DEEP SPACE EXPLORATION: EXAMINING THE IMPACT OF THE PRESIDENT'S BUDGET

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

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CONTENTS

October 9, 2015

DEEP SPACE EXPLORATION: EXAMINING THE IMPACT OF THE PRESIDENT'S BUDGET

FRIDAY, OCTOBER 9, 2015

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

The Subcommittee met, pursuant to call, at 10:17 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
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Congress of the United States
House of Representatives
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Subcommittee on Space

Deep Space Exploration: Examining the Impact of the President's Budget

Friday, October 9, 2015
9:00 a.m. to 11:00 a.m.
2318 Rayburn House Office Building

Witnesses

Mr. Doug Cooke, *Owner, Cooke Concepts and Solutions; Former Associate Administrator, Exploration Systems, NASA*

Mr. Dan Dumbacher*, Professor of Engineering Practice, Purdue University; Former Deputy Associate Administrator, Human Exploration and Operations Mission Directorate, NASA*

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

"Deep Space Exploration: Examining the Impact of the President's Budget"

CHARTER

Friday, October 9, 2015
9:00 a.m. – 10:30 a.m.
2318 Rayburn House Office Building

Purpose

At 9:00 a.m. on Friday, October 9, 2015, the Subcommittee on Space will hold a hearing entitled *Deep Space Exploration: Examining the Impact of the President's Budget*. The purpose of this hearing is to examine the President's five-year budget projection for the Space Launch System and Orion crew vehicle development programs. The Subcommittee will evaluate NASA's plans for future major tests and milestones and how the budget requested by the Administration affects development schedules and milestones for these programs.

Witnesses

- **Mr. Doug Cooke** – Owner, Cooke Concepts and Solutions and former NASA Associate Administrator for Exploration Systems
- **Mr. Dan Dumbacher**- Professor of Practice, Purdue University and former NASA Deputy Associate Administrator, Human Exploration and Operations Mission Directorate

Background

Following the Space Shuttle *Columbia* accident in February 2003, the subsequent investigation, and the policy debate on the future of human spaceflight with the retirement of the Space Shuttle, 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 for astronauts to return to the Moon, 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 this vision. The Constellation Program began with NASA's budget request for Fiscal Year 2005 and development of these systems continued until Fiscal Year 2010 (FY10).

[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 significantly cut the Constellation program's 5-year budget projection in the Administration's FY10 budget request released in May 2009,[2] and then directed NASA, through the Office of Science and Technology Policy, to establish a blue ribbon committee to review the plans and programs going forward. The Committee report observed that "[t]he U.S. human spaceflight program appears to be on an unsustainable trajectory" under the 10-year funding profile assumed in the President's FY10 budget.[3]

The President's FY11 budget request, released in February 2010 proposed to cancel the entire Constellation program. Additionally, 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 outlined his plans for NASA in a speech at Kennedy Space Center in April 2010. Later that year, Congress authorized some of the changes to the human exploration program, while mandating continued development of the Orion Multipurpose Crew Vehicle (Orion) and heavy-lift Space Launch System (SLS).[4]

Since the NASA Authorization Act of 2010, the President has consistently requested lower levels of funding for the SLS and Orion programs. Despite these annual reductions by the Administration, Congress continued to fund the programs at the levels necessary to keep the programs on track, eventually leading to the achievement of successful milestones such as Exploration Flight Test – 1 (EFT), the first uncrewed flight of Orion; Qualification Motor Test – 1 (QM-1), the first test of the five segment booster; and a test of the RS-25 engines that will power the SLS.

On August 27, 2014, NASA announced a one year slip of EM-1, the first launch of SLS, from 2017[5] to 2018.[6] This announcement was made despite numerous statements from NASA officials to Congress that the program was on schedule and that no additional funding was needed. Last month, NASA made a similar announcement about the Orion, pushing the launch readiness date for Exploration Mission-2 (EM-2) back two years to no later than 2023[7] from an original date of 2021.[8]

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[2] See page EXP-2 at http://www.nasa.gov/pdf/345955main_8_Exploration_%20FY_2010_UPDATED_final.pdf.

[3] See pages 7 and 9 of the report *Seeking a Human Spaceflight Program Worthy of a Great Nation* by the Review of U.S. Human Spaceflight Plans Committee (October 2009) found at: http://www.nasa.gov/pdf/617036main_396093main_HSF_Cmte_FinalReport.pdf

[4] NASA Authorization Act of 2010 (P.L. 111-267) found at: https://www.congress.gov/111/plaws/publ267/PLAW-111publ267.pdf

[5] 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.

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

[7] NASA Press Release, September 16, 2015, "NASA Completes Key Milestone for Orion Spacecraft in Support of Journey to Mars." Retrieved at: https://www.nasa.gov/press-release/nasa-completes-key-milestone-for-orion-spacecraft-in-support-of-journey-to-mars

[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.

Exploration Systems Development Budget

Budget Authority ($ in millions)	Actual 2014	Enacted 2015	Request 2016	FY15 vs FY16	Notional 2017	2018	2019	2020
Exploration Systems Development	3,415.2	3,248.3	2,862.9	(385.4)	2,895.5	2,971.7	3,096.2	3,127.1
Orion Multipurpose Crew Vehicle	1,197.0	1,194.0	1,096.3	(97.7)	1,119.8	1,122.9	1,126.7	1,138.0
Space Launch System	1,600.0	1,700.0	1,356.5	(343.5)	1,343.6	1,407.6	1,516.5	1,531.6
Exploration Ground Systems	318.2	351.3	410.1	58.8	432.3	441.2	453.0	457.5

The Exploration Systems Development program is responsible for the design, construction, and integration of the next step in human exploration beyond low-Earth orbit (LEO). There are three separate systems that make up the program; the SLS heavy lift rocket, the Orion, and Exploration Ground Systems (EGS). The President's budget request for Exploration Systems Development is $2.86 billion, an 11.7 percent reduction from the FY15 appropriation.

Orion Crew Vehicle – The Orion is the next generation crew vehicle that will carry astronauts beyond LEO. Although Congress has consistently appropriated roughly $1.2 billion per year for the development of Orion in recent years, NASA requested a reduction in funding for the fourth year in a row. The request of $1.096 billion is a reduction of approximately eight percent from the FY15 enacted levels. Last December, NASA completed Exploration Flight Test 1 (EFT-1), which is the first in a series of flight tests for the SLS/Orion systems. EFT-1 was a major success and was the subject of a Subcommittee hearing last December.[9]

Space Launch System – The SLS is the next generation heavy lift launch vehicle that will carry astronauts beyond LEO and will eventually have a 130 ton "lift to low-Earth orbit" capability, as required by federal law.[10] This year's request includes a reduction of approximately $343.5 million (20 percent) relative to the enacted FY15 levels.

Exploration Ground Systems - The Exploration Ground Systems program received an increase in the President's budget request of $58.8 million as a result of continued work at the Kennedy Space Center to ensure the facility is prepared to handle the SLS in 2018. NASA has stated that this work is on track for that launch date. Both the Government Accountability Office (GAO) and the NASA Inspector General have cautioned that potential schedule risks for the ground systems program could delay EM-1.[11]

[9] Subcommittee on Space hearing: An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities. See: http://science.house.gov/hearing/subcommittee-space-hearing-update-space-launch-system-and-orion-monitoring-development

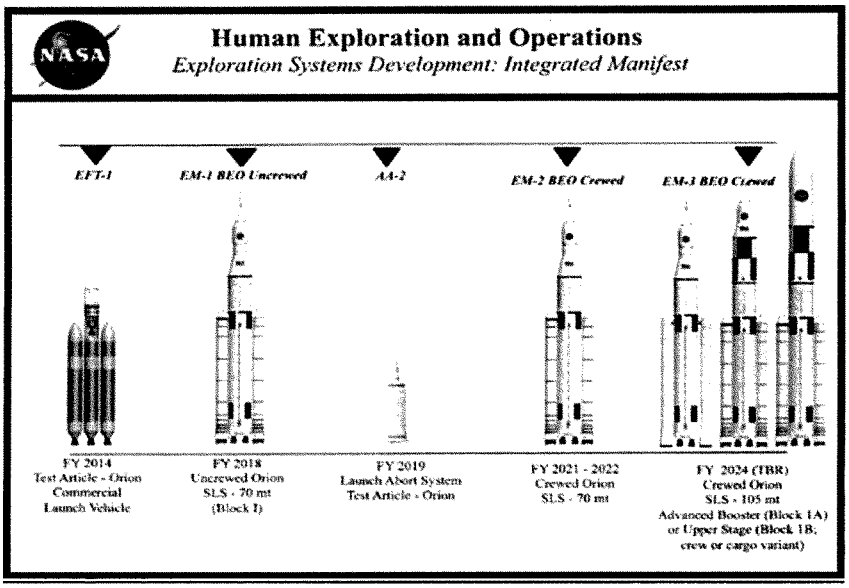
[10] 51 USC 18322(c)

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

SLS and Orion Schedule

The first test flight of the 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 conducted to validate various systems including Orion's heat shield, avionics, and parachutes used for landing. In FY18, 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 not later than 2023–would launch an Orion and SLS with as many as four astronauts.

The Orion and SLS programs are not currently baselined to the same launch readiness date. The Orion program baseline is committed for the EM-2 launch and the SLS program is committed for the EM-1 launch. NASA informed the Committee in previous responses to questions for the record that it will not create an integrated EM-1 launch date until the end of calendar year 2015 after all the element Critical Design Reviews (CDRs) are complete.[12]



[12] Testimony of Associate Administrator Bill Gerstenmaier in response to questions for the record for Science, Space, and Technology, Subcommittee on Space hearing on December 10, 2014, *An Update on the Space Launch System and Orion: Monitoring the Development of the Nation's Deep Space Exploration Capabilities.*

SLS KDP-C

In August of 2014, NASA completed Key Decision Point-C (KDP-C) for the SLS program, which included a cost and schedule commitment. In this agency baseline commitment, the Administration slipped the launch readiness date for EM-1 to November 2018 despite numerous assertions from the Administration that no additional funds beyond previous requests would be needed to keep the SLS and Orion on schedule. NASA program managers contend that there is a two pronged process to managing the SLS program.[13] The program has the official NASA agency baseline commitment used for cost controls and accounting measures as required under federal law[14] and separate from that is a "management agreement" or "internal planning date" used by program managers.[15]

According to NASA program managers, when building a JCL, they project funding levels in line with the President's budget request, as opposed to the amount previously appropriated for the program in the previous fiscal year or historical norm.[16] In the FY13, FY14, and FY15 budget requests, the Administration asked for reductions of $157.5 million, $75.1 million, and $219.7 million respectively.[17] Had Congress agreed to the requests compared to the enacted appropriation, the SLS program would have incurred over $450 million in reductions.

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."*[18]

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

> *"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..."*[19]

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[13] NASA Associate Administrator Bill Gerstenmaier testified on December 10, 2014 that NASA was internally planning to a different launch readiness date for the SLS than was in the agency baseline commitment. Hearing transcript retrieved at http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg92331/html/CHRG-113hhrg92331.htm.

[14] 51 USC 30104

[15] NASA Associate Administrator Bill Gerstenmaier testified on December 10, 2014. Hearing transcript retrieved at http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg92331/html/CHRG-113hhrg92331.htm.

[16] NASA Associate Administrator Bill Gerstenmaier testified on December 10, 2014 that the development of the JCL and the agency baseline commitment were "consistent with the President's budget request" and that NASA "[has] 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." Hearing transcript retrieved at http://www.gpo.gov/fdsys/pkg/CHRG-113hhrg92331/html/CHRG-113hhrg92331.htm.

[17] *Ibid.*

[18] 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.

[19] *Ibid.*

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, Administrator Bolden 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."*[20]

Despite these statements, the GAO 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."[21] Despite these claims and the finding of the GAO, when NASA released the KDP-C Decision Memo and the agency baseline commitment a year later, it supported a slip of one year in the launch readiness date for SLS from 2017 to 2018.

Orion KDP-C

Similarly, the Orion program recently finished KDP-C and released an agency baseline commitment. 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.

The next test of Orion, Exploration Mission-1 (EM-1), is scheduled for no later than 2018 (as supported by the delayed launch readiness date for SLS in the Administration's KDP-C) 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), was originally scheduled for 2021 (now not later than 2023) and will include the 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 17 (December 1972)

The President's budget request for the Orion has been 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.[22] 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 potentially longer delays.

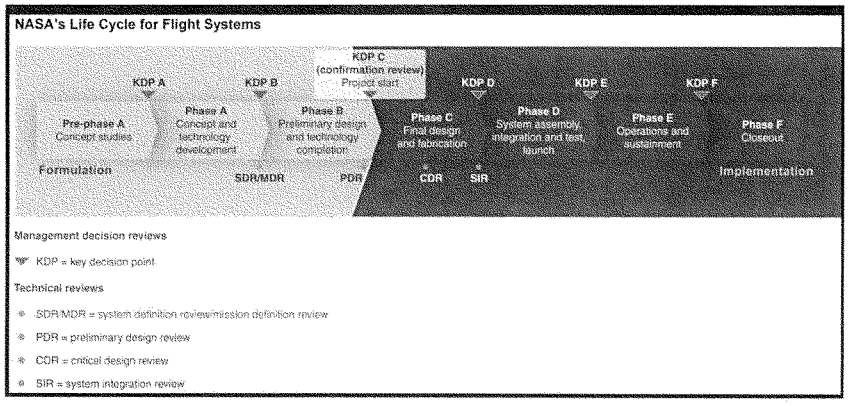
As with the SLS, the Orion KDP-C resulted in a launch readiness slip and the promise that program managers were working towards different internal dates than the agency baseline commitment.[23] The baseline includes a "no later than" date of April 2023 for launch readiness on

[20] 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.
[21] 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
[22] President's Budget Requests for Fiscal Year 2013, Fiscal Year 2014, and Fiscal Year 2015.
[23] NASA Press Release, September 16, 2015, "NASA Completes Key Milestone for Orion Spacecraft in Support of Journey to Mars." Retrieved at https://www.nasa.gov/press-release/nasa-completes-key-milestone-for-orion-spacecraft-in-support-of-journey-to-mars

the EM-2 mission. This is an indication that the Administration believes, with a 70 percent confidence level, that if the President's budget request was enacted, the Orion could be ready to launch for a crewed mission by 2023, directly in contradiction to the Administration's previous budget requests and the testimony of the Administrator which touted a launch readiness of 2021.[24]

Agency Baseline Commitment

All flight development programs at NASA go through a specific development cycle which includes management key decision points (KDP) to determine the fitness of a program for the next stage of agency commitments.[25] The graphic below from the GAO illustrates this lifecycle process and the various stages of development.[26]



Each of the KDP's represents a "gate" that the program must pass through to proceed to the next phase of development. There are three sub-phases of development in the "formulation" phase of the program. The most critical milestone for a flight development program, KDP-C, takes the program through preliminary design review into the implementation phase of development. During KDP-C, NASA makes an "agency baseline commitment"[27] to Congress and the Office of

[24] 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.
[25] Government Accountability Office Report Gao-15-320SP, released March 2015, "NASA: Assessments of Selected Large-Scale Projects." P. 5. Retrieved at http://www.gao.gov/assets/670/669205.pdf
[26] *Ibid.*, p. 6.
[27] NASA Procedural Requirement 7120.5E defines the agency baseline commitment as "an integrated set of project requirements, cost, schedule, technical content, and an agreed-to JCL that forms the basis for NASA's commitment to the external entities of OMB and Congress. Only one official baseline exists for a NASA program or project, and it is the Agency Baseline Commitment."

Management and Budget (OMB) on schedule and cost requirements. Progress on the project is measured against this baseline, including statutory reporting requirements.[28]

As part of the agency baseline commitment, NASA program managers provide Congress and OMB with a "joint cost and schedule confidence level" that justifies the agency baseline commitment on cost and schedule.[29]

Joint Cost and Schedule Confidence Level (JCL)

The JCL process essentially makes a commitment to Congress and OMB that the agency believes, given a specific schedule and budget requirements, it is confident that that program will be able to close out within the parameters of the agency baseline commitment. Beginning in 2009, in response to recommendations from GAO, NASA implemented a minimum 70 percent JCL for all projects undergoing a KDP-C.[30]

The development of a JCL is technical in nature and requires significant data analysis and risk modeling. According to the NASA Cost Estimating Handbook (CEH), "the backbone to the entire JCL analysis is the schedule. Having a quality schedule with logic networking is the key to a successful JCL."[31] According to the CEH, there is a six step process for the development of a JCL:[32]

> *Step Zero: Identify goals for the JCL*
> *Step One: Build a JCL schedule/logic network (a summary analysis schedule)*
> *Step Two: Load cost onto the schedule activities*
> *Step Three: Incorporate risk list*
> *Step Four: Conduct uncertainty analysis*
> *Step Five: Calculate and view results, and iterate as required*

According to NASA's CEH, the second step in the JCL development process is to build a schedule and logic network and then load cost for the schedule into the analysis. Put plainly, in the creation of the JCL, one must first determine the schedule and then determine the cost associated with that schedule. The CEH states that "once a robust schedule that accurately portrays project work flow is established, the next step is to costload the schedule. Cost loading is accomplished by mapping cost to schedule. You want to load the cost effort for each task by how that cost (or effort) interacts with the schedule activity." It is important to note that, in this

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[28] Section 30104 of title 51, U.S. Code, requires NASA to notify Congress if a program with a life-cycle cost of greater than $250 million is going to exceed its agency baseline commitment for either; cost of greater than 15 percent, or schedule by greater than six months. Programs that slip more than 25 percent must be reauthorized by Congress.

[29] NASA Procedural Requirement 7120.5E defines the joint cost and schedule confidence level as "(1) The probability that cost will be equal to or less than the targeted cost and schedule will be equal to or less than the targeted schedule date. (2) A process and product that helps inform management of the likelihood of a project's programmatic success. (3) A process that combines a project's cost, schedule, and risk into a complete picture. JCL is not a specific methodology (e.g., resource-loaded schedule) or a product from a specific tool. The JCL calculation includes consideration of the risk associated with all elements, regardless of whether or not they are funded from appropriations or managed outside of the project. JCL calculations include the period from KDP C through the hand over to operations, i.e., end of the on-orbit checkout.

[30] NASA Inspector General Report No. IG-15-024, "Audit of NASA's Joint Cost and Schedule Confidence Level Process." P.3. Retrieved at http://oig.nasa.gov/audits/reports/FY15/IG-15-024.pdf

[31] NASA Cost Estimating Handbook, J.1.6.2, p. J-11. Retrieved at http://www.nasa.gov/sites/default/files/files/CEH_Appj.pdf

[32] *Ibid.*

process, the development of a JCL schedule comes first and cost loading comes second. This sequence ensures that project development is driven by a logical schedule, rather than budget.

Key Questions

- When developing the JCL for the SLS and Orion, did NASA start with a schedule and cost load that schedule, or did it start with a budget and build a schedule to match it?
- When the Administration requires NASA to use the President's Budget Request instead of realistic appropriations levels as a baseline for the JCL, how does that effect the development of the program?
- How do large discrepancies between Congressional appropriations and budget requests effect management of the programs?
- Are NASA managers required to develop program development plans based on the President's budget request, or are they free to present realistic timelines and budgets in line with historic appropriation levels?
- How have the Administration's budget requests for large reductions in the SLS and Orion budgets affected the ability of NASA managers to run these programs efficiently and effectively?
- How are the risk reduction, schedule, and cost controls used by NASA to manage these programs affected by favorable Congressional appropriations?

Chairman BABIN. The Subcommittee on Space and will come to order, please.

Without objection, the Chair is authorized to declare recesses of the Committee at any time.

Good morning. Welcome to today's hearing entitled "Deep Space Exploration: Examining the Impact of the President's Budget." I recognize myself for five minutes for an opening statement.

