding affects the ability of the program to address known and unknown challenges, which increases the overall risk to the program. Program officials also report that while they would like to develop the human support systems required for the first crewed mission—EM-2—earlier, they cannot do that within the given budget profile. Any reductions to planned funding could impact the program's ability to meet the yet-to-be-determined dates for EM-1 and EM-2.

   b. **Does GAO believe the technical issues were foreseeable or are they a result of high-risk technology development?**

      While there are always unanticipated risks and challenges in any acquisition program, we believe that some of the current challenges in the Orion program were foreseeable, as they were originally identified in our prior work on the Constellation program. For example, we have previously reported on the design challenges for the heat shield development as well as the program's struggles to constrain the capsule's mass. The program is still analyzing the data collected from Orion's first exploration flight test, EFT-1, to inform decisions about the heat shield design. Also, the agency recently addressed a mass issue for EM-1 by alleviating some of the constraints for EM-1, but the program continues to track this risk for EM-2. Specifically, the program is working to reduce the total mass of the crew capsule as it is above required levels.

   c. **How could NASA or the contractor mitigate these risks?**

      In general, NASA should ensure that both the Orion program and the contractors are realistic in their risk assessments, and allocate sufficient funding and schedule to address issues.

   d. **How does the program track these risks internally and what do they currently assess would be the result if these risks are realized?**

      NASA would be in the best position to explain its risk management approach for Orion, but generally the program identifies risks and assigns each a likelihood of occurring and consequence of occurring. Additionally, the Orion program classifies each risk based on its possible impact on safety, performance, or schedule. Based on the combination of the likelihood and consequence associated with a risk, the program ranks those risks and reports on the top risks each month. Currently, the program is tracking a number of risks, including budget uncertainty, the parachute system, and the capsule's mass. The

program's assessment indicates that the likelihood of realizing these three risks is likely or nearly certain. The risks vary in their individual potential cost impacts, but range from $5 million to more than $500 million.

e. What is the likelihood that Orion and SLS will be ready for EM-l concurrently?

The likelihood of concurrent readiness for launch will be more apparent after the Orion program completes its confirmation review, which will include a joint cost and schedule confidence level (JCL) associated with the cost and schedule baselines. However, the Orion program faces a number of technical challenges that may impact the program's ability to be ready by November 2018—the SLS program's committed launch date.

f. Is NASA taking the appropriate steps to mitigate this schedule discrepancy? If not, what is NASA not doing that it should be?

The agency reports that it will wait until each program holds its critical design review in 2015 before establishing an integrated system schedule for EM-1. As I testified in December 2014, we are concerned about the lack of integration between the SLS, Orion, and GSDO programs. We believe the programs should be proactively integrating the separate risk systems and schedules in order to identify the risks associated with EM-1 and EM-2 as well as future missions. In addition, as significant risks may arise during this process, integration should occur as early as possible to allow the programs to address any issues that may materialize. The Aerospace Safety Advisory Panel also shares these concerns, stating in its January 2015 report that the panel continues to be concerned about the system's integrated risks.

2) If EM-l and EM-2 were delayed, what would the potential budgetary consequences be to the SLS program?

The potential budgetary impacts of delays of EM-1 and EM-2 on the SLS program will depend on why the flights are delayed. For example, if EM-1 or EM-2 were delayed because the Orion or GSDO programs were unable to meet the planned schedule—but the SLS program had met its schedule target—the SLS program's budget might not be affected. The SLS program could potentially continue work developing the exploration upper stage or the advanced boosters needed to increase the capability of the SLS vehicle. In the meantime, the completed EM-1 SLS launch vehicle could be held in a ready state until the Orion and GSDO systems were ready to support a launch. While the program could begin production of the EM-2 launch vehicle, as NASA Associate Administrator for the Human Exploration and Operations Mission Directorate Bill Gerstenmaier indicated during his December 10 testimony before your Committee, doing so would put the program at risk of proceeding without updated design information. Specifically, should data resulting from EM-1 indicate changes to SLS are necessary after construction of the EM-2 launch vehicle has already begun, redesign or rework could be costly and delay production.