Last week was an amazing time for the space community. A major Hollywood film about the exploration of Mars debuted within days of NASA announcing a significant scientific discovery: liquid water on Mars. The coincidence of these two events garnered the public's attention, and rightly so. Rarely does popular culture and science align in such a serendipitous fashion.

The attention also prompted obvious questions from the public such as "how will discovering water on Mars impact future exploration," "are we really going to Mars," and "how and when are we going to get there?" These are all questions that the general public may not have the answers to, but thankfully NASA does.

Because of bipartisan direction and investments made by Congress, we are well on our way to Mars. We are building the most powerful rocket ever built, the Space Launch System, so we can launch large payloads to beyond-Earth orbit with decreased risk to overall missions. We are building the Orion crew capsule so that our astronauts can travel farther into deep space than ever before, and we are upgrading our Ground Systems to support 21st century operations. NASA has already tested the RS–25 engines and five segment boosters that will power the SLS; they've already launched an uncrewed version of Orion; and the Kennedy Space Center is undergoing revolutionary upgrades.

But there is much more that needs to be done if the United States plans on launching a mission to Mars. We need to build a habitat module, advanced in-space propulsion, and a lander and ascent vehicle to name a few components.

Fortunately, we don't have to develop all of these capabilities at once. We can develop them incrementally over time. There are also potential opportunities for international and commercial partnerships that could be leveraged as well. The first step on the journey to Mars, however, begins with the development of SLS, Orion, and the related Ground Systems.

Unfortunately, Congress's support has not been matched by the Administration. In 2010, the President signed the NASA Authorization Act of 2010 into law, thereby directing NASA to develop the SLS and Orion systems. This piece of legislation was the product of a democratically controlled House and Senate that passed with 185 Democrats and 119 Republicans, demonstrating overwhelming bipartisanship. These programs are critical for the journey to Mars, and yet since 2010, the Administration has attempted to cut their funding every year.

This year alone, the President's budget request contains a cut of $343.5 million for SLS and a cut of $104 million for Orion. All told, the President's budget has requested nearly half a billion dollars in cuts to these programs this fiscal year. This Committee's NASA Authorization Act for 2016 and 2017 fully rejects these proposed

cuts, and both the House and Senate Appropriations Committees have approved bills to do the same.

Even though Congress consistently rejects the Administration's proposed cuts year after year, the proposed cuts still have a negative impact on the programs. The annual budget uncertainty that the Administration perpetuates impairs NASA's ability to manage the program efficiently on behalf of the taxpayer.

At the same time that the Administration has been strangling these programs, the NASA workforce has been diligently trying to keep the programs moving by setting up alternative cost and schedule commitments called Management Agreements. The agreements are separate from the official commitments in the KDP–C. While it is promising that NASA is trying to make the best out of a poor situation, having multiple plans could potentially lead to confusion and inefficiencies.

Fortunately, SLS and Orion have been successful in spite of the external challenges placed on the programs. This is largely thanks to the supremely professional workforce at NASA and the contractors. To all the hardworking men and women who are advancing the development of these programs, please know that your hard work is very much appreciated. Your work on these programs will inspire the next generation of explorers, maintain U.S. leadership globally, and chart new courses for humanity. Thank you for all that you do. You are the best this nation has to offer. My hope is that folks across the Administration will reverse course and begin to support the SLS and Orion programs, and the workforce that makes them possible, with the funding necessary to continue their success. SLS and Orion are crucial for deep space exploration, and the first steps to Mars.

We have two steely-eyed missile men before us today who were directly involved in the management of the human exploration program while they were at NASA. I look forward to hearing about how we can all ensure the success of our nation's human exploration program.

[The prepared statement of Chairman Babin follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
CHAIRMAN BRIAN BABIN

Last week was an amazing time for the space community. A major Hollywood film about the exploration of Mars debuted within days of NASA announcing a significant scientific discovery—liquid water on Mars. The coincidence of these two events garnered the public's attention, and rightly so. Rarely does popular culture and science align in such a serendipitous fashion. The attention also prompted obvious questions from the public such as "how will discovering water on Mars impact future exploration," "are we really going to Mars," and "how and when are we going to get there?"

These are all questions that the general public may not have the answers to, but thankfully NASA does. Because of bipartisan direction and investments made by Congress, we are well on our way to Mars. We are building the most powerful rocket ever built, the Space Launch System, so we can launch large payloads to beyond Earth-orbit (BEO) with decreased risk to overall missions; we are building the Orion crew capsule so that our astronauts can travel farther into deep space than ever before; and we are upgrading our ground systems to support 21st century operations. NASA has already tested the RS-25 engines and five segment boosters that will power the SLS; they've already launched an uncrewed version of Orion; and the Kennedy Space Center is undergoing revolutionary upgrades.

But there is more that needs to be done if the United States plans on launching a mission to Mars. We need to build a habitat module, advanced in-space propulsion, and a lander and ascent vehicle to name a few components.

Fortunately, we don't have to develop all of these capabilities at once. We can develop them incrementally over time. There are also potential opportunities for international and commercial partnerships that could be leveraged as well.

The first step on the journey to Mars, however, begins with the development of SLS, Orion, and the related ground systems. Unfortunately, Congress's support has not been matched by the Administration. In 2010, the President signed the *NASA Authorization Act of 2010* into law, thereby directing NASA to develop the SLS and Orion systems. This piece of legislation was the product of a Democratically controlled House and Senate that passed with 185 Democrats and 119 Republicans—demonstrating overwhelming bipartisanship. These programs are critical for the journey to Mars, and yet since 2010, the Administration has attempted to cut their funding every year.

This year alone, the President's budget request contains a cut of $343.5 million for SLS and a cut of $104 million for Orion. All told, the President's budget has requested nearly half a billion dollars in cuts to these programs this fiscal year. This Committee's NASA Authorization Act for 2016 and 2017 fully rejects the proposed cuts, and both the House and Senate Appropriations Committees have approved bills to do the same. Even though Congress consistently rejects the Administration's proposed cuts year-after-year, the proposed cuts still have a negative impact on the programs. The annual budget uncertainty that the Administration perpetuates impairs NASA's ability to manage the program's efficiently on behalf of the taxpayer.

At the same time that the Administration has been strangling these programs, the NASA workforce has been diligently trying to keep the programs moving by setting up alternative cost and schedule commitments called Management Agreements.

The agreements are separate from the official commitments in the KDP-C. While it is promising that NASA is trying to make the best out of a poor situation, having multiple plans could potentially lead to confusion and inefficiencies. Fortunately, SLS and Orion have been successful in spite of the external challenges placed on the programs. This is largely thanks to the supremely professional workforce at NASA and the contractors. To all the hardworking men and women who are advancing the development of these programs, know that your work is appreciated. Your work on these programs will inspire the next generation of explorers, maintain U.S. leadership globally, and chart new courses for humanity.Thank you for all that you do. You are the best this nation has to offer.

My hope is that folks across the Administration will reverse course and begin to support the SLS and Orion programs, and the workforce that makes them possible, with the funding necessary to continue their success. SLS and Orion are crucial for deep space exploration, and the first steps to Mars.

We have two steely-eyed missile men before us today who were directly involved in the management of the human exploration program while at NASA. I look forward to hearing about how we can all ensure the success of our nation's human exploration program.

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

Ms. EDWARDS. Good morning, and thank you, Mr. Chairman, and I want to welcome back our two witnesses, Mr. Dumbacher and Mr. Cooke, today, and I say "back" because both of you have appeared before our Subcommittee previously, as former leaders of NASA's human exploration programs. I appreciate your past public service as well as your willingness to testify here today.

Mr. Chairman, last December, millions of people in America and around the world tasted the future when NASA conducted the Exploration Flight Test-EFT–1 in which the Orion crew vehicle traveled farther into space than any human spaceflight vehicle since the Apollo era. That future is an exciting one that includes sending humans to the surface of Mars. And Mars is the goal that we established in our bipartisan House-passed, overwhelmingly House-passed, NASA Authorization Act of 2015. We sent it over to the Senate. And it's the consensus goal for human space exploration of

a distinguished National Academies panel that recently examined U.S. human space exploration.

So, it's quite fitting, Mr. Chairman, that we follow up on our Subcommittee's review of the Space Launch System and Orion crew vehicle programs that was held last December, just after the EFT–1 flight test, and see where these programs stand now. By any measure, the progress on SLS and Orion is visible and tangible. NASA and its contractors deserve credit for the many accomplishments achieved to date. Tests of the SLS solid rocket booster engines and the RS–25 main engine are reviving and modernizing the propulsion activities that brought us through the successful Shuttle era. Elements of the Orion crew vehicle that will return American astronauts to deep space are being fabricated even as I speak. And just a few weeks ago, the Orion program was approved to transition from formulation into development, a major milestone known as Key Decision Point C or KDP–C.

This hearing should provide an opportunity to discuss the outcomes of the Orion KDP–C review and clarify any questions, including the perception, by some, of a two-year "slip" to the first crewed flight test known as Exploration Mission-2, or EM–2. However, I would note that the members of the panel were not involved in this recent Orion KDP–C review. Only NASA can address questions regarding the KDP–C milestone, discuss the breadth of accomplishments achieved to date, and inform us of the challenges going forward. Only NASA can do that.

That's why, Mr. Chairman, I'm actually quite puzzled that NASA was not initially invited to testify, and why I extended an invitation to the Associate Administrator of NASA's Human Exploration and Operations Mission Directorate to serve as a witness. Unfortunately, the Associate Administrator's international travel schedule precluded his ability to appear this morning. So, I hope, Mr. Chairman, that we'll give NASA the opportunity in another hearing to provide the details on the SLS and Orion programs that this Subcommittee needs to hear.

The fact is that ensuring that SLS and Orion make maximum progress, especially in this environment of budgetary uncertainty, is a job for both the Administration and for Congress. And just as a side note, I would say that the budget caps known as the sequester give rise to the inability for us to get a multiyear bipartisan authorization and appropriation to the President's desk as the evidence of our support for SLS and Orion and for the journey to Mars. We have to lift those budget caps in order to accomplish the goals that we've set out for the agency and for its contractors. Ensuring that SLS and Orion make maximum progress, especially in this environment of budget uncertainty, is a job both for the Administration and for Congress. And as the National Academies report reminds us, achieving the goals for sending humans to deep space requires a joint commitment on the part of Congress and on the part of the Administration.

Mars is a goal that's worthy of this great nation, and I look forward to working with you, Mr. Chairman, to enable NASA's continued progress toward that goal.

And before I yield, I want to welcome an intern for a month in my office, Salil Maddy, who is at the Madeira School. We share in-

terns with them every year, and two of them here today are very interested in space, and so we welcome them.

And thank you, Mr. Chairman, and I yield back the balance of my time.

[The prepared statement of Ms. Edwards follows:]

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

Good morning. I'd like to welcome back our two witnesses, Mr. Dumbacher and Mr. Cooke. I say "back" because both of you have appeared before our Subcommittee previously, as former leaders of NASA's human exploration programs. I appreciate your past public service as well as your willingness to testify today.

Mr. Chairman, last December, millions of people in America and around the world tasted the future when NASA conducted the Exploration Flight Test—EFT-1—in which the Orion crew vehicle traveled farther into space than any human spaceflight vehicle since the Apollo era. That future is an exciting one that includes sending humans to the surface of Mars.

Mars is the goal that we established in our bipartisan House-passed NASA Authorization Act of 2015. And it's the consensus goal for human space exploration of a distinguished National Academies panel that recently examined U.S. human space exploration. So, it's fitting, Mr. Chairman, that we follow-up on our Subcommittee's review of the Space Launch System and Orion crew vehicle programs that was held last December, just after the EFT-1 flight test, and see where these programs stand now.

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However, I would note that the members of the panel were not involved in this recent Orion KDP-C review. Only NASA can address questions regarding the KDP-C milestone, discuss the breadth of accomplishments achieved to date, and inform us of the challenges going forward. That is why I was puzzled, Mr. Chairman, that NASA was not initially invited to testify, and why I extended an invitation to the Associate Administrator of NASA's Human Exploration and Operations Mission Directorate to serve as a witness. Unfortunately, the

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Mars is a goal worthy of this great nation and I look forward to working with you, Mr. Chairman, to enable NASA's continued progress toward that goal.

Thank you, and I yield back.

Chairman BABIN. Thank you, Ms. Edwards.

I now recognize the Chairman of the full Committee, the gentleman from Texas, Mr. Smith.

Chairman SMITH. Thank you, Mr. Chairman.

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 planet.

The American people are fascinated with space exploration. Just last week, the discovery that water sometimes flows on Mars' surface made headlines across the world. And the latest space film, The Martian, has sparked questions about when NASA will send astronauts to Mars. Today's hearing seeks to answer those questions and examine the effect of the President's budget on our exploration programs. In its fiscal year 2016 budget proposal, the Obama Administration proposed a cut of over $440 million from the programs that will take us to Mars: the Space Launch System and Orion crew vehicle. This isn't new; the President has tried to cut SLS and Orion every year since he took office.

But there should be no misunderstanding: there is bipartisan support within Congress for SLS and the Orion crew vehicle. This Committee restored the proposed cuts in our authorization bill, and the House and the Senate Appropriations Committees restored these funds and supported SLS and Orion at the levels necessary to keep their development on track. Yet the Administration continues to try to strangle these programs.

NASA recently announced that the first crewed mission for SLS and Orion was delayed by two years because the Administration would not allow NASA to budget for the programs. The Administration regularly cuts SLS and Orion, and Congress continues to restore its cuts. The budget instability caused by the Administration makes it hard for NASA to plan and execute these critical programs. The fact that NASA can still maintain these earlier dates in the face of Administration opposition is a testament to the ingenuity, resolve, and professionalism of the NASA workforce.

The Obama Administration cannot continue to claim that it prioritizes Mars exploration if it refuses to prioritize and support the programs that will get us there.

The SLS and Orion programs represent what is most impressive about the American spirit: our desire to explore. The technologies that are developed for these programs exemplify our greatest breakthroughs and demonstrate American ingenuity.

The Apollo program 50 years ago demonstrated that we could reach the Moon. Orion and SLS will take us beyond that and rekindle the American spirit of discovery and advance humanity farther in space than ever before. Congress will continue to ensure that these national priorities receive the funding they need to stay on schedule and on budget.

Great nations do great things, and fortune favors the bold. The next several years will determine whether American astronauts will be the first to plant a flag on Mars. We want them to have arrived there onboard an Orion crew vehicle, propelled by the Space Launch System.

Mr. Chairman, I also just want to comment on the recent handout that we have all seen by the Administration called "NASA's Journey to Mars." Regrettably, however, this proposal contains no budget, it contains no schedule, no deadlines. It's just some real pretty photographs and some nice words. That is not going to do it. That is not going to get us to Mars. This sounds good, but it's actually a journey to nowhere until we have that budget and we

have the schedule and we have the deadlines. And I hope the Administration will change its posture and decide in the future that it is actually going to support SLS and Orion and keep them on schedule because their proposals to cut SLS and Orion every single year is not helping us achieve the great goals that most Americans want to achieve in space.

And I'll yield back.

[The prepared statement of Chairman Smith follows:]

PREPARED STATEMENT OF FULL COMMITTEE
CHAIRMAN LAMAR S. SMITH

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 planet.

The American people are fascinated with space exploration. Just last week, the discovery that water sometimes flows on Mars' surface made headlines across the world. And the latest space film, The Martian, has sparked questions about when NASA will send astronauts to Mars.

Today's hearing seeks to answer those questions and examine the effect of the president's budget on our exploration programs.

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And I hope the administration will change its posture and decide in the future that it is actually going to support SLS and Orion and keep them on schedule because their proposals to cut SLS and Orion every single year is not helping us achieve the great goals that most Americans want to achieve in space.

Chairman BABIN. Thank you, Mr. Chairman.

I now recognize the Ranking Member of the full Committee, the gentlewoman from Texas.

Ms. JOHNSON OF TEXAS. Thank you very much, Mr. Chairman, and good morning. Let me welcome our witnesses. I look forward to your testimony.

In view of the uncertainties in today's schedule, I will be brief in my remarks so that we can have enough time for a good discussion with our witnesses.

This Committee has long supported a strong human spaceflight and exploration program for the nation. I'm excited about the prospect of America leading an international team to the surface of Mars not too many years from now. And I hope that our two witnesses, who have significant previous experience in NASA's human exploration program, will help us better understand the challenges NASA faces in realizing the goal.

NASA has just released its updated "Journey to Mars" report, and I hope that we will invite NASA to come before this Committee to discuss it. As Ms. Edwards has noted, NASA should really be at the table today for this hearing.

Getting to Mars will be very challenging. We all know that. And we know that it will take adequate funding if we are to get there efficiently and safely.

I have made no secret of my willingness to invest more in NASA, and this Committee has that authority. All we have to do is authorize it and its human exploration, aeronautics, science, and technology programs because it is an investment, not just spending, an investment that will pay long-lasting dividends to this nation as it has in the past.

But it's not just a question of more money. It's giving NASA more predictability as to when that money will actually show up. If this Congress is looking for reasons why NASA's exploration program faces potential delays, we need to look no further than ourselves right here on this Committee. Too many times in recent years, NASA has had no idea when it would actually get an appropriation, whether it would actually be reauthorized, whether that appropriation would be for more than a few months, or whether they may even have to suspend their work due to a government shutdown. That is no way that a government should treat a premier program and a premier R&D enterprise and its dedicated workforce to have it to operate.

If we are going to ask NASA and its contractors to carry out the extremely challenging job of getting America to Mars, this Congress is going to have do its job as well.

So I thank you, Mr. Chairman, and I yield back, and I wait to hear what you are going to authorize for this mission.

Thank you.

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

PREPARED STATEMENT OF FULL COMMITTEE
RANKING MEMBER EDDIE BERNICE JOHNSON

Good morning, and welcome to our witnesses. I look forward to your testimony. In view of the uncertainties in today's schedule, I will be brief in my remarks so that we can have enough time for a good discussion with our witnesses.

This Committee has long supported a strong human space flight and exploration program for the nation. I am excited about the prospect of America leading an international team to the surface of Mars not too many years from now. And I hope that our two witnesses, who have significant previous experience in NASA's human exploration program, will help us better understand the challenges NASA faces in realizing that goal.

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If we are going to ask NASA and its contractors to carry out the extremely challenging job of getting America to Mars, this Congress is going to have do its job too.Thank you, and I yield back the balance of my time.

Chairman BABIN. Thank you, Mrs. Johnson.

Let me introduce our witnesses now. First we have Mr. Douglas Cooke who will be testifying, the Owner of Cooke Concepts and Solutions, and a former Associate Administrator of Exploration Systems at NASA. This division is responsible for building Orion and the SLS, the two vehicles that will take humans to deep space destinations including Mars. Mr. Cooke is the recipient of several awards including the Presidential Distinguished Rank Award and Presidential Meritorious Rank Award. He has over 40 years of experience in human spaceflight. He received his bachelor's in Aerospace Engineering from Texas A&M University, and we're very happy to have him here today. Thank you, Mr. Cooke.

Our second witness today is Mr. Daniel Dumbacher. Mr. Dumbacher is a Professor of Engineering Practice at Purdue University. Mr. Dumbacher served as Deputy Associate Administrator in the Exploration Systems Development Division at NASA. He has received the Presidential Rank Award for Meritorious Service and the NASA Exceptional Achievement Medal. Prior to this 35-year career with NASA, Mr. Dumbacher earned his bachelor's degree in Mechanical Engineering from Purdue University and a master's in Business Administration from the University of Alabama. He is also a graduate of the Senior Managers and Government Study Program at Harvard University.

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

TESTIMONY OF MR. DOUG COOKE, OWNER, COOKE CONCEPTS AND SOLUTIONS; FORMER ASSOCIATE ADMINISTRATOR, EXPLORATION SYSTEMS, NASA

Mr. COOKE. Thank you, Chairman Babin——

Chairman BABIN. Mr. Cooke, if you could start over and turn on your mic.

Mr. COOKE. I apologize.

I want to thank Chairman Babin, Ranking Member Edwards, and from the full Committee, Chairman Smith and Ranking Member Johnson, and Members of this Committee for this opportunity.

My interest in human exploration of space has been a primary focus of my life and career since the flights of Yuri Gagarin and the Mercury astronauts. The success of programs to send people to the Moon and Mars is of paramount importance to me, and I believe to everyone.

I applaud your bipartisan support and the people at NASA and in industry who work diligently every day to make these and other NASA programs successful.

The important questions you're asking specifically address deep space exploration, so that is the part of the budget I'll address.

The most challenging aspect of managing these programs is due to constrained budgets and unplanned changes to operating budgets, whether real or contrived. The technical challenges are fun in comparison. The disparity between the President's budget request, or PBR, and budgets passed by Congress for exploration vehicles—the Space Launch System, Orion, and Ground Systems—causes problems in managing and executing these programs. It also causes issues in perceptions of program health.

To advance these programs Congress has consistently passed budgets each year that are significantly greater than the PBR. It has been clear Congress intends to follow through with this necessary funding, yet the Administration asks for less.

NASA managers are required to plan the complex development schedules to the PBR over the five-year runout. NASA fixed cost are included, and are a higher percentage of a lower PBR budget. This leaves less money for SLS and Orion progress. Constrained budgets limit what work can be accomplished more efficiently in parallel. It moves stated flight dates later than if they planned to Congressional budget runouts. Contracts are negotiated with companies for content and schedule, flight dates and expectations are set. When there are major policy or priority shifts or disruptions to the budget process on funding, these detailed plans and their interdependencies have to be changed, schedules and contracts are renegotiated at additional cost, adding to the problem.

As an example, the 2016 President's request for SLS, Orion, and Ground Systems is 2.86 billion. Under current spending under the Continuing Resolution, NASA should be spending at a rate commensurate with the 2015 level of 3.25 billion, or 382 million more. In fact, the current 2015 spending level is 118 million more than the President's budget proposes for the year 2020 in their five-year runout.

On the other hand, for 2016 alone, this year's House bill is 546 million over the President's 2016 request and the Senate's bill is 647 million more. If a budget bill is passed for NASA this year at these higher levels, the programs will adjust spending upward. Programs will make the most of these funds in advancing progress, but changing spending rates creates inefficiencies. They will still plan to the budget's reduced level for 2017 and beyond. I do advo-

cate for the higher levels. If the Administration would propose at needed values within small percentage points of consistent Congressional levels, spending rates would be much more stable and planning more reliable. I believe this disparity in policy priorities has remained since the cancellation of the Constellation program.

I was asked to comment on the use of the Joint Confidence Levels, an analysis used in the KDP–C milestones for SLS last year and the same milestone for Orion this year. These milestones led to NASA announcements of delays for SLS of a one-year and up to a two-year slip of the first crewed flight. Theoretically, the JCL is a good statistical analysis for evaluation of the uncertainties in programs that affect budget and schedule. An accurate JCL calculation requires meticulous collection of extremely detailed tasks, costs and schedules; costing program resources.

The JCL provides a valuable function for rigorous inspection of a program. However, from my direct experience in implementing it, I believe it has little utility for predicting schedule milestones in this budget environment when planning to the President's budget request rather than actual Congressional appropriated budgets. JCL outcomes become a self-fulfilling prophecy. Because actual budgets are actually higher year-to-year, NASA tries to maintain earlier planning dates and is trying to mitigate this confusion but could be more efficient if the source of confusion were not there.

There are significant differences in budget and oversight practices between the Commercial Cargo and Crew and the traditional exploration programs. With the experience gained thus far, best practices should be established for both while preserving safety and accountability.

SLS and Orion are first critical developments in our human exploration of the solar system. They are making great progress in spite of these burdens.

I want to thank the Committee and your staff again for your continued support of NASA and human spaceflight. I have submitted further detail in my written testimony, and welcome your questions. Thank you.

[The prepared statement of Mr. Cooke follows:]

Hearing of the House Committee on Science, Space, and Technology
Subcommittee on Space

"Deep Space Exploration: Examining the Impact of the President's Budget"

Friday, October 9, 2015

Testimony of Douglas R. Cooke
Cooke Concepts and Solutions

Thank you Chairman Babin and members of the committee for the opportunity to address important budget-related aspects of running Deep Space Exploration programs; the Space Launch System, the Orion Crew Vehicle and the associated Ground Systems. I applaud your bipartisan support. I also applaud the people at NASA and in industry who work diligently every day to make these and other important NASA programs successful.

My interest in human exploration of space has been a primary focus of my life and career since the flights of Yuri Gagarin and the Mercury astronauts. The success of programs to send people to the Moon, Mars and its moons is of paramount importance to me, and I believe important to everyone for many reasons. I began work at NASA after Apollo. I worked on Space Shuttle, Space Station and Exploration Programs anticipating the day Americans would travel again and explore places like the Moon and Mars. I believe in the idea that NASA human space flight should focus on exploration beyond Low Earth Orbit and transfer the routine travel to Earth orbit to American companies, as they are ready, safe and become certified.

The questions you are asking here are important ones that specifically address Deep Space Exploration, and the impacts of the President's budget. That is the part of the NASA budget I will focus on.

The most challenging aspect of management and successful execution of these programs is the impact of constrained budgets and unplanned changes to operating budgets, whether real or contrived. The technical challenges are fun in comparison and engineers can solve them.

The disparity between the President's Budget Request and budgets passed by Congress for Exploration vehicles (i.e., the Space Launch System and Orion) causes problems in managing these programs. It also causes issues in perceptions of program health.

To advance these programs Congress has consistently passed budgets each year that are significantly greater than the President's Budget Request (PBR). It has been clear Congress intends to follow through with this necessary funding, yet the Administration continues to ask for less.

NASA managers are required to plan the complex development schedules to the President's Budget Request over the 5-year runout, rather than the more probable budgets passed year after year by Congress. NASA fixed costs, including people and facilities are included, and are a higher percentage of the lower PBR budget, as compared with the budgets appropriated by Congress. This leaves less money for SLS and Orion progress. Constrained budgets limit what work can be accomplished in parallel and moves stated flight dates later than if they planned to Congressional budget runouts.

Another constraint applied to program budgets is protection for Termination Liability, where funds are held back to cover costs in case the program is terminated for the convenience of the government. Currently this is approximately $420M for SLS and Orion. Since these amounts are held back from spending, they are not available for program execution. It is the responsibility of the contractors to protect for this, but the biggest source of unnecessary uncertainty has been created by the Administration that has enforced this legal requirement using the most onerous terms.

The constrained President's budget also affects the content of the programs and the decisions NASA can make. NASA talks about evolving the SLS and Orion design developments. Their development is evolving because there isn't sufficient funding in the Administration's planning budget to design and build the components of the complete vehicles in parallel. That would be more efficient than taking wasteful intermediate steps. For example, the SLS Program could likely move forward with the Exploration Upper Stage if they could plan on receiving Congressional budget levels. The first test flight of the SLS will use the Interim Cryogenic Upper Stage (ICPS), a modified Delta upper stage with a lift capacity of about 70 metric tons to orbit. If the SLS Program could count on the appropriated budget levels, it could make the decision now to fund the Exploration Upper Stage (EUS). If it were ready for the first crew flight with Orion and SLS, NASA would save about $150M on human rating the ICPS for that flight, a cost that will otherwise be wasted in the long term. (The $150M human rating cost is according to a recent article, quoting NASA.) This $150M could then also be applied to the EUS development. The SLS would have lift capability of over 100 metric tons for exploration missions with the EUS upper stage.

The SLS design itself is a compromise, because there wasn't enough money in the President's budget to build what was considered to be the best design. However, it is still a very good design. The preferred design would have used the RS-68 engine for the Core Stage. These engines are currently used on the Delta. The engine production would have been least expensive long term but cost more in the near term. The RS-68 based Core Stage design would have required engine modifications necessary for human rating and a new large diameter tank design.

Since the Shuttle was being retired we could use the remaining used RS-25 Shuttle main engines for the first few SLS flights. They were in hand, human rated and low cost. RS-25s are more efficient than the RS-68s and can use the smaller Shuttle diameter

tank. We could not afford the larger diameter tank for the RS-68s at that time. As the existing inventory of Shuttle engines is used up, however, this engine design will have to be modified for follow-on engines to simplify the nozzle design and to make them less complex to manufacture.

Between Bill Gerstenmaier and myself, we decided we could afford only the Core Stage with RS-25s, because of the near term cost difference. It had to be started right away to catch up with other SLS components. We already had the five segment solid boosters well underway, in full scale testing, and under contract with ATK. We would come back to develop an advanced booster with more performance when we could afford it. We had an upper stage design for Ares I from the Constellation Program that could be modified under contract with Boeing, for SLS.

These are examples of the kinds of decisions that are driven by a severely constrained budget. At that time were "under the gun" to have an Independent Cost Assessment to show there was a reasonable chance of executing this program within the budget. That was before we would be allowed to announce the SLS design and move forward with the program. This announcement eventually occurred in September 2011.

Another example of budget inefficiency is associated with the Orion Pad Abort Test in 2010. The test was flawless. Unfortunately, contractors who were critical to the success of the test were laid off, because under funding constraints, the next Orion development priorities required the funding. So people with important knowledge and experience in an important spacecraft design were lost. That system will obviously be used again and the knowledge will have to be reestablished.

Under constrained budgets, the Orion Program has also had to back off of full concurrent development of its systems, which would allow for all systems to be developed in parallel in a more integrated manner. This has been necessary to focus on flight test milestones such as EFT-1 last December. Now they will focus on what is needed for the EM-1 test with SLS and evolve to the full crew vehicle design for EM-2. This too is inefficient as compared with full concurrent development. Generally speaking, the inability to use concurrent development will add cost to a program and draw out the schedule.

These are just examples of the inefficiencies associated with overly constrained budgets. Planning with Congressional Budget levels and NASA being able to state what is really needed for these programs would result in much more efficient developments and lower long-term costs to the nation.

Another source of inefficiency is budget instability or unanticipated changes. Contracts are negotiated with companies for content and schedule. Flight dates and expectations are set. When there are major policy or priority shifts, or disruptions to the budget process and funding, these detailed plans and their interdependencies have to be changed. Schedules and contracts are then changed at additional cost, adding to the problem. These issues are not new with the current programs.

My first major encounter with this problem was on Space Station Freedom, when in 1993 I was on a red team review. It was apparent that one major problem was that the budget was changed year to year resulting in major contract changes every year. Following the redesign and transition to the International Space Station Program, Congressional budgets were initially stable at $2.1B per year. Although not optimum from a development standpoint, we could plan to that and make steady progress.

Continuing Resolutions create perturbations in spending rates, as programs are required to plan for the least amount from the current year funding, or the House or Senate appropriations bill levels. NASA has tended to protect for the worst possible scenario based on anti-deficiency regulations. If an appropriations bill is passed later, any additional funds are released later in the year. Although beneficial to the program, this creates inefficient spending profiles.

Using the current case, the 2016 President's Request for SLS, Orion and Ground Systems is $2.863B. Under the current Continuing Resolution NASA should be spending at a rate commensurate with the 2015 level of $3.245B, or $382M more. In fact, the current spending level is $118M more than the President's Budget proposes for the year 2020 in their 5-year runout. On the other hand, for the fiscal year 2016 alone, this year's House Bill is $546M over the President's 2016 Request and the Senate's Bill is $647M more. These varying budget levels over a 5-year runout have a significant effect on schedule and program content, and ultimately the pace of human exploration.

If a budget bill is passed for NASA this year at these higher levels, the programs will adjust spending upward. Programs will make the most of these funds in advancing progress, but changing spending rates creates inefficiencies. NASA will still have to plan to the President's reduced level for 2017 and beyond. I am an advocate for the higher levels. If the Administration would propose budgets at needed levels within small percentage points of consistent Congressional levels, spending rates would be much more stable. This would allow for much more efficient program development at a faster pace, with much better value for the taxpayer. This is particularly true for long-lead time programs which are required to advance a robust space exploration program.

I believe a disparity in policy priorities has remained since the cancellation of the Constellation Program in February 2010. This was obviously the biggest program disruption imaginable. Congress immediately reacted to ensure that contracts would not be cancelled until a reasonable outcome could be resolved. That policy outcome was the NASA Authorization Act of 2010. It was not until September of 2011 that the final Administration hurdles were cleared. That was when the SLS program was announced.

Unstable budgets for Exploration programs did not begin or end there. Beginning budget projections for Exploration and Constellation in 2005 were adversely affected by budget issues. Reductions included funds for the last 2 Shuttle flights that OMB did not provide for. In 2009 there were deductions for Soyuz seats to ISS, the cost of cargo missions to ISS, transfers to help Shuttle Transition and Retirement and transfers to

other NASA mission priorities. Admittedly there were also natural program content changes with increased costs as designs were refined. There was a full year continuing resolution in 2007, and Exploration lost $577M. This did not affect Constellation, but we cancelled a lunar robotic lander mission to protect programs that were higher priority. This basically eliminated most Exploration Program flexibility afterwards. The original intent in the NASA planning was that Exploration would be increased with the wedge from retirement of the Space Shuttle. That did not happen, because the Shuttle funds went to other Administration policy priorities, not Exploration.

The 2010 President's Budget Request (generated in 2009) transferred out of the 2009 Exploration budget projected runout about $1B in 2011 to 1.7 B in 2013, basically eliminating human lunar mission long lead content through 2014. This was the budget that the Augustine Committee was given to evaluate in 2009. In their report "Seeking A Human Space Flight Program Worthy of a Great Nation," the Augustine Committee stated:

Options for the human spaceflight program: The Committee developed five alternatives for the Human Spaceflight Program. It found:

- Human exploration beyond low-Earth orbit is not viable under the FY 2010 budget guideline.
- Meaningful human exploration is possible under a less-constrained budget, increasing annual expenditures by approximately $3 billion in real purchasing power above the FY 2010 guidance.
- Funding at the increased level would allow either an exploration program to explore the Moon First or one that follows the Flexible Path. Either could produce significant results in a reasonable timeframe.

Constellation was cancelled the following February 2010.

I was asked to comment on use of the Joint Confidence Levels, an analysis used in the KDP-C milestone of SLS last year and the KDP-C milestone of Orion this year. These milestones led to NASA announcements of delays for SLS of one year and up to a two-year slip of the first crewed flight. Theoretically, the JCL is a good statistical analysis tool for evaluating uncertainties in programs that affect budget and schedule. An accurate JCL calculation requires meticulous collection of extremely detailed program schedules with planned tasks and their costs measured against available budget and reserves. To assemble this data is a monumental effort, costing significant program

resources. The JCL provides a valuable function for rigorous inspection of a program. However from direct experience with implementing it, I believe it has little utility for predicting schedule milestones in this current budget environment, when planning to the President's Budget Request rather than the actual Congressional appropriated budgets. Uncertainties created outside the program swamp uncertainties inside the program.

In contrast, the Commercial Orbital Transportation Services (COTS) development of cargo transportation capability to the International Space Station (ISS) did not require development of a JCL and doing so was not possible under a Space Act Agreement in any event. To my knowledge "Commercial Crew" capability development does not have a JCL either. I am not sure it is even possible, since these are fixed cost contracts with cost sharing. NASA also waived "Certified Cost and Pricing" from FAR regulations in these contracts. Therefore NASA does not necessarily have the cost data or programmatic insight to perform this independent analysis. In my view, the only estimates of flight dates are what the provider claims. Yet for SLS and Orion, scrutiny is intense and NASA announcements of flight date slips are due to a JCL that is based on questionable assumptions. JCL outcomes can become self-fulfilling prophecies.

Because budgets are actually higher year-to-year compared to the President's Budget Request, programs maintain earlier planning dates. This is positive, but the situation creates confusion and headlines. To their credit, NASA is trying to mitigate this confusion internally and externally. It would be better if the source of uncertainty were not there in the first place.

Even under the duress of these burdens, excellent progress is being made on Deep Space human space flight programs. Companies from our aerospace industrial base are now building flight hardware that we will see launched and flown. SLS and Orion are these first critical developments for our human exploration of the Solar System. They have both reached their Key Decision Point-C (KDP-C) milestones where NASA commits to their technical, cost and schedule baselines.

The International Space Station (ISS) is providing the means for human research, testing and technology demonstrations in preparation for human exploration missions to the Moon, Mars and other destinations. Astronaut Scott Kelly and Cosmonaut Mikhail Kornienko have completed six months of a one year stay on the ISS, adding to the significant body of human research that is being conducted to prepare for Mars missions. Six months is the approximate transit time between the Earth and Mars. Methodical research and technology testing on ISS provide information needed for astronaut health and leads to reliable systems for them to thrive and be productive on exploration missions. Great progress is being made on mitigating the effects of weightlessness and other issues.

NASA is well into development of a heavy lift rocket, the Space Launch System (SLS). It is essential for Mars missions to minimize the number of launches and provide large payload volumes. The SLS has recently completed its Critical Design Review (CDR),

where the program demonstrated that it is ready to proceed to full-scale fabrication, assembly, integration and testing. This will lead to its first test flight with Orion, EM-1. The SLS core stage welding of the first tank is underway. Avionics are being tested. The five segment solid booster project is preparing for the second full scale qualification test firing. The RS-25 engines have completed the first series of engine firings at 109% thrust levels, higher than was flown on the Space Shuttle. A new engine controller has been designed to replace the Shuttle controller and was tested in this series.

The Orion spacecraft, successfully flight tested last December, will be the launch and high speed entry spacecraft needed to safely return exploration crews.The successful Orion EFT-1 flight test demonstrated many spacecraft systems, including navigation, guidance, flight control, ground control of the spacecraft, electronic systems, the high speed entry heat shield, landing systems, ground processing and others. Efficiencies in the design and manufacturing are being made based on that experience. The heat shield is being lightened. Welds have been significantly reduced to improve manufacturing. The next flight spacecraft is now being built. Between SLS and Orion, the Michoud Assembly Facility in Louisiana is filling with flight hardware.

Our international partners want to explore with us. For that reason, they also depend on the success of these programs; and genuine progress is being made. With the progress made and the amazing potential for future exploration, the SLS and Orion programs deserve good stewardship. The NASA-industry team should be afforded the opportunity to manage to the best of their abilities, in a stable, positive budget environment. The espoused goal of going to Mars needs to be supported with appropriate funds and positive help from the Administration, including OMB and OSTP.

In addition to the budget issues discussed, there are a related set of points. To provide the best opportunity for success and efficiency for all programs, I believe a strong effort needs to be made by NASA to draw the appropriate line in:

- Division of development responsibilities between government (NASA) and contractors.
- Insight and oversight of programs
- Streamlined human rating requirements, including safety.
- Verification of requirements and hardware certification
- Parts quality and inspection
- Contracting practices

The objective is to have the most efficient NASA programs possible, while preserving safety, accountability for the essential requirements, and accountability for taxpayer dollars.

There are significant differences between the way "Commercial Cargo and Crew" and the more traditional SLS and Orion programs are run with regard to these points. With the experience gained thus far, best practices should be established that could be applied to both.

Again, I want to thank this committee and your staff again for your continued support of NASA and human space flight.

I welcome your questions.