If the flights were delayed due to SLS program delays, however, the result may be increased development costs to address whatever issue caused the delay. In the case of

the SLS program, the agency is maintaining a relatively flat budget profile—spending, on average, $118 to $142 million per month to execute the program. At this spend rate, every 4 months of delay equates to $472 to $568 million in cost growth for demonstration of the SLS Block 1 capability. Further, there may also be rippling schedule impacts that may increase program costs or delay the program's schedule. For example, the program is planning to continue development work between EM-1 and EM-2 for a new upper stage and boosters with increased capability. If the program has to use additional funds and time to address issues for EM-1, then the planned development efforts that would have used those funds would likely be delayed.

a. What could the potential consequences of such delays be on the agency's budget as a whole?

The potential consequences of delays on the agency's budget depend on the extent of the delay to the human spaceflight programs, whether funding is transferred from other agency programs to reduce the delay, or whether instead, the schedule is pushed to the right. In this era of relatively flat spending levels, increased spending on any project within NASA's portfolio could potentially result in reduced spending in other areas, but this is especially the case for its most expensive programs such as SLS and Orion. For example, an average month's spending for SLS—$118 to $142 million—would fund many science projects for a year or more. While the agency has more resources available than allocated to SLS, Orion and GDSO, the three programs comprise 18 percent of NASA's fiscal year 2015 budget. As such, cost and schedule growth on those three programs could have far-ranging impacts on NASA's budget for smaller projects if the agency has to absorb cost growth within human spaceflight with budget cuts in other areas.

3) You mentioned in your testimony that NASA was reluctant to request more funding to meet program demands.

a. What does GAO believe is the cause of this reluctance?

We cannot speak for the reasons behind NASA's reluctance to request more funding. This question would be best directed to NASA.

b. Has NASA responded to your finding that the agency is reluctant to request what it needs? What was their response?

In our July 2014 report, we found that NASA was not requesting funding for SLS necessary to meet its launch estimate of December 2017. We stated that the agency would need to increase funding, delay schedule, or both when NASA set the program's agency baseline commitment. In its comments on the report, NASA management concurred with our finding and stated that the SLS commitment baselines would be consistent with NASA policy. NASA subsequently increased SLS funding by $1.1 billion to $9.7 billion, and delayed SLS launch readiness by 11 months—to November 2018—relative to its preliminary cost and schedule estimates. While it remains unclear whether the program will meet the committed cost target or launch date, these revised estimates reduce schedule pressure and risk to the program.

4) **Your testimony refers to Orion's parachute and heat shield challenges. According to best practices, do you feel that adequate budget reserve is available should a significant redesign be necessary? Is there enough schedule reserve to ensure that appropriate changes are made to ensure both crew safety and technical completion for EM-2?**

Until the Orion program is confirmed, the program's documentation of available cost and schedule reserve is limited, so we are unable to determine if the program has sufficient budget or schedule reserve to address technical challenges. However, the Orion program has an aggressive schedule and will need to address several technical issues before it is ready for EM-1 or EM-2.

5) **At this past year's hearing on the President's FY 2015 budget request for NASA, Administrator Bolden indicated that providing more funding for SLS would not be helpful for completing the first version of SLS by 2017. However, your testimony states that the "top risk" for meeting its deadline for EM-1 in December 2017 is insufficient funding.**

a. **Would you please explain this discrepancy?**

As I testified, and GAO reported in July 2014, the SLS program has been tracking the availability of sufficient funding as a top program risk since its Preliminary Design Review in September 2013. In addition, senior SLS program officials discussed this issue repeatedly with us through the course of our reviews of the SLS program. We cannot speak to the discrepancy between the program's and Administrator Bolden's positions at that point. This question would be best directed to NASA.

b. **Would additional funding make meeting the December 2017 test flight possible or at least more likely?**