Short Biography: Douglas R. Cooke

Doug Cooke is an aerospace consultant with over 42 years in human space flight programs. He advises on company and program strategies, program management, proposal development, strategic planning and technical matters. He retired from NASA after a 38-year career at Johnson Space Center (JSC) and NASA Headquarters, where in his last 3 years he served as the Associate Administrator of the Exploration Systems Mission Directorate (ESMD). In his last year at NASA, he led efforts to adopt the current vehicle designs for the Orion and Space Launch System. During his career, he had senior leadership responsibilities and achievements during critical periods of the Space Shuttle, ISS, and Human Exploration human spaceflight programs. As Associate Administrator, Mr. Cooke was responsible for the Constellation, Lunar Reconnaissance Orbiter, Lunar Crater Observation and Sensing Satellite, Commercial Cargo and Crew, Human Research and Exploration Technology Programs. Prior to this he was Deputy Associate Administrator of ESMD, since its formation in 2004. He has been in leadership positions for most of NASA's advanced studies in human space exploration since 1989, including the White House studies "The 90 Day Study" in 1989 and the "Synthesis Group Report, America at the Threshold" in 1990. He also had several high priority detail assignments to other NASA centers and NASA Headquarters. Mr. Cooke was NASA technical advisor to the Columbia Accident Investigation Board in 2003. He is on the Board of Advisors for the Coalition for Space Exploration and a member of the National Research Council Space Technology Roundtable; Mr. Cooke has also been a member of the International Space Station (ISS) Advisory Committee.

Mr. Cooke has received the Presidential Distinguished Rank Award, Presidential Meritorious Rank Award, NASA Distinguished Service Medal, three NASA Exceptional Achievement Medals, NASA Outstanding Leadership Medal, NASA Exceptional Service Medal, two JSC Certificates of Commendation, a number of NASA Group Achievement Awards, and the Space Transportation Association Lifetime Achievement Award. Most recently he was awarded the Texas A&M Outstanding Aerospace Engineer Alumni Award. Mr. Cooke received a B.S. in aerospace engineering from Texas A&M University.

Chairman BABIN. Thank you, Mr. Cooke. We appreciate it.

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

TESTIMONY OF MR. DAN DUMBACHER,
PROFESSOR OF ENGINEERING PRACTICE,
PURDUE UNIVERSITY;
FORMER DEPUTY ASSOCIATE ADMINISTRATOR,
HUMAN EXPLORATION AND
OPERATIONS MISSION DIRECTORATE, NASA

Mr. DUMBACHER. Chairman Babin and Members of the Committee, thank you for the opportunity to discuss NASA's deep space exploration efforts on this, the 31st anniversary of Astronaut Kathy Sullivan's spacewalk. On this day in 1984, Dr. Sullivan, current NOAA Administrator, became the first U.S. woman ever to see the Earth from that unique vantage point.

I thank you also for your support of our nation's space exploration efforts. It is an honor for me to represent Purdue, a public land-grant university, educating the next generation of explorers. I find the students of today to be part of a curious, passionate, and dedicated generation. These young voters are ready to build and create a better future for all of us.

And, as a former NASA team member, I want to express my utmost respect for the NASA/industry team's accomplishments in the current environment. This team is working on a scale larger than Apollo with a constrained budget. Much like today's students, their enthusiasm and dedication to the mission is evident every day and sets the leadership example.

The NASA 2010 Authorization Act and the 2014 Pathways to Exploration Report from the National Research Council provide a sound, inclusive basis for space exploration goals and objectives that should be adequately funded.

I believe we are at a critical juncture in our exploration efforts. As we continue missions to extend our presence further into the solar system, we must build the foundational capabilities for humans to go onward: the Space Launch System and Orion. We must effectively utilize humanity's principal technological achievement, the International Space Station, as an exploration test bed and valuable research facility, and we must seed the initial phases of commercial space travel.

Given the budget instability and continuous policy debates, the NASA/industry team is making great progress. The team is dedicated to building all systems as safely as possible, as soon as possible, and as cost-efficiently as possible. The Space Launch System has successfully passed its Critical Design Review along with engine tests, booster tests, and structures that were flight-tested last December. The Orion capsule completed its first flight test last December, and is proceeding to systems testing. Orion's European Service Module is on track for the first flight and launch infrastructure is on schedule.

Keeping these critical programs on schedule is essential for two reasons. One, the United States needs to continue to maintain our global leadership in space. We must leave this legacy of leadership

for the next generation. Two, schedule equals cost. Maintaining funding stability, and therefore schedule, is essential to minimizing the cost of these programs. NASA's leadership, plans, and management implementation reflects the need for cost efficiency with reduced insight/oversight, reduced management and integration overhead, all while carefully maintaining and improving crew safety over previous systems.

Budget stability is the major issue in executing these programs. All players in the appropriations process have a stake in maintaining this budget stability. This budget stability has two basic components. First the annual debate between the Executive Branch request and Congressional appropriations is an important factor that drives inefficiency. The second aspect of budget stability is the recent history at the national budget level of continuing resolutions and government shutdowns. Both components lead to cost and schedule impacts to the programs via continuous re-planning, confusion across the entire team, and loss of team focus.

NASA diligently manages risk, cost, and schedule through daily, direct contractor interaction, periodic element program reviews with detailed discussions of technical and programmatic progress, issues, and risks. The Joint Confidence Level is a model risk-based approach to assess potential technical and programmatic uncertainties and their possible sensitivities and impacts to the cost and schedule of a program. This has proven to be successful in robotic mission programs but is much more difficult for the large, longer term programs such as the Space Launch System and Orion.

In summary, the biggest challenge in developing the Space Launch System, Orion, the launch support infrastructure, and Commercial Crew is budget stability, not the eventual technical issues. Managing these programs efficiently and effectively is the result of the dedicated NASA/industry team across this country, and the international partners.

The government-funded Lewis and Clark expedition helped open the frontier for the commercial development of rail transportation and other opportunities to the West Coast. Today, NASA is opening the frontier of space and helping to build the space economy.

Thank you for your time and attention. I look forward to your questions.

[The prepared statement of Mr. Dumbacher follows:]

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Testimony before the
House Science, Space, and Technology Subcommittee on Space
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Washington D.C.

October 9, 2015

Chairman Babin, and Members of the Committee, thank you for the opportunity to discuss NASA's Deep Space Exploration efforts on this, the 31st anniversary of astronaut Kathy Sullivan's space walk. On this day in 1984, Dr. Sullivan – current NOAA Administrator - became the first US woman ever to see the Earth from that unique vantage point. I thank you for your support of our Nation's space exploration efforts.

It is an honor for me to represent Purdue, a public land grant university, educating the next generation of explorers. I find the students of today to be part of a curious, passionate and dedicated generation. I see this everyday with the students and my three children. These young voters are ready to build and create a better future for all of us.

And, as a former NASA team member, I want to express my utmost respect for the NASA / Industry team's accomplishments in the current environment. This team is working on a scale larger than Apollo with a constrained budget. Much like today's students, their enthusiasm and dedication to the mission is evident every day and sets the leadership example.

The National Aeronautics and Space Administration Act of 2010 clearly provides the goals and objectives for future space exploration, including the use of the International Space Station for human exploration research, testing and, "enabling an expanded commercial presence in, and access to, low-Earth orbit...", also development of the Space Launch System, Orion, launch support infrastructure, and a balance of human and robotic missions. These are the key elements needed to continue this Nation's space exploration enterprise.

In the 2014 "Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration" from the National Research Council, it is recommended that NASA:

1. "Commit to design, maintain, and pursue the extension of human presence beyond low earth orbit...."
2. "Maintain long term focus on Mars as the "horizon goal" for human space exploration..."
3. "Establish and implement the pathway approach..."
4. "Vigorously pursue opportunities for international and commercial collaboration..."
5. "Engage in planning that includes mission requirements and a systems architecture..."

These recommendations from diverse perspectives should serve as the basis for an overall strategy and plan of human exploration, a plan that Congress and the Administration should adequately fund.

I believe we are at a critical juncture in our exploration efforts. As we continue missions to extend our presence further into the solar system and beyond, we must build the foundational capabilities for humans to go onward. We must effectively utilize humanity's principal technological achievement, the International Space Station, as an exploration test bed and valuable research facility, and we must seed the initial phases of commercial space travel.

Future generations, as well as today's societies, are dependent on the development and exploration investments being made today. Think for a moment what it would be like if all cell phone service ceased, satellite weather imagery ended or, medical research on health and aging, happening right now in zero-g, was stopped. Investments in space projects provide us with the capability to continue the human quest for discovery. They let us apply those discoveries here on Earth, enriching private industry with new technologies, new markets, and valuable opportunities.

There is no doubt that among all of the important priorities that this Nation and others need to address, space exploration is valuable, yet its costs need to appropriately fit within funding constraints. It is also clear to me that long-term sustainability of exploration is at least partially dependent upon increasing the space economy and fostering commercial opportunities.

Given the budget instability and continuous policy debates, the NASA / Industry team is making great progress. The team is dedicated to building all systems as safely as possible, as soon as possible, and as cost efficiently as possible.
The Space Launch System, its Orion capsule, and their support infrastructure together create the needed foundation for US expansion beyond Earth's boundaries. Each of the Programs is making significant progress, despite substantial fiscal obstacles. The team is diligently working to build this powerful launch vehicle, and its spacecraft, to reach Mars and eventually, go beyond. The Space Launch System has successfully passed its Critical Design Review, the milestone that approves the final drawings and manufacturing processes for the entire system, along with engine tests, booster tests, and structures that were flight-tested last December. The Orion capsule completed its first flight test last December, and is proceeding to systems testing. Orion's European Service Module is on track for the first flight. Launch infrastructure is on schedule - the retooling of Vertical Assembly Building has begun, along with the launch support structure being outfitted.

Keeping these critical Programs on schedule is essential for 2 reasons. (1) The U.S. needs to continue to maintain our global leadership in space. We must leave this legacy of leadership for the next generation. (2) Schedule equals cost. Maintaining funding stability, and therefore schedule, is essential to minimizing the cost of these Programs. These Programs are significant resource investments in terms of people and money. It is imperative that we diligently work to develop and operate the SLS and Orion as cost efficiently as possible. NASA's leadership, plans, and management implementation reflects the need for cost efficiency, with reduced insight / oversight, reduced management / integration overhead, all while carefully maintaining and improving crew safety over previous systems. For example, NASA has reduced, by almost an order of magnitude, the systems integration funding requirements, as compared to previous human spaceflight programs. NASA is applying the lessons learned from its project and programs such as DC-X/XA. NASA is also working to integrate the latest in technology, such as advanced manufacturing, to reduce costs while maintaining or improving performance and safety.

This team is being asked to develop hardware to go further into space than ever before, with new levels of reliability and safety, all on a flat line budget. Each year the budget policy debates, continuing resolutions, and late year appropriations result in endless, multiple planning scenarios. This is in addition to the challenges of technically complex programs.

Budget stability is THE major issue in executing these programs. All players in the appropriations process have a stake in maintaining budget stability. NASA and their

industry partners are being asked to develop unprecedented, critical capabilities within a contentious, constrained, and ever changing budget environment. How can they resolve complex technical issues, hold schedule, and predict flight dates with pin point accuracy if their budget is constantly in flux?

Budget stability is driven from 2 basic aspects. First, our Constitutional appropriations process requires an Executive Branch budget proposal and Congressional appropriations for NASA. The very nature of this debate requires the NASA / Industry team to develop a set of Program plans to meet the proposed budget, and then be prepared for significantly modified Congressional appropriations. This debate alone causes the team to develop significant program planning and execution options and is the major component of budget stability.

The second aspect of budget stability is the recent history at the National budget level of continuing resolutions, government shutdowns, brinksmanship of the appropriations process, and tardiness in receiving final appropriations. These all lead to cost and schedule impacts to the Programs, in addition to the continuous debate between the President's Budget Request and Congressional appropriations.

This unpredictable process leads to significant inefficiency. The need to constantly have backup plans for each potential appropriations outcome, different budget planning levels, along with flexible workforce blueprints, all but invites confusion and miscommunication – at all levels, from the Administration to the technician on the manufacturing floor. Let me be clear, I am speaking of inefficiency **externally** imposed on the NASA / Industry team. Yes, appropriations increases are obviously helpful, and have been vital in the Programs' progress to date, but budget stability is key to a well-executed Program.

NASA diligently manages risk, cost and schedule through daily, direct contractor interaction, periodic element / program reviews with detail discussions of technical and programmatic progress, issues, and risks. Reviews are conducted at all levels of the Programs, at the Exploration Systems Division, and Human Exploration and Mission Operations Directorate levels. Technical status and risks are addressed and fed into the budget planning cycles. During my tenure, NASA provided OMB a bi-weekly briefing on the status and issues of the SLS, Orion, and Ground Systems Programs. Similar status briefings were provided upon request to House and Senate staff. All of these steps were utilized along with the Joint Confidence Level analysis.

Joint Confidence Level is a model / risk based approach to assess potential technical and programmatic uncertainties and their possible sensitivities / impacts to the cost and schedule of a project or program. The models analyze project risks, and budget /

schedule uncertainties to develop combined probabilities of success from cost and schedule viewpoints. In the past, NASA has used the 70% Joint Confidence Level as the Agency commitment to Congress as required by Public Law 109-155 (Nunn-McCurdy). In this analysis, NASA uses the President's Budget Request as the budget baseline, and makes assessments assuming higher and lower budget estimates to understand the impact on the schedule. This has proven to be successful in robotic mission program planning and commitment mainly due to specific expected launch dates for science objectives, and therefore a known life cycle of a project or program. NASA has been working to apply this process to human spaceflight programs; however, this is proving difficult due to the longer duration of these programs. Large human spaceflight, single-project Programs, that are long term investments, to be used over multiple decades, have relatively undefined life cycles. These Programs are subject to greater budget planning uncertainty due to overall economic conditions and Presidential / Congressional policy changes. The September 29, 2015 NASA IG report on the NASA JCL Process states "...JCL policy may not be suitable for single-project programs..". This caution should apply to SLS/Orion/Ground Systems use of the JCL process. I must add that during my tenure, the process of analyzing the detail program plans, risks, sensitivities, and uncertainties has resulted in more thorough planning for SLS.

In the most recent announcement of Orion, and the Agency approval of the Key Decision Point – C, it was noted that the new crewed flight date is April 2023. This date is based on model analysis of projected costs, risks and uncertainties, of the detailed program plan, including expected budgets, and calculating a combined 70% probability of success. **This is only an estimate.** NASA openly stated that they continue to work toward the 2021 date.

During my tenure, NASA would continue to work toward an earlier date, what is known as a management agreement, to keep sufficient focus on doing what is needed, minimize unnecessary work, and thereby execute the Program as efficiently as possible. All of this while being very careful to make sure safety and technical decisions are sound. In Orion's case this is the 2021 crewed flight date.

NASA is an Executive Branch Agency that works with and responds to the Office of Management and Budget (OMB). Therefore, NASA communications with the Legislative Branch are coordinated with OMB and the Office of Science and Technology Policy. Budget planning follows a typical process, of bottoms-up development and top down assessment to assure budgets are developed based on program realities, Human Exploration and Operations Mission Directorate priorities, and Agency priorities. Once the Agency has developed a budget request, it is then transmitted to OMB for review and negotiations within National priorities to support

the Presidents Budget Request submittal to Congress. During my tenure, OMB was involved only at the Agency level and not directly in the detailed Program budget prioritization.

In summary, the biggest challenge in developing the Space Launch System, Orion, the launch support infrastructure, and Commercial Crew is budget stability. Managing these Programs efficiently and effectively is the result of the dedicated NASA / Industry team across this country, and the international partners. The team demonstrates every day their ability to deliver. NASA carefully manages the Programs at all levels, recognizes the cost constraints, and most importantly assures the future safety of our space travellers.

The government funded Lewis and Clark expedition helped open the frontier for the commercial development of rail transportation and other opportunities to the West Coast. Today, NASA is opening the frontier of space and helping to build the space economy.

Thank you for your time and attention. I look forward to your questions.

Daniel L. Dumbacher

Daniel (Dan) L. Dumbacher is a Professor of Engineering Practice in the School of Aeronautics and Astronautics at Purdue University. He teaches courses in systems thinking, systems engineering, and space policy. He is also helping establish the Purdue Systems Collaboratory to bring together the many perspectives and disciplines needed to address complex problems for today and the future, as well as prepare the next generation of practitioners, researchers, and leaders in systems thinking.

Prior to joining the faculty at Purdue, Mr. Dumbacher served as the Deputy Associate Administrator, Exploration Systems Development Division, for the Human Exploration and Operations Mission Directorate at NASA Headquarters. In that capacity, he provided leadership and management as the Program Director for Exploration Systems Development encompassing the Space Launch System, Orion, and Ground Systems Development and Operations (GSDO) development and integration efforts. He led a team of over 5000 people spanning all NASA Centers and Industry. He was responsible for a $3B annual budget.

From 2007-2010, Mr. Dumbacher served as the Director of the Engineering Directorate at NASA's Marshall Space Flight Center. Appointed to the position in May 2007, Mr. Dumbacher led an organization of 1,400 civil service and 1,200 support contractor employees. Under his leadership, the Engineering Directorate supported the Space Shuttle propulsion elements, design and development of the Ares launch vehicles, operation of NASA's Payload Operations Center—the command post for scientific research activities on board the International Space Station, and supported all Marshall Space Flight Center International Space Station and Science missions.

Previously, Mr. Dumbacher was Deputy Director of the Ares Projects Office and, prior to that, was Deputy Director for Product Assurance in the Safety and Mission Assurance Office, focusing on Space Shuttle return-to-flight efforts. Other assignments included Manager of the X-37 Flight Demonstrator, Deputy Manager of the Space Launch Initiative Program, and Program Manager of the Second Generation Reusable Launch Vehicle Program. He has served as Deputy Manager of the X-33 Flight Vehicle Program and Manager of the Delta Clipper-Experimental Advanced Flight Vehicle Project. He also served as Assistant Manger of the Space Shuttle Main Engine Project and Manager of the Technology Test Bed Project, overseeing hot-fire testing of large liquid propulsion engines.

Mr. Dumbacher joined NASA in 1979 as a summer student performing thermal analysis on Spacelab missions, and in the summer of 1980 worked on turbomachinery and systems analysis of the Space Shuttle Main Engines. Following graduation from Purdue in 1981, he returned to NASA in the Liquid Propulsion Systems Branch performing systems analysis on the Space Shuttle Main Engine ground test and flight engines. In 1985 he ventured into missile vehicle integration work on the Strategic Defense Initiative for Teledyne-Brown Engineering. He returned to NASA in 1987 as the Chief Engineer for the Alternate Turbopump Development Project.

During his career, he has received numerous awards and honors. In 2014, he was awarded the coveted Silver Snoopy Award, and the NASA Distinguished Service Medal. In 2007, he was awarded the Presidential Rank Award for Meritorious service. In 2003, Purdue University recognized him with the Outstanding Mechanical Engineer award. He received the NASA Exceptional Achievement Medal in 2002 for accomplishments related to NASA's Space Launch Initiative Program, and in 1997 for his work on the DC-XA Project. In 1996, he was honored with a Marshall Director's Commendation for accomplishing two flight tests within 26 hours in the DC-XA Project flight test series.

Mr. Dumbacher earned a bachelor's degree in mechanical engineering from Purdue University in 1981 and a Master's in Business Administration from the University of Alabama in Huntsville in 1984. He has completed the Senior Managers in Government study program at Harvard University. Mr. Dumbacher has authored several papers on liquid propulsion technologies, space transportation systems development, and systems engineering.

Mr. Dumbacher is a native of Indianapolis, IN and attended Bishop Chatard High School. He and his wife Lee have three grown children: Erin, an Elliott School graduate in International Affairs from The George Washington University, residing in Washington, D.C., pursuing graduate studies at the Johns Hopkins School of Advanced International Studies, Dana, a 2011 graduate of Marquette University, currently pursuing graduate studies in Public Policy at the University of Minnesota, and Brad, a recent graduate of Marquette University and member of their Men's basketball staff, attending the University of Georgia Law School.

Chairman BABIN. Thank you, Mr. Dumbacher. We appreciate your testimony.

I now recognize myself for five minutes of questioning. I presume these will be for both of you guys, if that's okay.

When the Administration slipped the recent Orion launch schedule, NASA was very quick to point out that they were still planning the original launch date. If NASA program managers believe that the earlier launch readiness date could be kept on track with historical Congressional appropriations, then why doesn't the agency commit to those earlier dates to begin with?

Mr. Cooke, how about you first?

Mr. COOKE. I understand what you're asking. Within the agency and within the Administration, NASA plans to the President's budget request, which is the Administration policy, and that's where the confusion comes in when the Congressional budgets are higher. Naturally, people in these programs are wanting to progress, they are wanting to plan as much work into the funding they get, and so the appropriated budgets are utilized, and they make as much progress as they can. However, if planning in out years to the President's budget request, if they're doing that, then at some point it becomes self-fulfilling as the long lead items can't be planned on or bought or paid down, and so gradually the advanced planning overtakes what the schedule that they might have held.

Chairman BABIN. Okay. And how about you, Mr. Dumbacher?

Mr. DUMBACHER. Congressman Babin, I agree with everything that Mr. Cooke just said. I think it's clear from a program implementation perspective that when we try to put the best plan together that we can and we are continuously working—in my tenure at NASA, we were continuously dealing with a plan against the President's budget request as necessary by policy within the Administration, and also having to recognize that the appropriations process was probably going to change that number and increase it, that we also had to develop another set of plans to be prepared for the appropriations process. That was standard operating procedure. We did it annually because of the policy debates that were ongoing, and we did the best we could with the planning and with the execution given that uncertainty that we were working with each year.

Chairman BABIN. Okay, sir. Thank you.

My second question would be, 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 and how would that impact the schedule?

Mr. COOKE. In terms of the past, for instance, for the International Space Station, there were actually words in legislation that helped that situation so that termination liability was less of a burden to the programs. Currently, or early in—actually as post termination of Constellation program, the programs—each program has to set aside, and each project has to set aside funding to protect for termination liability. As I understand it, the number for SLS and Orion right now is on the order of 420 million, and that—if that is held back, then that's money that's not going to execution.

I think there may be some relaxing of how that's done currently but the contractors are actually, as I understand it, responsible for maintaining the termination liability. So in any event, any help that they could have in not having to hold back funding would be beneficial, in my view.

Chairman BABIN. Okay. Thank you.

Mr. Dumbacher?

Mr. DUMBACHER. Chairman Babin, I agree with Mr. Cooke just said. There—during our execution of SLS and Orion up until I left the agency, termination liability, having to withhold that work or having to hold that money back each year meant that it was that amount of work that we were not making progress with across SLS and Orion. It was an impact to the program. It was an impact to our schedule. And it became—and it was an annual issue that we had to deal with both from a government policy implementation perspective as well as a corporate risk management strategy perspective.

Chairman BABIN. Thank you, and I'll recognize the gentlewoman from Maryland.

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you again to the witnesses.

Mr. Dumbacher, in your prepared statement, you referred to the National Academies' Pathways to Exploration report and note that its recommendations "should serve as the basis for an overall strategy and plan for human exploration." This Subcommittee and the House have similar views and called for a human exploration roadmap in the House-passed 2015 NASA authorization bill.

I just wonder what your views are on the key thrusts that are made by the Pathways report and whether NASA's strategy of Earth-reliant proving ground and Earth-independence satisfy the National Academies' recommendation, and if they don't, why not? And then what should Congress expect to see in a solid strategy? What are the key elements for a roadmap that we should be looking at that have a little bit more precision?

Mr. DUMBACHER. Congresswoman Edwards, I think the 2014 NRC report that—and I will be honest, I am speaking from my own, not the fact that the chairman of that committee is now the president of my university——

Ms. EDWARDS. That's not a conflict.

Mr. DUMBACHER. That's the way the faculty look at it.

That report lays out a very sound approach. It lays out an approach and should be, in my opinion, used as a touchstone along with the 2010 Authorization Act to put a strategy together. I think your question about the Earth-reliant proving ground, Earth independent, that's the first level of it. It's not—it needs to be fleshed out in greater detail with more strategy along the way. I think the key elements of that strategy need to recognize that this is exploration—we will be learning each step of the way—and it has to be flexible and we have to have the ability to modify the strategy based on what we learn because, in essence, what we are doing with exploration is, we are expanding our neighborhood from low Earth orbit out to cislunar space and then eventually to Mars, and I hope beyond that.

So I think those elements are essential to build upon the plan, and I think the NRC report gives us a good methodology by which to think about it, a good starting point, and also some good indication frankly from a funding perspective in terms of what kind of funding would be reasonable along with an inflation growth to be able to implement such a strategy.

Ms. EDWARDS. So let me just ask you, Mr. Cooke, then about funding because we've heard talk already on this Committee about the debates and the push and pull that have gone back and forth between Congress and the Administration, but do you have some thoughts about the constraints that this uncertain environment with the sequester caps in place and basically living at level funding in what Mr. Dumbacher has described as an exploration environment, what kind of constraints that puts on our ability to fully explore and develop this program?

And then lastly, I mean, I have often thought that it might make more sense for Congress to simply put a date certain, an endpoint. NASA is saying maybe in the 2030s. Well, what if Congress came back and said, well, how about 2020, and then we develop a budget and a program around something that's more certain than just continuing to expand it into the future, and I'll leave you with the balance of my time.

Mr. COOKE. I believe that the flat budget is one—well, it's a fact that with inflation, a flat budget has less buying power over time, so to explore and move beyond where we are, move to the next steps after SLS and Orion, it will require increased funding. There was at some level, and not terribly high, I think, but funding does need to be restored over time to exploration in order to make these goals, and I think it is a good question to ask if we are to get to, say, the Moon, by a date, to Mars at some date, what does it take to do that and I think that's your question. I think it's a great question. It's one that deserves an answer. It's—that's really the way it should be done.

And then of course, you can decide, and then it gets into debate of deciding whether or not it can be afforded, but certainly that's the way a program should be laid out, in a way that has development funding that is more efficient than what's being done currently under caps and flat-lined budgets.

Ms. EDWARDS. Thank you, Mr. Chairman.

Chairman BABIN. Thank you.

Now we recognize the gentleman from Alabama, Mr. Brooks.

Mr. BROOKS. Thank you, Mr. Chairman.

This is a question for both of you. How should NASA pick a human exploration mission end timeline?

Mr. COOKE. I believe—and I have been able to briefly read the report that was put out yesterday by NASA. I think there are a lot of good elements in it. But I think in laying out a program, one thing that is missing from it and one thing I've stated before, in fact, I testified on it in May of 2013 in this Committee, I believe that we need to start with a discussion in the community, whether it is science or the exploration committee including our international partners, those who are interested in developing resources on the Moon, we need to have a conversation up front to lay out objectives for what we will achieve on these missions. It's not just

a matter of well, we're going to build this rocket to go to this place. It's important to understand what we want to achieve, and I think laying that out helps guide the steps involved. And personally, I believe those steps include going to the Moon, to going potentially to the moons of Mars and to Mars itself.

Mr. BROOKS. Mr. Dumbacher, do you have anything to add?

Mr. DUMBACHER. Congressman Brooks, yes, I do. A couple of points to add to Mr. Cooke is that as it's necessary to bring the stakeholders along, it's also—I think we need to be very careful recognizing the funding constraints that we operate within that we need to make sure that the elements that we build for exploration don't just become one-offs or just be able to used once, that they have a continuous applicability through the rest of the exploration strategy. I think that's a key element that we need to do, and we also frankly need to be very careful about making sure we live within the funding constraints that are in the appropriations levels that are provided by the Congress. So those are the two key elements I would add to what Mr. Cooke had.

Mr. BROOKS. Thank you. This is again a question for both of you, and Mr. Cooke, I've already heard your comments about going to the moon, Mars's moons and perhaps Mars, but if you have any additions, please offer that.

What do you recommend as NASA's SLS and Orion missions?

Mr. COOKE. I believe that the SLS and Orion represent the first critical steps in any exploration activity beyond Earth orbit. You need the lift capacity of the Space Launch System. You need the volume if its payload——

Mr. BROOKS. I understand that, but do you want our missions to be?

Mr. COOKE. I think personally, there's discussion about cislunar space. That is definitely a possibility. It could be a very good intermediate point in Mars, a place to send Mars missions from, but I do believe in going to the Moon.

The Moon that we know now based on spacecraft that have gone there since Apollo has opened up a different Moon than we've seen before that's much more dramatic and landscaped. We've mapped resources. I think there's a lot to learn if we sent people there. So I think that the Moon is still an important place to go on the way to Mars eventually.

Mr. BROOKS. Mr. Dumbacher, do you have anything to add?

Mr. DUMBACHER. Yes, Congressman. A couple of things I would add are, again, everything we do needs to be buildable towards Mars. It needs to help take us towards Mars and be usable along the way. We need to do the testing necessary to make sure that we learn how to operate in environments where we are further away from home than we've ever been in the distant retrograde orbit cislunar space area. We'll be nine days away from home as compared to three days away from home during Apollo.

Another aspect I would add is an increase in mission frequency. I think it's important that we shorten up the time between missions. That means additional funding, but it is—I believe it's important that we increase the mission frequency to maintain our skills, build our skills and then be able to learn as quickly and provide the benefits back as quickly as possible.

Mr. BROOKS. I'm almost out of time, but this is a short question.

Since Orion is running behind schedule, what can be flown on the Space Launch System in its place from a test standpoint?

Mr. DUMBACHER. Congressman, that's a—I'll take that first.

We—that's a good question. I think the two programs have been integrally linked from the beginning in that the first flight test EM–1 needed to have an uncrewed version of Orion, and I believe that they are on schedule for that flight, and with NASA continuing to work to the management agreement of 2021, assuming the Congressional appropriations levels, they're still working to the existing plan. What other cargo missions there might be would remain to be seen but I think we would have to have—NASA would need to take a look at possible cargo missions, other possible payloads, other possible science missions.

Mr. COOKE. And I would agree that there are possibilities. I agree with what Mr. Dumbacher said, and the plan is for Orion to fly. But in the future, SLS will provide a unique capability for larger telescopes with larger apertures potentially. There has been discussion on a Europa mission at some point.

There are potentially uses in defense space as well. It has unique capabilities that could provide other very good opportunities.

Chairman BABIN. The gentleman's time has expired. Thank you.

Now I call on the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman.

I'll begin with Mr. Dumbacher. You talked about budget stability. You mention in your testimony that the NRC report and the 2010 Authorization Act should be followed to ensure adequate funding for SLS and Orion. Could you please explain what you mean by that, and especially in light of the fact that the last time humans left low Earth orbit was 1972 with Apollo 17? What would this do to increase our confidence that the EM–2 launch will actually be carried out in 2021?

Mr. DUMBACHER. I think, Congressman, first of all, at the Congressional appropriations level and NASA continuing to work towards the 2021 date for the Orion first crewed flight, I think the Congressional appropriations levels and accounting for inflation over this time period, recognizing the loss of purchasing power that that infuses into the system, can help—Congressional appropriations can maintain the 2021 date, and I think that's important.

For the overall exploration, I think the thoughts put together as part of the NRC report that talk about a level of funding that basically starts out similar to the Congressional appropriations level, grows at about two to three percent per year in real growth plus inflation on top of that, I think provides a good, sound basis, and importantly, if NASA knows that that's going to be the plan over the long term, they can plan to that, and that's the important part is if you know what you're working to over a longer horizon and you can plan to that, that is a key part.

One of the things we struggled with in my time at NASA was the budget request that came out as a one-year budget request and the budget horizon from then on was labeled as "notional." As a program manager, I struggle with, how do I plan to a notional budget? So the key point is, knowing what the numbers are, having some feel for what those numbers are going to be over a five-, ten-

year budget horizon and then you can put a reasonable program together.

Mr. BEYER. Thank you very much.

Mr. Cooke, Chairman Babin talked in his opening statement about the Administration's strangling NASA with the budget cuts. I along with many of our colleagues on both sides offered amendments in Committee to increase the NASA authorization, only to be told that our Committee hands were tied by the Budget Control Act and by the bicameral budget passed in the House and the Senate with Republican majorities.

How much of these budget cuts are driven by sequester, by the Budget Control Act?

Mr. COOKE. I honestly can't answer that specifically on the Budget Control Act. My experience has been primarily between Congressionally passed budgets and President's budget, and I would say as an example right now of what I think could be done, if NASA were to be able to count on the Congressionally approved levels, is make a decision to go to a larger upper stage than the first—than the one flown on the first test flight. We're flying an interim upper stage based on Delta upper stage for this test flight, and if NASA could count on the Congressional levels, it could probably make a decision to go to the upper stage it needs for exploration. That would keep NASA from having to human-rate this interim upper stage for the first crew flight, which would save a significant amount of money. So just the efficiencies gained in a higher budget in terms of the development, in developing the right answer instead of interim steps would be of great benefit.

Mr. BEYER. Thank you, Mr. Cooke.

Mr. Dumbacher, again, budget stability. We just avoided a government shutdown at the end of September. We're now looking at hitting the debt ceilings in the next couple of weeks. We've postponed the budget and the government shutdown debate until December 11th. What would—what was the impact on Orion and SLS when we shut down the government for 16 days in 2013? What would be the impact if we shut it down for 10 days later this year?

Mr. DUMBACHER. Well, I cannot speak to the exact details of what a potential impact would be for 10 days down the road from here, but back two years ago when we did have that 16-day shutdown, there was a significant impact to the program, particularly because at that point we were— particularly Orion was coming up on the hardware and the integration, a year away from the exploration flight test. And so having to stand down the team for 16 days and then restart it, when you consider the level of budgets that we're talking here and the burn rate that we had at that time, which I recall, if I do my math correctly, was on the order of $60 million a week, that's a significant impact to the program because it's not just the 16 days, it's the planning that the team had to go through to prepare for that, it's the phasing down to get to that shutdown, and then it's the restart to come up after the shutdown. So that was a significant impact to Orion and to SLs as well as Ground Systems across the board just for a 16-day impact.

Mr. COOKE. I'd like to add to that just briefly. NASA is in a unique situation on something like a shutdown. It is not like most agencies. It's developing something. It's developing hardware. It's—

they're programs that are underway. So it's a lot of people with a lot of interrelated tasks and jobs that most agencies don't deal with. So a shutdown does have an impact in development.

Mr. BEYER. Thank you, Mr. Chairman.

Chairman BABIN. Thank you. I would remind the gentleman from Virginia that in our budgeting and authorization and issues of exploration, we fully funded—this Committee always fully funded that, and what you were referring to was not exploration with some of those issues.

I now would like to recognize Mr. Rohrabacher, the gentleman from California.

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

It's good to see you fellows again and again over the years.

How much is the Mars initiative going to cost when it's completed? When we get the person on Mars and back, how much will we have spent?

Mr. COOKE. I think at this point, since we don't have a specific roadmap with missions laid out, we really don't know the cost. I will say that if you take any program—if you take the Shuttle program, if you take the Space Station program and if you put the full cost at the front end of it and said this is what it was going to cost, it would be a big number, and——

Mr. ROHRABACHER. Okay. Well, let me ask you this then. Has—you mean there's no document that you've read that NASA—and we've all signed on that says this is how much is going to be spent to achieve this goal? What did we agree to? Congress hasn't—we don't even have a budget so we don't even know how much it's going to cost for the biggest project in NASA to achieve its goal? I mean, this is insane. How much have we already spent on the Mars project?

Mr. DUMBACHER. Well, Congressman, let me—first of all, this has been a long-term investment from the initial vision for space exploration days and going into the Constellation program. I cannot give you off the top of my head specific numbers, but I can tell you——

Mr. ROHRABACHER. Hold on. Do you think NASA knows? So what I'm getting here is that we don't even know how much—there is no figure as to how much is going to be spent and we don't know how much has already been spent, which means we don't know how much more will be necessary to be spent from now to achieve the goal, but we're talking about, you know, tens of billions of dollars here. The NASA budget altogether is 17 billion. Let me just note, when we started off down this road, some of us suggested that we were going to have to drain money from every other NASA program or it wasn't going to work, and it's not working, and it's because we don't have the money, and right now just from the testimony, you're saying we're not being responsible at this level, they're not being responsible at NASA either.

We have a huge asteroid that's going to come by the Earth or at least not right by the Earth but closer to the Earth than usual in the next few days, and we have no plan that if something happened that we recognized something was coming and that five years from now it was going to hit the Earth and destroy it. We don't even have in place a plan to actually deflect an asteroid yet.

We've got—and let me just note, people are complaining about the budget, we're not giving NASA the money that it needs for the development of this huge rocket that's necessary for Mars. Well, if we were going to—if people really believed that having a man on the Moon planting our flag as compared to just having robots is worth all of these billions, well, they've got to put their money where their mouth is, but nobody does that. We have—nobody's willing to prioritize.

NASA spends a billion dollars a year proving global warming, just to prove it, a billion dollars a year. Well, maybe if someone on that side of the aisle might be willing to give up that money and put it—if they really believe in going to Mars, putting it into the big rocket that we need to take us to Mars, well, then maybe we'd have some hope that we can be successful in something, but nobody's that responsible here.

By the way, of the billions of dollars our government spends, we are borrowing 20 percent of it from our children who will repay the Chinese or the Japanese or whoever is buying up our debt. We aren't even—and people are complaining. That's why we have the sequester in place because no one was willing to make a choice.

What I'm seeing here, and again—look, my father was a pilot. My dad—and we have this great aviation technology that we put to use for humankind now. That happened because people were actually responsible. They made responsible decisions about development of technology.

And Mr. Chairman, I'll just end my little tirade by saying that I think that we are not being responsible. I think Elon Musk will be on Mars before NASA is and not him spending any government money as well. Thank you.

Mr. BRIDENSTINE. [Presiding] The gentleman yields back.

I recognize the gentleman from Colorado, Mr. Perlmutter, for five minutes.

Mr. PERLMUTTER. Gentlemen, thank you for being here. Thank you for your service to the country. Thank you for your service to the future because that's what this is about. And I just feel very fortunate that I got a place on this Committee to talk about things like this, and had an astronaut in my office not long ago, a guy named Terry Virts, and my guess is, both of you have worked with him, where he said this is not rocket science, this is political science, and the part that we're dealing with right now is political science, and Mr. Rohrabacher and I, you know, may have some differences but generally this Committee—and I have been on a lot of committees in this Congress. This Committee gets along and agrees more than almost all the other ones.

And so looking at this, you know, we're the authorizing committee so you got the Budget Committee, the authorizing committee and the Appropriations Committee. I on this Committee would like to be able to give you something that says you are authorized to get us to Mars as quickly as possible. You know, I'd like to be able to say something in an authorizing language—ten years from now, we're going to have our astronauts on Mars for the future, for science, for discovery, for whatever. And so for us, if there's a goal of something like that, then we've got to find a way to do it so that you can provide a ten-year plan, knowing under the

Constitution from year to year, no Congress can bind the next Congress—that's just the way the Constitution is—but to give you some real guidance in setting a plan over a period of time to get us there.

And so for me, I just suggest to my friends on this Committee, you know, say this is a national interest, it's a huge investment, either we raise taxes to make that investment, which, you know, will give some people, you know, heartache, or we say we're going to prioritize this against the whole other budget, all the other appropriations. Or we can do a public-private partnership and get some additional investment, or we could do a joint venture with some other countries as we've done with the Space Station. And I'm a Star Trek guy and I look at the bridge of the Enterprise and I see every nationality possible and then people from other planets too. But we can do those kinds of things or maybe fee-based, but that's our problem. That the political science piece of this thing.

Now, the two of you have had to deal with Congress, you've had to deal with the White House. What would you suggest that we do to give you a ten-year plan? Mr. Cooke?

Mr. COOKE. I can tell you from experience that the Authorization Acts have been very beneficial to laying out our future, and the 2010 Act was very important to us. I encouraged development of plans because they represent—in the end, they're obviously a compromise in the end when they all get passed, and having a consensus on a direction is very important. The 2005 Act was important to us, the 2010 Act was.