At this point, even with additional funding, the SLS program is unlikely to meet its internal goal of launch readiness by December 2017. As we reported in July 2014, and I testified in December 2014, the SLS development schedule to achieve the first test flight in December 2017 has always been aggressive. NASA's recently released JCL indicates that the program acknowledged it was only 30 percent likely to meet the December 2017 EM-1 launch readiness date, even with the increased appropriations the program had been receiving from the Congress. Further, at the time of the December 2014 hearing, NASA's Associate Administrator for the Human Exploration and Operations Mission Directorate stated that the technical work that remained before achieving readiness for the first test flight of SLS would not be complete by December 2017 regardless of any additional funding. He said that that as a result, the program was already looking at slipping its internal goal to spring 2018. Further, even if SLS were to be ready for launch by the December 2017 target date, the Orion, and GSDO programs are unlikely to be ready. Specifically, the GSDO program's JCL indicates it is unlikely to be ready for launch before November 2018, and the

Orion program faces a number of technical challenges that may impact the program's ability to be ready by November 2018.

c. Would additional funding decrease the likelihood of further schedule slips?

In July 2014, GAO reported on the necessity of matching resources, such as funding, to SLS requirements in order to reduce risks such as those related to the aggressive schedule for SLS core stage development and ensure long-term affordability. It is generally the case that additional funding or time can help to lower risks and provide acquisition programs with increased flexibility to address anticipated and unanticipated risks, especially when significant technological advances are not required, as is the case with the initial version of SLS.

6) In GAO's May 2014 report, GAO recommended NASA establish life-cycle cost and schedule baselines for each stage of development of the SLS program leading to EM-2. NASA responded that while they partially agreed with GAO's recommendations, they felt their approach was adequate, and that any further cost estimates should be delineated by each of the subsequent year's presidential budget requests. Why would NASA rely on the President's budget request to determine the cost and schedule of SLS development, instead of implementing a multi-year strategy based on long-term cost and schedule baselines designed by NASA?

We cannot speak for NASA's reasons behind its budget planning. This question would be best directed to NASA. However, without complete life-cycle cost and schedule estimates, NASA's ability to make important decisions about the affordability of the program in the context of the agency's overall budget and competing priorities is limited. Budget requests neither offer all the same information as life-cycle cost estimates nor serve the same purpose. An agency's budget submission reflects its current annual fiscal needs and anticipated short-term needs through an additional 4-year period for a particular program, is subject to change based on fiscal negotiation, and is not necessarily linked to an established baseline that indicates how much the agency expects to invest to develop, operate, and sustain a capability over the long term. Conversely, life-cycle cost estimates establish a full accounting of all program costs for planning; procurement; operations and maintenance; and disposal and provide a long-term means to measure progress over a program's life span.

7) The NASA Authorization Act of 2014, which passed the House with overwhelming bipartisan support in June, directs NASA to develop a Human Exploration Roadmap, which would outline the practical path and the necessary capabilities and technologies required to land humans on the surface of Mars. How would a roadmap of this type be useful for the development of SLS?

A human exploration roadmap would allow the agency to better define the development plan for the SLS launch vehicle and to identify and begin work on other systems—such as landing craft and habitation modules—necessary to execute potential future missions. In addition, a roadmap would provide industry with an indication of what direction the agency intends to take, including identifying the types of scientific investigations the

agency plans to pursue, so that companies can plan according to their interest in future hardware and software competitions. Finally, such a roadmap would provide longer-term information with which the Congress, GAO, and other independent groups (e.g. The National Academies) could provide oversight and independent analysis of the program's and agency's plans. Human exploration efforts will require a long-term commitment that spans several administrations. Without a clear path as to the direction of the program, the agency may not be able to maintain the necessary level of commitment, and risks leaving the United States with no ability to launch humans into space. In NASA's comments on GAO's 2015 Assessment of Selected Large-Scale NASA Projects, the agency identified a number of systems that the agency plans for the SLS to launch in the future. Until a human exploration roadmap is defined, however, NASA risks investing in systems that may not be needed for the first missions selected, or unintentionally delaying work on systems that will be needed to complete the initial mission. Likewise, without initial work to gauge the feasibility of the systems needed to complete proposed missions, the agency risks selecting missions that are not technically or programmatically executable. The Aerospace Safety Advisory Panel shares our concerns in this regard and reported in January 2015 that NASA should unambiguously articulate a well-defined purpose for the human space flight program and that without such a purpose, NASA's current "capabilities-based" investment approach will have "deleterious impacts on cost, schedule, performance, safety, and workforce morale," rather than deliver an integrated capability.