So those do have an impact, and we—they actually—the 2010 Act actually set the motion forward to announce in 2011 the Orion and SLS programs.

Mr. PERLMUTTER. Mr. Dumbacher?

Mr. DUMBACHER. Congressman, as I stated in my testimony, I think that as Doug has said, that the 2010 Authorization Act provides the good starting point. It laid out three years. worth of funding levels. We-recognizing the constitutional appropriations process, NASA can do a better job of planning when it has some idea of what budget level to plan to, recognizing that that cannot be passed in an appropriations perspective because of the Constitution but having some concept of a plan so that if, for example, someone—this body were to come back and say use something like the 2014 NRC report as a planning basis, then NASA could go forward and use that.

Mr. PERLMUTTER. So just a last question. If we said we want to be on Mars in 2025 in an authorizing bill, could you give us a budget for that?

Mr. DUMBACHER. Then the question would go to NASA to put that plan together and then they would need to put a budget requirement to meet that plan and they would need to come back and show that to this body for funding purposes.

Mr. PERLMUTTER. Thank you very much.

Mr. BRIDENSTINE. The gentleman yields back.

I have taken the gavel here so I'm going to recognize myself for five minutes before we go to Mr. Posey here for the next question.

What I'd like to share, I heard Mr. Beyer earlier talk about the C.R. and shutdown and want to know the impact on NASA explo-

ration and all that's critically important. I would like to highlight the fact that under a Continuing Resolution, NASA exploration actually gets more funding than if we went forward with the President's budget request, which—and I'm not saying that because I'm advocating for a Continuing Resolution. I just want to make sure people understand the President's funding priorities.

Now, my friend, Mr. Rohrabacher, earlier was talking about SLS and Orion and how much money it's going to cost, and I don't share his sentiment that maybe those programs are ill-advised. What I do believe is that if you're going to have those programs like what Mr. Perlmutter was talking about, we need to fund them. If we're going to have these programs, we need to fund them, and it's pretty simple.

So we have seen the Administration repeatedly underfund the program in its fiscal requests every year. The inadequate funding requests coupled with delays in program announcement, arguments over destinations, and the use of accounting tools such as termination liability have caused further delays in SLS and Orion. When I see this back and forth between Congress and the Administration, I am left wondering a number of things. Since the President is not committed to this or at least it wouldn't appear that he has been, is this political? Are we setting ourselves up for political failure? And if I could get—maybe because he wasn't committed to it from the beginning. Could I get your opinion on that, both of you?

Mr. COOKE. I don't think we're going toward failure. The programs, SLS and Orion, are moving forward and making great progress. It's definitely true that under these circumstances where the budgets are different and the President's budget request is less than what's appropriated, it does cause problems in programs. Decisions have to be made that are not optimum. So it ends up being inefficient and costs more in the end. However, even so, you have dedicated people at NASA that make them work, and they're making great progress.

Mr. BRIDENSTINE. Mr. Dumbacher?

Mr. DUMBACHER. I totally agree with everything Mr. Cooke just said. I have nothing fundamentally to add to that. I think I would like to reiterate that I do not believe we are working towards failure either. I think you see success out there. It's going to be hard at times because we are doing technical things that no one has done before in terms of manufacturing technology, manufacturing requirements, bringing in new technologies and taking humans further than we've ever gone before. It will be hard, but it's not failure.

This dedicated team across NASA and industry is making it happen in spite of the political budget debate, and I think they should be commended for the progress that they are making to date.

Mr. BRIDENSTINE. And just so everybody here understands, I just want to make sure that we're going forward and actually accomplishing what we're setting out to do, and I think people on both sides of the aisle want to make sure that what we are funding is not in vain, and I think that's Mr. Rohrabacher's frustration, you know, people on both sides of the aisle, and it seems to me that if we continue to hit the president's budget request and in many case go beyond the President's budget request and yet we still have

delay after delay and we don't have the launch frequencies necessary maybe to maintain the safety that is perfectly appropriate for this kind of program, the question is, are we adequately funding this program, and how do we go forward in a way that is appropriate, given that this is very serious business and lives ultimately will be at stake.

Last question for you guys. As we move forward for deeper and deeper space exploration, do you see an environment where commercial habitats would be used maybe as, you know, something to, you know, orbiting the Moon for the long term, for example, if you guys could answer that?

Mr. COOKE. I think that's potential. I encourage commercial development. Actually in the directorate that I managed when I was at NASA, we had the Commercial Cargo and Crew, and those are being developed and are needed at this point, and I certainly think that's a possibility. If the business case is there to support it, I think that's certainly in the realm of what could happen.

Mr. DUMBACHER. And Congressman, if I may, I would like to add to what Mr. Cooke just said in that in my view, it's critical that we continue to perform this exploration initiative and help build commercial opportunities because that is the future for the next generation, and it's going to be hard. We have the real-life things that we have to work through in terms of business plans and commercial markets and technical issues and all of that, but this country has a long history of pushing forward and working to solve those kinds of problems, and I think we need to continue doing that, not just for our own benefit but for the benefit of the next generations coming behind us.

Mr. BRIDENSTINE. Thank you, gentlemen.

Mr. Johnson from Ohio is recognized for five minutes.

Mr. JOHNSON OF OHIO. Thank you very much, Mr. Chairman, and gentlemen, thank you for being here.

Two reasons that I appreciate this hearing. I'm a big fan of space exploration. I grew up in the age of the Apollo Moon race. I remember vividly sitting in front of my television so many times listening to Walter Cronkite as he called the play by play, and everybody in our country was captivated by everything that was going on because each mission we were learning something newer and newer and newer about the tasks that lay before us, and it's amazing to me to think that we were able to accomplish that. In 1903, we flew the first airplane off the sands of Kitty Hawk, and 66 years later Neil Armstrong stepped out on the surface of the Moon. That's what we're capable of in America, and so much technology and marvels that we enjoy today came out of that effort, and so I applaud it.

I'm also a program manager by trade, having spent 30-plus years in information technology. I've managed large programs. So from the perspective of a NASA program manager, gentlemen, what is the difference between a target date and a commitment date, and why might it be useful to have a target date that is earlier than the commitment date?

Mr. DUMBACHER. First of all, Congressman, the difference between a commitment date and a target date is the commitment date is the agency is legislatively held to reporting requirements on

programs' progress. They—when we were—when I was in the agency, we purposely had to work through the commitments, recognizing that I believe it's the Nunn-McCurdy Act that required that we had to put a commitment there. If we were 15 percent over schedule or cost, then it was subject to a cancellation conversation. So the agency had to worry about that commitment, not just from a legislative perspective but also from an integrity/trust perspective to demonstrate it can do what it says it's going to.

The target date is the date that I used, my team used, to try to keep the appropriate amount of schedule pressure on getting the work done as cost-efficiently as possible, as technically correct as we could, and maintaining the safety. It is the art of project management that says I used the schedule to help make sure I keep driving the work forward, recognizing that I don't want to do that at the expense of poor technical decisions, poor safety decisions, but I still keep enough work going on because that way I keep—I get it done as efficiently as I can.

Mr. JOHNSON OF OHIO. I liken this to an analogy of a student in college, even in high school. You handle the tough subjects first. You get those things done early in the semester. That way you're not sitting there with two weeks left to go before grade reports come out and you're behind. You don't want to get to that commitment date and find out that you've got that 15 percent overage in budget or schedule and have to face a Congressional mandate to come back and worry about cancellation. So I get it. I just wanted you guys to explain.

A target date is the discipline to make sure that you don't miss the commitment date.

Mr. DUMBACHER. Right, and the difference between the target date and the commitment date is the program manager's schedule margin.

Mr. JOHNSON OF OHIO. Yeah. Got it.

How might additional funding during the period—let's talk about budget for a second. How might additional funding—during the period fiscal year 2012 and 2013, how much additional funding during that period have changed the planning and management of the SLS and the Orion programs in ways other than schedule? Am I clear? Does that make any sense? How might additional funding during that period—other than schedule, how would it have affected those programs?

Mr. COOKE. The additional funding at that time as well as now, I believe, helps you to get work done in parallel that you otherwise have to phase out if you have a limit to your funding. So you can plan things in a normal sense, things that are better integrated because you're developing them in parallel, you know the interfaces, you know how to pull them together, and if you're constrained where you can't do that, then you phase things out and you start this task, you stop that one. In some cases we've had a test, had a flight test on Orion back in 2010. We ended up laying off people who were critical to the success of the task because the next priorities were somewhere else.

Mr. JOHNSON OF OHIO. Right.

Mr. COOKE. We achieved that. We still need it. But we had to make decisions so we could address the next priorities, and those things don't necessarily have to happen.

Mr. JOHNSON OF OHIO. Now, Mr. Chairman, this is a great example of how only a program manager can know how critically important the certainty around funding to keeping a project on schedule and not winding up in that conflict with a commitment date and ultimately see everything wasted if it's cancelled very, very important.

Gentlemen, thanks for sharing your perspective this morning.

I yield back.

Chairman BABIN. Yes, sir. Thank you.

Now I recognize the gentleman from Florida, Mr. Posey.

Mr. POSEY. I thank you very much, Mr. Chairman, and let's dash back to reality just for a second.

Every year, NASA's requests for Orion are lower than what's needed. Do you both agree with that statement?

Mr. DUMBACHER. I would agree with that statement. There is a prat of that statement, Congressman, that I'm trying to figure out how to answer you better in that the request is really the President's budget request.

Mr. POSEY. Yes. NASA's request—the President's request is NASA's request, and vice versa, and it's always lower than the program needs. Congress always comes back and pays more. The question is, why doesn't NASA, the Administration request the amount of money they think they need?

Mr. DUMBACHER. Well, I think that would be a question directly to the Office of Management and Budget because it's in that budget process that the agency goes through as we build the budget from the bottom up, from the programs and then they get submitted and they work within the agency priorities and then go over to the higher national-level priorities, it's in that last step where at least from my perspective, I saw here the numbers change.

Mr. POSEY. Well, the fact is, they request less year after year than they know that they need to keep the project on schedule. It's a fact. I mean, it's not a political statement and it's not a scientific statement. It's a fact. And Congress does in fact always pay more.

Several Members were a little bit concerned about a budget, how much it will cost to Mars and what the total costs will be, and I think that's almost a laughable question at this point because they don't even have a plan yet. You know, in the last several NASA authorizations, Congress has mandated that NASA come up with a detailed roadmap for Mars, a steppingstone approach to exploration, if you will. I believe many on this Committee feel we've never seen a detailed plan, and I'd like for both of you to comment on what you see as essential steps in getting human to Mars and your thoughts on why NASA has not submitted a detailed plan to Congress as requested?

Mr. COOKE. I have actually got written testimony from 2013 that addresses that specific—that question specifically, but I'll go ahead.

I believe the front end of it is laying out your objectives for what you want to achieve in your exploration program by destination, what is it we want to learn, how is it we want to prepare from one step to the next, and have a rational approach to——

Mr. POSEY. I agree with you. That's what should be done. The question is, why haven't they done it?

Mr. COOKE. I can't say—I can't say why since I have left it has not been done. Actually when——

Mr. POSEY. Why wasn't it done while you were there?

Mr. COOKE. Well, when I was there—I left at the end of September in 2011—we had just gotten through the period after the 2010 Authorization Act where we worked very diligently within exploration to answer that, what was asked for in the Authorization Act, and we announced SLS design and program the same month I retired. That was the first step. Our immediate concern was getting the front end of this started. We actually had a plan that we talked about that after we get the first steps on the way, we're going to come back and develop the plan, and——

Mr. POSEY. All right. I got that. I got it.

Would you care to respond?

Mr. DUMBACHER. Congressman, I think I—agree with what Doug said. I think part of what needs to happen is a more public discussion about some of the planning and some of the strategies that need to be implemented to go to Mars and making sure we are all clear, that the stakeholders are all clear on what the goals and objectives are, and then allow NASA to go put a plan together.

Mr. POSEY. You know, every Member on this Committee, bar none, both sides of the aisle, want NASA to be successful. I can give you just so many instances, though, when at least from this perspective, they're their own worst enemy. If they can't come up with a plan, they want somebody else to do it, if it takes more funding for a plan, but you know, you have to have a plan actually before you do a budget. I mean, you can see, I hope, the negative effects of building a development schedule around a budget rather than letting the most logical schedule dictate the financial needs, and it appears that is what's happening, and Mr. Chairman, I don't know how we reel this thing in but it's just not something that I'm proud of the way it's being done, and I see I'm over my time. Thank you.

Chairman BABIN. Thank you, Mr. Posey.

You know, I would also add that, you were asking the question of what is the cost of going to Mars, and I would ask what is the cost of not going to Mars.

In our—we had a meeting of some industry specialists in space the other day, and I was told that there was a Chinese program planning a permanently crewed space station for 2020, and I think everybody in this room is aware of who holds the high ground, has the great advantage. So I would say that we can't afford not to try to get organized and get this planned and funded adequately.

I want to thank the witnesses for being here, both of you folks today, and thank the Members for your questions, and the record will remain open for two weeks for additional written comments and written questions from Members.

So this meeting is adjourned. Thank you.

[Whereupon, at 11:43 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Doug Cooke

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

"Deep Space Exploration: Examining the Impact of the President's Budget"

Questions for the record, Mr. Doug Cooke, Owner, Cooke Concepts and Solutions; Former Associate Administrator, Exploration Systems, NASA

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

Doug Cooke's Answers to Questions

1. As a former member of a leadership team at NASA that managed human exploration programs under a variety of administrations. How would you characterize the priority this Administration puts on exploration?

1. It is my belief that this administration puts the highest priority on ISS cargo and crew programs and very low priority on human exploration as evidenced in the President's budget requests. The most prominent example is that human exploration in the form of the Constellation Program was cancelled in 2010 and replaced with "commercial" initiatives for cargo and crew along with priority on technology development and demonstrations. This would have ended government run human space flight developments for Shuttle replacement and exploration. The retirement of the Space Shuttle was in the works and occurred in 2011. Subsequently, every budget cycle has reflected low priority for SLS and Orion as directly compared to "Commercial" Cargo and Crew programs. The PBRs have consistently proposed budget increases in the "commercial programs" at the expense of funding for the SLS and Orion. Additional evidence of human exploration being a low priority is the lack of leadership in developing a meaningful space policy versus leaving it to implementation through the budget process. It is important to recognize that all of the programs in human space flight are important for the future, including cargo and crew to ISS, ISS, SLS, Orion, Ground Systems, Human Health and Research, and supporting technology programs.

2. The expected low flight rate of Orion and the SLS once they become operational has raised safety concerns. According to NASA's Aerospace Safety Advisory Panel, the current plan for one launch about every two to four years "would challenge ground crew competency."
   a. Based on your experience in human spaceflight, what flight rate would ameliorate this concern?
   b. What would you expect to be the annual cost of the additional flights?
   c. Are there other ways to address the safety concerns arising from a low flight rate? If so, what are they, and what are their cost implications?

2. In my experience, a flight every 2 to 4 years is inadequate on many levels. I agree with the ASAP conclusions. It would challenge competency and proficiency of NASA engineers and management, who also support operations. The flight rate reflects the inadequate PBR budget runout, to which NASA is required to plan. This reflects the low priority that the administration puts on NASA-run human exploration programs. Flights at this rate cannot support a meaningful Exploration Program in terms of exploration achievements and mission needs.
    a. Flights should be on the order of 2 to 4 per year with a surge capability of perhaps 6 to implement meaningful exploration campaigns.
    b. I don't have adequate information on current costs. To put this question in perspective, in 2008, NASA was flying the ISS, launching several Space Shuttle flights per year, and had a human exploration program, including Constellation and related programs. Exploration programs were funded at about $3.5B per year. The Shuttle was about $3B. Shuttle was the equivalent of flying a heavy lift vehicle like SLS and was more complex. Exploration is now on the order of $4B per year. The original intent was that the retirement of the Shuttle would create a wedge in Exploration to ramp up the development. The difference in funding from that time to present went to other program priorities in NASA. The flight rate of 2 to 4 per year of a human exploration vehicle should be in the realm of expectations for the future based on our experience with Space Shuttle operations. I also believe it will be needed for missions to Mars. At this point, cargo and crew transportation to ISS must be supported. Overall, NASA priorities should be examined in my view.
    c. Thorough documentation of processes and constant training can help mitigate risks, but there is no substitute for a flight rate that keeps all personnel proficient. Traditionally a higher flight rate brings down the marginal cost of flight. The trained personnel have to be paid for anyway, regardless of the flight rate. If they are not actively engaged in supporting flights, they are inefficient and are still a cost to the program. The cost of programs is largely the cost of people. If they are launching regularly, the marginal costs go down, the people are more proficient and the missions are achieving the desired returns in knowledge and discoveries.

3. **Does the pace of development in the Orion program have any effect on NASA's plans for developing the SLS exploration upper stage (EUS)?**
    a. **Is it cost effective for the SLS program to forego human-rating the Interim Cryogenic Propulsion Stage for use in EM-2 and proceed directly into the development of the EUS for EM-2?**
    b. **How likely is NASA to fly crew on an EM-2 flight using an EUS that has never flown before? If NASA incorporated EUS into the SLS architecture for EM-2, would that have an effect on the date of the first crewed flight to EM-3?**

3. The pace of SLS development should be maintained for efficiency. The EUS should be developed as early as possible.
    a. The SLS Program could likely move forward with the Exploration Upper Stage if they can plan on receiving Congressional budget levels. If the EUS were ready for the first crew flight with Orion and SLS, NASA would save about $150M on human rating the ICPS for that flight, a cost that will otherwise be wasted in the long term. (The $150M human

rating cost is according to a recent article, quoting NASA.) This $150M could then also be applied to the EUS development. The SLS would have lift capability of over 100 metric tons for exploration missions with the EUS upper stage. This lift capability is closer to the launch capability specified in the 2010 Authorization Act (130MT) and will be needed for exploration.

b. The EUS will go through the human rating process. The RL-10 engines for the EUS have a long successful history. I believe the rationale can be developed to fly a crew on the EUS for EM-2. There are potentially components of Orion that will not have been flight-tested before EM-2. The boosters and SLS core stage with proven RS-25 engines will be tested on EM-1, along with the functionality of the ICPS which is much the same as the EUS. It also uses the RL-10 engine. The entire Space Shuttle system was flown by astronauts on the very first flight. The SLS is not as complicated. The rationale will obviously have to go through significant safety reviews and discussion to make sure flying crew on it is as safe as possible, before this decision is made. If the Orion could be made ready with the necessary systems, a rationale for flying crew on EM-1 should be posed. Accelerating the EUS to EM-2 will leave the SLS configuration in a very good state for exploration missions. The schedule for EM-2 and subsequent flights will depend on the success of EM-1 and stable funding at the appropriate level. Implementation of the EUS on flights starting with EM-2 is the most efficient development progression.

4. **NASA's KDP-C for the Orion program was developed to meet a schedule for EM-2 rather than EM-1. How does the NASA JCL model discern between those funds needed to support a first mission and those needed to support future missions?**

4. The program planning reflects NASA's anticipated approach and associated work content from flight to flight based on the anticipated budget. The JCL is based on the PBR and the analysis is run on the program plan. The plan can be used to represent one or more flights if the content is included. It therefore reflects laying out the specific tasks and their associated schedule. That content would include any anticipated redesign and rework to get from one flight to the next. The knowledge gained or unanticipated results could cause a change to content and schedule for the next flight. The JCL confidence level percentage would reflect this at some level. The farther out this content goes in time, the lower the fidelity of the analysis, especially since it includes the development of new vehicles. With the disparity between the PBR versus Congressional levels and the unknowns associated with early flights of a new capability, I believe JCL results including out year flights would be low fidelity and suspect. Results will be pessimistic over a longer period of time, because the analysis is based on the low funding levels in the PBR.

5. **Please describe the process for determining the JCL of a large NASA program like Orion or the SLS. Who does the engineering calculations? Who oversees that work? Who approves the final result?**
    a. **If the JCL is determined to be unacceptably low, what is the process for making changes to the program's scope, schedule, or budget?**
    b. **What is the process for recalculating the JCL following any such changes?**
    c. **Which of these processes are carried out internally by the staff of the program, and which are conducted independently by others?**
    d. **Would additional independent oversight help to ensure that the JCL is determined appropriately? Who would be best positioned to provide such independent assistance?**

5. NASA should be asked the exact process for developing the JCL, since it may have changed since I was at NASA. It is also likely that it is changing right now, since NASA is eliminating the PA&E Office. In the future I understand that the independent analysis of the JCL will be the responsibility of the programs and NASA centers. In these large programs, the program content and schedule are developed by the programs for assessment. There are NASA Standing Review Boards that independently assess the results of the JCL. The NASA Associate Administrator approves the KDP. Once again, NASA should be consulted on the exact process.
    a. If the JCL is low, external commitment dates are established different than the program schedules based on probability curves. The programs manage their detailed schedules according to a determined along with the program estimates on the cost of the work to be done.
    b. For updating the JCL based on changes in the actual budget, requirements, or problems in development, the detailed program schedules and content are reconstructed by the program or modified. Contracts may have to be changed to renegotiate contract tasks and spending rates.
    c. These changes are carried out by the programs.
    d. I believe the JCL is a questionable model for the way it is being used. I believe NASA has had sufficient independent review of the process and results. However the process may be changing and NASA should explain what changes are being made. The changes may reduce the level of independent review. The biggest problem in the usefulness of the JCL has to do with the ground rules for the assessment, where PBR funding levels are used instead of Congressional funding projections. I believe this disparity tends to make the JCL under these ground rules pessimistic and self-fulfilling.

6. **NASA program management includes using Joint Confidence Level (JCL) exercises to predict the likelihood a program will meet predicted schedule. As you state in your testimony, this process is laborious and highly technical.**
    a. **In this model, how does the use of a lower set of budget numbers, such as the artificially low requests from the President, influence the JCL projections?**

6. Use of the artificially low PBR projections affects the JCL by causing the program schedule to fit this funding level, artificially stretching out the program, based on artificially low spending rates. This also drives inefficiencies, because the program would be unable to design and develop the vehicle in a more optimum way. Stretching the program causes the program to carry overhead

rates over a long period of time. This further drives the schedule out.

7. NASA's Cost Estimating Handbook (CEH) and GAO best practices advise that when constructing a JCL, the agency should first build a schedule and then cost-load that schedule. Can the JCL process be manipulated to presuppose a budget and then build a schedule to that budget?
    a. What are the negative effects of building a development schedule around a budget rather than letting the most logical schedule dictate the financial needs?

7. The JCL for these programs is not based on an optimum development schedule. The NASA approach to the JCL is that schedule is dictated by the PBR budget constraints. This schedule as described in (6) is not optimum. The resultant overall cost is higher and the schedule is stretched out due to the inefficiencies caused by the constrained budget.

8. There is not always agreement between the President's budget requests and the enacted budget. For instance, SLS and Orion budget requests have been well below the annual enacted levels.
    a. How does the NASA JCL process address such budget discrepancies, given the well observed pattern of SLS and Orion funding above the President's request for the past five years?
    b. Are there changes that you would recommend to NASA's JCL model regarding the budget inputs to provide a more realistic prediction?

8. I agree that the problem revolves around the disparity between the PBR and the higher traditional funding levels for SLS, Orion and Ground Systems.
    a. I have addressed this in (6) and (7) above. Since the JCL is based on the PBR, it causes the Congressional budget and run-out to appear to be too high and unrealistic, although it is and has been real.
    b. I would require NASA to use the best understanding of budget projections (Congressional levels in this case) in calculating a JCL. It would be more work, but if OMB requires the planning to be consistent with the PBR, I would require the programs to show schedules according to both sources (PBR and Congressional).

9. The majority of NASA's high-cost development programs are single projects rather than ongoing development. As an example, NASA builds a single and unique scientific probe for each mission compared to multiple SLS and Orion builds to meet current and future exploration missions.
    a. Based on your experience with multiple build programs, are the current SLS and Orion budgets entirely dedicated to meeting only the objectives of their first mission?
    b. What are the implications to a multiple build program if all the allocated funds are directed to accomplish only the first mission?

9. By their nature, single projects dictate that the entire vehicle be designed and built through one development cycle.
    a. Because of budget constraints on programs the major focus of SLS and Orion is on the next test flight, although I am sure there is work progressing on the overall design. I believe this was the case for Orion, working for the EFT-1 flight test last year. The following is an example of what can be done with sufficient funding. If NASA has funding

consistent with what would likely be passed by Congress for FY2016, I believe NASA could begin the Exploration Upper Stage (EUS), in addition to working towards EM-1. The EUS is essential for future Exploration milestones. This would be a more cost effective approach. It would save Human Rating the ICPS for EM-2.

b. If NASA only develops what is needed for the next flight due to constrained funding, it is very inefficient. The most cost effective approach is to design the complete integrated vehicle end product. This results in a more optimized design in the end. It is more economical than sub-optimizing for the next build, to be followed by the next. With sub-optimal steps, there ends up being a level of redesign and rework between builds.

10. **NASA's KDP-C for the Orion program was developed to meet a schedule for EM-2 rather than EM-1. How does the NASA JCL model discern between those funds needed to support a first mission and those needed to support future missions?**

10. (Same as question 4) The program planning reflects NASA's anticipated approach and associated work content from flight to flight based on the anticipated budget. The JCL is based on the PBR and the analysis is run on the program plan. The plan can be used to represent one or more flights if the content is included. It therefore reflects laying out the specific tasks and their associated schedule. That content would include any anticipated redesign and rework to get from one flight to the next. The knowledge gained or unanticipated results could cause a change to content and schedule for the next flight. The JCL confidence level percentage would reflect this at some level. The farther out this content goes in time, the lower the fidelity of the analysis, especially since it includes the development of new vehicles. With the disparity between the PBR versus Congressional levels and the unknowns associated with early flights of a new capability, I believe JCL results including out year flights would be low fidelity and suspect. Results will be pessimistic over a longer period of time, because the analysis is based on the low funding levels in the PBR.

11. **The Agency Baseline Commitments made for the SLS and Orion programs were made based on the President's budget request, rather than historical favorable Congressional Appropriations. In your opinion, do the President's budget requests reflect the needs of the program to keep to the Management Agreements for earlier launch dates, or will they require launch readiness delays?**

11. In my opinion, the PBRs in the current Administration do not reflect the funding necessary to meet the Management Agreement for the earlier flight dates. The Congressional levels are needed to have a chance of meeting the earlier dates.

12. **The Management Agreement for SLS and Orion uses a JCL that is lower than 70 percent. What is the main driver of this lower JCL?**
    a. **How does the maturity of the SLS system compare to other major NASA development programs?**
    b. **What other major NASA programs of similar maturity have used a JCL less than 70 percent in their management agreement?**
    c. **What was the outcome of those programs and how were the programs affected by using a lower JCL?**

12. I believe the focus on JCL for the SLS and Orion programs is distracting and counterproductive in the budget environment created by the Administration fighting Congress on funding levels. Since it is based on the PBR, it is unrealistic. NASA should be able to plan, focus and execute to a realistic stable funding level, and it will result in achieving the earliest possible milestones. This will in turn result in the most productive use of funds. There really is no equivalent program at NASA to compare with. JWST is a very large program, but it is a single development with single launch and mission. Science missions large and small lend themselves more to use of the JCL approach. They are generally not subject to the political turmoil as experienced by the SLS and Orion Programs.

13. The Orion and SLS programs have already spent more than $10 billion despite only recently being given authority to proceed to the implementation phase of the program. To a lay person, it might seem that these programs were being "implemented," not just "formulated," long before they reached KDP-C. How would you respond to that perception?

13. The human exploration programs have experienced incredible turmoil since they began from a plan in 2005. Five years later in 2010, the current administration cancelled the Constellation Program, which included Orion and the Ares I. Constellation finished its Preliminary Design Review (PDR) in the month after it was cancelled. The booster for Ares I had already begun full scale testing before the cancellation, including the Ares I-X flight test. These booster tests were possible, since the five-segment booster was a modification of the Shuttle boosters, and they utilized Shuttle hardware. If this were not the case, this scale of testing probably would have occurred later. Under these circumstances, testing on this scale was the most expedient and helped to establish confidence in the design leading into program milestones. Major ground test facilities, such as those at Plum Brook in Ohio were being revamped or built to be ready for testing. Orion was reinstated as a rescue vehicle a month and a half after the cancellation. Orion then reemerged as the Crew vehicle for exploration in 2011. The heavy lift SLS emerged as the exploration heavy lift vehicle in 2011 as well. The contracts from Ares I were preserved and modified to make progress on this vehicle. This entire experience of reinitializing the programs after cancellation was inefficient and costly, contributing the total cost to date. Now in 2015 these programs are on track and working through these latest milestones. It should be noted that components of each program reach these milestones in advance of and contributing to the total program milestone. To pass the Critical Design Review and KDP-C, requires expensive large scale testing on hardware before the decision to go to full scale testing and manufacturing. Long lead components must be procured to be ready for full scale testing and manufacture. Much of the early work may appear to observers to be that the program is already operating before these major program commitments are made. But many of the tests and expenditures are necessary to be ready for the commitments and for smooth transition to the next phase. Once again, in this case there were inefficiencies and a major change to the launch vehicle due to the Constellation cancellation and reformulation half way into the program to date.

14. **When the Administration slipped the recent Orion launch schedule, NASA was quick to point out that they were still planning to the original launch date. If NASA program managers believe that the earlier launch readiness date could be kept on track with historical Congressional appropriations, why doesn't the agency commit to those earlier dates?**

14. As an Executive Branch agency, NASA must operate to Administration policy, passed legislation, and appropriations. Appropriations are not multiyear so NASA is faced with yearly turmoil, because the Administration has disagreed with Congress as to the priority of Human Space Exploration as reflected in the PBR. The fact that NASA has stated it would continue to press the work to the earlier date shows the good intent by NASA to work hard, to use the funding wisely and try to meet the earliest dates possible. This is in spite of the dichotomy between Administration and Congressional policy in this matter.

15. **If NASA managers are running the programs based on the Management Agreement, despite the public Agency Baseline Commitment, what tools does NASA have to monitor schedule delays or funding increases as a result of technical issues in these programs if they are planning to a budget request that is not realistic?**
    a. **How does this bifurcated management system affect the management of the programs?**
    b. **What could the Administration do to alleviate this issue?**

15. NASA has detailed schedules of all NASA government and contractor tasks. The managers at all levels measure their progress and any problems, whether technical or programmatic, against these schedules. When problems arise, the managers develop workaround schedules, and initiate or replan work to resolve the problems. They cover any additional work with schedule or funding reserves if possible. They will attempt to recover schedule margins. The programs have processes internally to communicate issues and to elevate problems to higher level management when necessary, when they need help or don't have sufficient reserves.
    a. The "bifurcated" commitments versus internal schedule targets can create confusion inside NASA, at the contractors and external to the program. This disparity can result in relaxing to the commitment dates at lower levels of the program if the top level direction is not understood or explained sufficiently.
    b. The Administration could better support the human exploration priorities instead of implementing policies that hinder it. The Administration could help NASA operate more effectively by recognizing intended Congressional funding levels and provide PBRs that are consistent with this intent or by working with Congress. Having an agreed to policy would enable more effective long term planning and earlier milestone commitments. Efficient implementation of these programs would demonstrate good stewardship of taxpayer investments.

16. The KDP-C review for Orion last month and the KDP-C review for the SLS last year both resulted in the announcement of unexpected schedule slips.
    a. To what extent is a formal KDP-C review necessary to identify schedule issues in programs of this magnitude?
    b. Conversely, to what extent should such issues be apparent on a continuous basis as part of NASA's ongoing program oversight and management?
    c. What changes could NASA make to its project life-cycle procedures to reduce the likelihood of schedule surprises at this point in a major program?

16. The KDP-C review is important to establish commitment to implement programs.
    a. It is the specific application of the JCL based on the PBR that is disparate from the Congressional budget appropriations that introduces the unnecessary slips in commitment dates.
    b. Normal program processes and communication, management systems and reviews, insight and oversight, provide a realistic understanding of program progress within NASA and the industry partners.
    c. NASA could stop blindly using the JCL in its current role in these decisions to establish commitment dates. NASA could use more judgement based on the overall realistic budget and policy environment in assessing program progress and outlook.

17. In July 2015 GAO reported that the SLS program's earned value management system provided limited insight into progress relative to the program's agency baseline commitment because it tracks performance relative to the program's internal management agreement.
    a. What are the other effects, both positive and negative, of managing to internal targets rather than to committed baselines?
    b. How do the programs track and report progress relative to committed baselines?
    c. Is the difference between NASA's management agreements and baseline commitment for SLS and Orion in effect just funded schedule necessary to allow the programs to satisfy the 70% confidence level guidance?

17. The GAO is correct that the earned value system based on the management agreement would not accurately reflect progress against the agency baseline commitment. Earned value systems are based on detailed tasks and their estimated cost based on the program teams' best realistic judgement on what it takes in time and money to get the task done. These tasks and schedules are developed within the cost spending rates as allocated and flowed down by layers of management. In my mind it would be unrealistic and near impossible to do this any other way. The agency commitment dates are the result of the JCL theoretical model and adding schedule based on the unrealistic PBR and assumed statistical inefficiencies.
    a. Managing to internal dates based detailed schedules and tasks developed by the people who are doing the work is the best understanding of what has to be accomplished on a day to day basis. A fictitious commitment date would be hard to allocate down to the working level. If it were done, it would instill non-urgency in getting the job done among workers. The more lax deadline on individual tasks would be self-fulfilling. Paying for this is a matter of paying wages over a longer period of time for the same work. As soon as the schedule is relaxed problems that arise will result in further delays.

b. The programs will know where they stand based on their internal schedules. At a macro level they will know whether they are ahead or behind commitment dates.
c. Based on my understanding. This is a good characterization of the situation, with the addition of the fact that the JCL using the PBR funding limits forces additional funded schedule as well.

18. **Over the past five years there have been significant disconnects between the Administration's budget requests for SLS and Orion compared to NASA Authorizations and Appropriations. This is not the case for the majority of NASA's programs. Despite the budget uncertainties caused by the Administration budget requests, these programs continue to make stable and predictable progress with the appropriated funds.**
    a. **Can you give the Committee a brief overview of how these budget requests are developed?**
    b. **How does the program influence these requests to reflect the needs of the program?**

18. NASA budgets are developed through a yearly internal process. Funding levels are based on the PBR. It is provided top down from the OCFO to the Mission Directorate and then flowed down through the programs from level to level through allocations based on past year allocations or additional direction from the Mission Directorate. The programs do a bottoms up collection of tasks and costs, with an eye to making established milestones and the tasks needed to achieve them. There are reviews at each level attempting to stay within constraints but establishing requests for work or content that is "over guidelines." These may be traded and approved or disapproved at each level of review. The final review for programs is at the Mission Directorate, which makes decisions among the proposals, trying to manage within constraints. It may take forward decision packages for "over guidelines" requests, which may be new work or initiatives. This may then be traded between directorates at the agency level. The agency makes its input, which may include changing priorities between directorates to OMB. There are presentations to OMB by the Mission Directorates of the programs and initiatives based on agency decisions. OMB usually provides a "pass-back" based on its deliberations and any new policy guidance from the Administration. This pass-back may provide new initiatives based on new policy. NASA usually has an opportunity to argue its case for any differences. The resulting Administration decisions are reflected in the President's Budget Request (PBR) usually scheduled in early February. NASA plans to this guidance. The actual budgets available to programs in the current year is based on appropriations, when they are passed, or continuing resolutions, etc.

19. **The expected date of the first test flight of Orion and the SLS (EM-1) has slipped from 2017 to 2018. In discussing the budget for Exploration Systems Development, NASA's position has been that it would be difficult to bring the launch date of EM-1 forward, even with additional funding, because the schedule depends on technical requirements**

such as engineering design and manufacturing schedules and the need for adequate testing.

    a. In retrospect, how likely is it that additional funding earlier in the program could have accelerated the date of EM-1?
    b. Even if bringing EM-1 forward would have been difficult, how likely is it that additional funding would have prevented the schedule from slipping as it has?

19. If budget had been available earlier, without the budget machinations discussed in earlier questions, I am confident that NASA could have made 2017 date. If the proper budget had been in place in 2011, when we established the SLS design, it might have allowed for slight acceleration of EM-1. This is recognizing that we were beginning the core stage design from scratch. Follow on flights and earlier development of the Exploration Upper Stage would have been accelerated. The following quotes help to make the point:

    In **Discovery News,** April 12, 2013, John Elbon, Boeing Vice President and General Manager of Space Exploration, is quoted as saying "We're on budget, ahead of schedule": http://news.discovery.com/space/nasa-sls-rocket-mars-deep-space-schedule-130412.htm

    On July 3, 2014, Todd May, NASA SLS Program Manager, was quoted by **CBS News** as saying "The SLS program team finished the core stage critical design review ahead of schedule and continues to make excellent progress towards delivering the rocket to the launch pad" http://www.cbsnews.com/news/nasa-finalizes-2-8-billion-boeing-contract-for-sls-rocket-stage/

20. **The President's budget request does not reflect the needs of the program while Congress continues to provide proper funding. The result is inefficiencies in how the program is managed. You address this oscillation in your testimony; could you expand more on the topic?**

20. Developing detailed integrated program schedules for large programs requires planning for thousands of workers for the design, analysis, testing and manufacturing work. Integrating these plans must be accomplished to efficiently develop components that must in turn be integrated into a total vehicle. Every individual schedule must provide a crucial result to be completed at the right time to be integrated into the final vehicle. This planning is negotiated into contracts with industry partners based on a specific budget over time, allocated to cover each component of the planning. When the budget changes for any reason, it affects this planning and if the change is big enough will cause replanning at a great expense of resources. Contracts are renegotiated, usually with increased expense and schedule. A major source of perturbation for SLS and Orion is the disparity between the PBR, which the programs are required by OMB and the OCFO to plan to, and the actual appropriated but (higher) budgets. The program manager may anticipate the higher funds that are finally passed and will have internal plans that reflect the additional funding. This is complicated by Continuing Resolutions, government shutdowns, etc. These changes and maneuvering are confusing to the workforce and cause anxiety. NASA management communicates to make everyone aware of what they should be doing. If NASA plans to the anticipated (higher) Congressional budget levels, and the higher levels do not materialize due to Continuing Resolution or Congress is unable to provide the funds for other reasons, NASA must correct its spending rates to not be anti-deficient at the end of the fiscal year. If the anticipated funding is reduced in the middle of the year, NASA finds that it has been spending at too high a rate and then must overcorrect, severely cutting the spending rate, potentially even laying off workers. NASA, through the OCFO lives in fear of being anti-deficient, since it is illegal. Therefore spending rates are applied conservatively. Due to these issues, NASA often has to change plans two or more times a year. A stable budget at an agreed to appropriate level would allow NASA to plan longer term and the work would progress efficiently. There would be more focus on getting the work done and less on re-planning and turmoil.

21. **Orion has completed several highly successful tests so far. Pad Abort-1 successfully test the crew escape system, and EFT-1 tested many the crew module capabilities as well as mission operations. Please describe how additional funding might be utilized to accelerate crew capability for Exploration Mission-1**

21. My information is second-hand, but I have been led to believe it may be possible for crew capability on EM-1 to be accelerated through some level of funding and firm direction to accomplish it. This is a question for NASA and Lockheed Martin.