Questions from Ranking Member Donna Edwards

1) **NASA is taking the approach of incremental development for the SLS and Orion. Based on your work on major development programs for NASA and DOD, how often has the incremental development approached been used, under what circumstances, and what were the results? What are the pros and cons of this approach for NASA's SLS and Orion programs?**

   DOD has used incremental development to successfully field and modernize systems. For example, the F-16 program successfully evolved capabilities over the span of about 30 years, with an initial capability delivered about 4 years after development started. We have reported that an incremental acquisition strategy that sequences capabilities over time based on proven technologies and design can reduce risk and deliver capability sooner. This type of acquisition is actually the preferred approach in DOD's acquisition policy for acquiring new systems for more rapid delivery of incremental capabilities. NASA, however, does not commonly employ incremental development on its science projects. Most of these projects do not lend themselves to incremental development as there is, generally, only one of each spacecraft built.

   The benefits to NASA of using an incremental approach for the SLS and Orion programs are reduced time to first flight. Using such an approach, NASA should be able to fly vehicles from the initial increment sooner than if it had attempted to develop the final capability, which will require several technology advancements, from scratch. Our Cost Estimating and Assessment Guide also states that studies have shown that "from scratch" development of new technology costs more than incremental development.

   NASA needs to be clear on its long term goals as a potential downside of incremental development is that hardware developed for the initial increment may not be robust

enough to meet future needs. For example, if the core stage or main engines prove to be inadequate to meet the requirements of future missions, they may require costly redesign and retooled production facilities. Likewise, with Orion, if the design trades that NASA is making to reduce mass before EM-1 and EM-2 result in an inability to meet requirements of future missions, the capsule will require redesign and testing to ensure the design meets safety requirements.

2) **To what extent do the SLS and Orion programs incorporate existing "heritage" technology and to what extent do they reflect innovations?**

As part of our annual review of the NASA portfolio of major projects, the SLS and Orion programs both reported that they employ mostly heritage technologies and do not require new technology development. Orion has reported one new technology development—its heat shield coating material—along with multiple heritage technologies; the SLS program reports only heritage technologies. Both programs, however, report heritage technologies with technology readiness levels (TRLs) that indicate further development or operational use is necessary to determine if the technology meets design specifications.

a. **What challenges are associated with integrating heritage technology?**

The benefit of using heritage technology, designs, and hardware is that they are more mature and are available to the program without incurring the same development costs as a new start. Further, according to agency officials, even when issues do arise—as they can when addressing form, fit, and function—addressing these challenges involves less time, money, and overall effort than developing new technology and hardware.

The challenges associated with the use of heritage technology largely stem from the change of operational environment from the component's original use to its use on a separate program or vehicle. For the SLS, each heritage element shares the common issue of operating in the SLS environment that is likely to be more stressful than that of its original launch vehicle—the Space Shuttle—as well as unique integration issues particular to each element. Our work has shown that the use of heritage components can increase the risk of problems when the items are not sufficiently matured to meet form, fit, and function standards for the program that will be using the heritage component. Programs can also encounter challenges eliminating obsolete and/or dangerous materials from existing system designs. For example, the SLS program has encountered extensive challenges and over $80 million in cost growth associated with eliminating asbestos from the insulating material in the solid rocket booster.

b. **How would you characterize NASA's response to the challenges that GAO raised regarding the use of heritage technology on the SLS program?**

NASA concurred that the program faces significant challenges integrating existing hardware into new systems with more demanding operational environments.

3) **The GAO issued a report in July 2014 that stated that the "SLS's top risk was that the current planned budget through 2017 would be insufficient to allow the SLS as designed to meet the EM-1 flight date." The report also stated that the "the insufficient budget could push the planned December 2017 launch date out 6 months and add some $400 million to the overall cost of SLS development". While your testimony noted that NASA has improved the overall risk posture of SLS by delaying the EM-1 test flight to no later than November 2018, do you believe the recently enacted FY 2015 budget is sufficient to meet the schedule and budget plan established as part of the KDP-C for SLS?**

   Strictly using NASA's cost and schedule estimates that were included in the SLS KDP-C baseline documentation in August 2014, the enacted funding for SLS in FY 2015 is sufficient to fund NASA's plan to achieve launch readiness by November 2018.

4) **Now that NASA has established a cost and schedule baseline for the SLS program through its first launch, how should Congress evaluate the program's progress to ensure the program stays on track within the 70 percent confidence level of achieving the EM-1 launch on cost and schedule?**

   The SLS program, along with Orion and GSDO, make up a significant portion—18 percent—of NASA's fiscal year 2015 budget and are high-profile programs within the agency's portfolio. These human exploration programs have received Congressional support via annual funding levels above agency requests. As these programs move forward it will remain critical that Congress has continuing oversight into their progress. If requested, we can assess Orion, GDSO, and SLS in depth to help ensure the programs adhere to best practices and to provide early warnings of potential problems. Because they are intrinsically linked, it is important to track all three efforts.

Question from Congressman Jim Bridenstine

1) **After agencies submit their budget requests to the Office of Management and Budget, OMB "passes back" revisions it has made in response to the request. In the past, this Committee has attempted to get this documentation from OMB, and those requests have not been fulfilled. This is a crucial step in the budgeting process, as it highlights the differences between the Administration's views and those of the individual agencies. As this strikes me as a lack of transparency and accountability, would the Government Accountability Office support making these documents public?**

   It is GAO's view that Congress should seek whatever information it determines is necessary in order for it to conduct its oversight responsibilities. As you know, Congress established a framework for the budget and appropriations process to enhance budgetary efficiency and aid in the performance of constitutional checks and balances. In doing so, Congress centralized the authority for the formulation of the executive branch budget request in the President and Office of Management and Budget (OMB). OMB is responsible for coordinating and formulating a consolidated budget submission, including coordination of supporting documentation. GAO has described the budget and

appropriations process in more detail in the Budget Glossary and its treatise on appropriations law also known as the Red Book.[1]

[1] GAO, *A Glossary of Terms Used in the Federal Budget Process*, GAO-05-734SP (Washington, D.C.: May 18, 1993); *Principles of Federal Appropriations Law*, vol. 1, 3rd ed., GAO-04-261SP (Washington, D.C.: Jan. 2004).

Appendix II

Additional Material for the Record

PREPARED STATEMENT OF FULL COMMITTEEE
RANKING MEMBER EDDIE BERNICE JOHNSON

Good morning. I'd like to join my colleagues in welcoming our witnesses to today's hearing. We have much to discuss, so I will be brief in my opening remarks.

Last week, NASA achieved an important milestone with the successful EFT-1 flight test of the Orion crew capsule, and I want to congratulate you, Mr. Gerstenmaier, and the entire NASA and contractor team on a very impressive achievement.

I look forward to hearing more about EFT-1 and the significance of what you are learning from it. Equally importantly, I want to hear what lies ahead for the nation's human exploration program, because EFT-1 demonstrates that NASA's exploration program is no longer simply something NASA would like to do-it's now a reality, with hardware being built, facilities being prepared, and vehicles being tested.

Yet there is much more that will need to be done to achieve the long-term goal of landing humans on Mars. As we prepare for the 114th Congress, I think we need to heed the words of the distinguished National Academies panel that testified before us earlier this year. At that hearing, former Governor of Indiana and co-chair of the panel, Mr. Mitch Daniels, stated the panel's consensus view that the goal of sending humans to Mars "justifies the cost, risk, and opportunities" of doing so.

However, Mr. Daniels also made clear that the panel believed that "any pathway that could successfully land humans on the surface of Mars would require funding above constant dollars." That is pretty clear guidance. And yet, to date we have asked NASA to achieve its exploration goals on a budget that doesn'teven keep pace with inflation. We in Congress have the ability to correct that deficiency if we have the will to do so. I want to work with my colleagues on both sides of the aisle in the next Congress to provide the funding that NASA will need to carry out a robust human exploration program as well as its other important tasks in science, aeronautics, and technology development.

It is our choice as to whether we will do so, and I hope we will choose wisely. As I said after last week's successful EFT-1 mission, EFT-1 demonstrates that America's best days in space exploration still lie ahead of us. NASA and its contractor team are working hard to achieve challenging goals-we in Congress need to do the same.

Thank you, and I yield back.