22. **The Government Accountability Office (GAO) has found that NASA's cost estimates do not capture the full life-cycle cost of developing and operating the SLS and Orion. In particular, the baseline cost estimates for the SLS and for associated ground systems omit the cost of EM-2 and none of these estimates, including the Orion estimates, include the cost of operational missions after EM-2.**
    a. **Based on your experience managing human spaceflight programs at NASA, would you expect the cost of these programs to increase or decrease after they transition from development to operations?**
    b. **What factors are most likely to affect that outcome?**

22. I believe costs after development of a vehicle should come down when it becomes operational. This depends on a lot of factors that have to be handled right. Once operational, the NASA and contractor workforce supporting the SLS and Orion must be reduced to small sustaining levels. They should be maintaining just enough expertise to work anomalies and obsolescence, etc. This will be resisted at the field centers if there are not new programs to work on. There is a need to address this issue with NASA and industry infrastructure as well. For Exploration Programs there are additional needs for flight elements downstream, such as habitats, landers, etc. Initiation of these elements would help existing NASA and industry workforce and facilities to be more productive. ISS operational costs are still high, but it is carrying the expense of buying Russian launches for cargo and crew, while continuing to pay for commercial launches. The ISS Program has also undoubtedly inherited institutional and workforce expenses at JSC that were not reduced with the retirement of the Space Shuttle. Although not an operational program yet, SLS has probably inherited institutional costs for Marshall Space Flight Center and Stennis after Shuttle retirement. To my knowledge, "Commercial" Programs are not burdened in the same way and therefore ISS, SLS, and Orion undoubtedly make up the difference at these centers and probably others. This phenomenon occurred in past years with costs from Research Centers, as NASA technology spending has declined. These overhead costs will translate into operational costs, if they are not addressed. Higher flight rates also tend to favorably drive efficiencies as well as the workforce is more productive.

23. **As members of the senior executive service at NASA, you were both engaged in budget formulations and pre-decisional submissions to the Office of Management and Budget under this administration. NASA has indicated that these programs are receiving the funding they need to achieve the programs' goals and milestones. Was that your experience during your tenure at NASA?**
    a. **Is it your opinion that the exploration systems development budget at NASA is sufficient to achieve NASA's exploration goals? Why or why not?**
    b. **In your opinion, what difference would additional funding make to the proposed launch dates for EM-1 and EM-2?**

23. My experience at NASA as AA of ESMD is evident in what occurred publicly. The Exploration budget projections eroded over this period. In 2009 they were reduced to the level of eliminating lunar content, just prior to beginning the Augustine Committee. In 2010, the Constellation Program was cancelled and the budget was again reduced significantly. Due to Congressional intervention, we entered a period of sustaining contracts and reformulating the exploration programs, which led to the SLS and Orion Programs. Pressures were put on Termination Liability during this period of time, further reducing spending rates. I do not believe that the Administration considers human space exploration a priority and has consistently attempted to put pressure on it through the budget process and practices.
    a. The only real goals NASA has for Exploration Programs are EM-1 and EM-2 flight dates. I believe NASA can make EM-1 and EM-2, but has slipped the dates based on application of the JCL. I believe that at the time of the EM-1 slip announcement, SLS could have made the 2017 date. Similarly, I believe EM-2 could make the 2021 date, but with the recently announced slip and current budget processes and practices, I am afraid that the commitment date will become self-fulfilling.
    b. It is probably not possible to recover the 2017 EM-1 flight date at this point. Additional funding could provide margins. With congressional budget levels and with program planning to those levels, EM-2 can probably still make 2021; but not with PBR levels. Beyond these test flights, there are no apparent Exploration mission goals. I am not aware of mission specific budget planning beyond EM-1 and EM-2. I believe NASA needs real goals for Exploration missions beyond the test flights and should present the necessary budgets needed to achieve these stated goals.

24. **Major NASA development programs typically have a development curve where funding increases during the course of development and then funding decreases during integration and test.**
    a. **Do you have any concerns with NASA's continued flat funding requests for the Orion and Space Launch System (SLS) programs?**
    b. **What sort of funding curves are optimal for development programs?**
    c. **What are some of the likely impacts of flat annual budgets on development programs?**
    d. **Do the planned budgets for SLS and Orion support the development schedule and retirement of risks?**

24. Major development programs do have a natural curve of work/cost through the development cycle. Concerning Exploration as a whole, including SLS and Orion:
    a. I do have serious concerns for a flat budget that I expressed at NASA and OMB, when I was still at NASA, and have continued to make a point of this since retiring. Flat budgets combined with inflation result in reduced buying power compounded at the negative rate of inflation over time. It does not allow for a sustainable program.
    b. As stated in the question, funding curves rise and fall over the phases of the program. The actual curve is specific to each program, depending on the complexity of the design and other related factors.
    c. Impacts to programs due to an artificially flat, low budget are that all tasks that should be done in parallel cannot all be done when they should be due to the budget constraint. Some are therefore phased out later based on the priority of the task. Tasks are phased in

and out to make certain milestones. This can be seen at a macro level on SLS, we decided during the formulation of the design. We were faced with a flat, low budget projection. We made specific decisions in the design to fit within the funding constraint. We had the 5 segment boosters under development from Ares I. Later when funds would be available, we would phase in more advanced boosters to reach the full lift capability defined in the 2010 Authorization Act. If the budget for that doesn't show up, then the current boosters get the lift capability to a manageable level for Exploration flights. We had the existing flown engines from the Shuttle vehicles that were efficient and the right thrust level. There were enough for the first few flights and were human rated. We would wait for upgrades to them for improving manufacturability by the time we ran out. We had the J2-X engine and an upper stage under development that could be modified for the larger SLS vehicle. We had to focus development funds on the SLS core stage, which did not exist. Since then, the J2-X has been shelved, and the upper stage was phased later. The ICPS will be used for the first test flight EM-1. If the funding levels had been there, the right upper stage could have been available for the first flight. Now it will fly when funding levels allow it to be phased in, hopefully for EM-2. Otherwise money will be wasted on human rating the ICPS. If the right funding level had been in place, Orion would have all of its systems ready for the first flight as well. So this shows historically how the available budgets have affected these particular programs, and how developments are phased at a top level based on available budgets. Under constrained budgets, budget pressures are felt at all levels of the program, and similar phasing trades are made down to the task level.

d. NASA by nature will use the available budgets to develop these programs as efficiently as they can. They will do what is necessary to mitigate risks. Are the budgets adequate to do this job right under a normal development curve? My answer to question 24c demonstrates the answer to this is emphatically **no**.

25. **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. Did NASA consider using this clause during your tenure? If not, can you explain why not?**

    a. Could NASA use uncosted or unobligated funds from other programs to cover the highly unlikely event of a termination for convenience on these national priority programs?
    b. Is this how other mission directorates currently handle this unlikely possibility?

25. In the spring of 2010, NASA through the OCFO strictly interpreted the Termination Liability requirement and implemented it contract by contract, allowing no flexibility. No other interpretation was allowed. At the time this implementation resulted in severe reductions in contract spending rates. If I remember correctly, this resulted in layoffs. In the ISS program a clause in legislation relieved NASA from strict application of Termination Liability. Other institutions, such as the Air Force spread the exposure across programs in a probability based approach. These approaches were not pursued for these programs. Alternative approaches such as these would have allowed higher spending rates and more progress. I believe that relieving this constraint now would free up funds for program progress. I believe relieving TL through

legislation is still the best solution, since it would help to preclude adverse interpretation. I believe NASA has relieved the strict adherence to the TL requirement. In the process, I believe that the contractors have taken more risk and are still legally responsible. Therefore the legislation is still beneficial.

a. An alternative to legislation would be an approach similar to the Air Force approach, which does spread the unlikely risk more broadly.
b. I believe other mission directorates spread the risk over multiple programs, but I am not absolutely sure. They should be asked this question.

26. The NASA Authorization Act of 2010 requires NASA to build the *Orion* crew vehicle with the minimum capability requirement to provide backup crew transfer services to the ISS in the event that commercial contractors are unavailable. This does not require *Orion* to be launched on SLS. The Administrator has said in the past that the Orion will not be used for this purpose. The law is clear that Orion should be capable of serving that purpose.

a. In the event that both Commercial Crew contractors experience failures similar to the Commercial Cargo program, do you believe it would be a bad idea to use *Orion* rather than rely on Russia?

26. I believe that Orion could be used for the purpose of supporting ISS in an emergency. Flying it on SLS would be an overkill and very costly for that purpose. The Soyuz would probably be less expensive, but has the drawback of reliance on the Russians. Although the Orion EFT-1 test was flown on a Delta IV, it is not prepared to fly people. The Delta IV would have to be human rated and the launch complex would have to be augmented to provide crew access and safety. Since the requirement for Orion to perform this mission is in law, I believe NASA should provide options either for how this capability could be achieved, compared with its preferred approach. NASA should compare the associated costs. It should show why this requirement should be removed if that is the case. In any event, as part of this discussion NASA should demonstrate how it satisfies the underlying requirement to protect crew safety and welfare.

27. Please explain how the agency budget is developed and how the negotiation process between NASA and OMB is conducted.

a. In your opinion, how effective is the current presidential budget request process?
b. How could the presidential budget request development and negotiation process be improved to ensure that programs are complying with Congressional direction and operating as efficiently and effectively as possible?

27. Please see the answer to question 18 for my understanding of the current budget process.

a. I believe the right steps occur in the process leading to the program and Mission Directorate levels, including the resolution of issues at those levels. I believe the budget process could be improved by being more open and transparent, particularly with Congress.
b. I believe that Mission Directorate needs and budget requests should be shared with Congressional oversight committees during the process. I also believe that OMB should be required to communicate more directly with the NASA oversight committees during this process to reach resolved budget levels if possible.

28. Please explain the benefits that come from passing a reauthorization bill before the beginning of the next Administration.

28. I believe that passing an Authorization Bill prior to the next Administration would help set policy that would be a well thought out nonpartisan consensus representing stake holders and constituents. This is important in that Presidential candidates do not engage in this level of detail during campaigns. An authorization act could be instrumental in providing needed stability for NASA programs.

29. After the Apollo program took us to the moon, three landing missions were cancelled: Apollo 18, 19, and 20. How can similar exploration programs, like a Mars exploration program, avoid termination after the first several human landings?

29. NASA/Exploration programs should learn from the experience at the end of Apollo, by developing more long term objectives for meaningful achievements. NASA should update the plan and objectives on a regular basis as it learns from missions and yet unknown discoveries.

30. The NASA Authorization Act of 2010 states that the long term goal of NASA human space exploration is "to expand permanent human presence beyond low-Earth orbit". Is there a pressing need to pursue that now?

30. There is a pressing need "to expand permanent human presence beyond low-Earth orbit." As a Nation, we are learning from robotic missions that are providing the information that points the way. We have the experts and scientists who are interpreting them and are current. We have the recent and ongoing experience from the Space Shuttle and ISS Programs that provide the basis for developing new large scale systems. We are in the process of developing the first critical capabilities, SLS and Orion, to perform these missions. We are building real hardware. We are developing the capabilities through companies to take over routine travel to and from Earth orbit, allowing NASA to focus on the exploration of space. We have cultivated an international community to work with us on these endeavors. We are a Nation, society and culture that is compelled to lead great endeavors, to improve, learn and discover. We are poised to send explorers beyond low Earth orbit. There is a cultural and societal need to take the next step in great endeavors, and we are positioned and prepared to take it.

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

"Deep Space Exploration: Examining the Impact of the President's Budget"

Questions for the record, Mr. Doug Cooke, Owner, Cooke Concepts and Solutions; Former Associate Administrator, Exploration Systems, NASA

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

Doug Cooke's Answers to Questions:

1. **How should NASA structure its human space exploration program so that it continues to make progress despite constrained budgets? What in your view would be the most important things for Congress to do to help NASA sustain progress on its exploration programs?**

1. In conjunction with NASA stake holders, NASA should develop a roadmap that lays out initial Exploration missions and develop a proposed budget, so the discussion moves forward. Current Congressional levels are important to maintain progress on SLS and Orion. Congress can help by building on the current SLS and Orion budgets and considering increased budgets for exploration to build what is necessary to conduct missions beyond the current test flights. This increase should include
    a. Potential increases to make up for past losses due to inflation.
    b. Right-sizing workforce and institutional overhead to free funds for the programs
    c. Opportunities for reprioritization within NASA's top line

   Congress can also help by addressing Termination Liability through legislation. Although NASA has internally relaxed the implementation, contractors still carry the risk. NASA is different from most agencies in that it has multi-year development programs that are most efficient if budgets are stable. Multi-year stable funding for these programs would make a significant difference. It would eliminate the perturbations that occur year-to-year with the differences between the PBR and Congressional budgets and in the case of Continuing Resolutions.

2. **To what extent is the Joint Confidence Level a suitable tool for managing the SLS and Orion programs at this point in their development? What, if any, alternatives exist and do they provide a benchmark to which Congress can measure progress?**

2. The process of developing the JCL has helped to provide a rigor in evaluating the program approach and has helped provide focus on detail in these programs. However, the current approach where PBR budgets are used as the basis for JCLs is counterproductive in my view. NASA can provide insight to Congress based on its progress towards pre-established program milestones based on its integrated program schedule. This can reflect the earned value system results. NASA should base the schedules on expected budgets based on congressionally passed

budgets. Congress was able to track programs prior to the introduction of the JCL. The JCL, particularly when based on the PBR has introduced confusion into the communication. I believe that responsive communication and the traditional Congressional insight/oversight is healthy and is responsible to taxpayers. I believe this can be reestablished without the confusion of the JCL and the associated approach in developing it. I also believe this Congressional insight/oversight should be extended to "Commercial Programs" for the same reasons.

3. **The EFT-1 test generated excitement around the world in sending the Orion test vehicle farther into space than any human spaceflight mission since the Apollo era. Given the long gaps between the EFT-1, EM-1, and EM-2 flight tests, what can NASA do to sustain the enthusiasm that EFT-1 created?**

3. First, NASA would make better progress and these milestones would be earlier in a more stable budget environment. NASA would also make better progress if were operating to 2010 Authorization Act levels. Human Space Flight budget projections have eroded over time even before inflation losses. NASA was flying Space Shuttles multiple times per year until it was retired in 2011. The original intent was for the retirement to provide a wedge for Exploration Program ramp-ups in development rate. This did not happen. The Space Shuttle was a heavy lift vehicle, putting the 240,000+ lb. Orbiter and payload into orbit every time. Now we are facing a low flight rate of a flight every year or two. Given the current situation, NASA can always do better in communicating major tests and milestones in development of the new vehicles. This was organized well for the Orion EFT-1 test flight. NASA could do much better in communicating achievements on ISS and how they relate to Exploration.

4. **How important is it to have a defined mission for the Space Launch System (SLS) and Orion beyond EM-2 at this point in time? What are the implications for the programs of not having a defined mission?**

4. It is very important to have an Exploration Roadmap with compelling missions utilizing SLS and Orion. The mission objectives serve to demonstrate the promise of inspiring achievements for the future. They also provide the focus for studies and conceptual designs for flight elements needed for these missions. Without this context it is difficult to demonstrate to stake holders the importance and potential benefits of these missions. The lack of a defined mission causes the programs to be criticized by people with alternate agendas, and the programs become vulnerable.

5. **In its 2015 Third Quarterly Meeting Report, the Aerospace Space Advisory Panel (ASAP) indicated that NASA's approach to developing SLS, Orion, and Ground Systems is in essence "capabilities-based management", which ASAP characterized as a slower and more flexible approach to building the systems (characterized as "parts" by ASAP) needed for the future. ASAP noted, without further explanation, that there are challenges in NASA's "parts" approach, both in program management and in integration.**
   a. **Having now been away from the program for some time, does the capabilities-based management approach still make sense? If not, what other approach should be taken and how would NASA transition to the new approach?**
   b. **What are the program management and integration challenges associated with the current approach?**

5. The ASAP provides valuable insights into NASA and its programs

a. "The capabilities based" management approach was put in place in the year following the 2010 Authorization Act. This was due to the fact that ESMD was faced with an incredible effort, responding to the 2010 Act in baselining the SLS and Orion. Baselining SLS and Orion was very important, because these capabilities represent the first critical/essential steps in developing Exploration capabilities. We were able to get final approval to announce SLS in the last month I was at NASA, September, 2011. It was my intent that once we established these baselines, we would begin mapping out an Exploration Roadmap as a plan for human exploration missions. This roadmap would reflect objectives proposed by the exploration and science communities, including International Partners. Actually, we were already working this through the International Space Exploration Coordination Group (ISECG). The ISECG published a Global Exploration Roadmap in August 2013. NASA has participated in developing it, but NASA has not adopted or produced such a Roadmap. The closest thing to producing a roadmap is "The Journey to Mars" document, which does not have the level of detail that I believe is necessary. I have advocated the development of a long term roadmap or strategy, since leaving NASA. I provided an approach for developing a roadmap in oral and written testimony for a hearing of this subcommittee in May of 2013. It will be included in the submission of these answers. I believe an Exploration Roadmap is needed and should be required for the next Administration.
b. The challenges with the current approach are that the critical programs, SLS and Orion, need a context and purpose. Based on my experience of over 25 years with human exploration studies, planning and implementation, I am sure the SLS and Orion capabilities are essential. However, a human exploration plan/strategy/roadmap is needed, and given the substantial progress that has been made on these programs it is important to begin working on the next developmental steps in such a roadmap. The SLS and Orion Programs by themselves become vulnerable without this context, particularly with organized detractors with self-promoting agendas.

6. Given the challenges of sending humans on future long-duration missions to Mars or other deep space destinations, such as radiation exposure and the need for generating food and water, do we need to consider developing an advanced crew transportation system based on nuclear-electric propulsion to reduce travel times? In your opinion, what are the risks associated with nuclear-electric propulsion, and how can they be mitigated?

6. NASA's current plans include the use of solar-electric propulsion. Technically speaking, nuclear-electric propulsion does not reduce travel times at the same power level. It is still electric propulsion. The difference is in the power source. At some level of power, solar array size could become unmanageable. A nuclear reactor would be compact in comparison. Higher power levels from a reactor could reduce travel times by increasing the thrust level. If solar power is used to spiral out of Earth orbit with electric power, the solar arrays would degrade at some rate due to the effects of the radiation from the Earth's Van Allen belts. The challenge for a nuclear reactor is the cost for development and the safety studies needed to implement it. The risks of a Uranium based reactor are known and can be mitigated. They do not pose a major risk during launch before they are turned on. Risks are less than flying Plutonium based RTGs on science

missions, which has been done successfully a number of times. The process for mitigating concerns for all of these radiation sources are manageable.

7. **During this Subcommittee's hearing on the SLS and Orion programs in December of 2014, Mr. Gerstenmaier, NASA's Associate Administrator for the Human Exploration and Operations Mission Directorate, said, "I would say the biggest technology areas that we need to work on are...radiation for the human being and look at radiation shielding." Do you agree? What are the most promising approaches for addressing the risks of radiation exposure in future human exploration of deep space? What is your view of the status of work on radiation shielding or technological approaches to this area of risk?**

7. I agree that the risk of radiation exposure for humans is one of the primary areas that need more research. The human risks to exposure to Galactic Cosmic Radiation (GCR) are not well quantified. This definitely is an area of scientific research that needs more effort. This can be done through further experiments at Brookhaven Laboratory, which has facilities that were augmented by NASA. I believe research is ongoing at Brookhaven for understanding these effects and for testing shielding technology. In-space experiments outside the Van Allen belts would also benefit this understanding, probably including animal and human tissue experiments. The effectiveness of shielding particularly for this form of radiation is also important. It is known that conventional shielding that is effective for radiation from solar flares can be more harmful than helpful for GCR. Shielding with water or Hydrogen, also used for other mission purposes can be effective. This is not the only major technology area needing further work. Entry and aerobraking technology for Mars vehicles, advanced in-space propulsion (solar electric, plasma, nuclear-electric, or nuclear thermal rocket), advanced life support, space suit, advanced power systems, advanced avionics, application of light-weight materials, and cryogenic fuel management and storage are other important technology areas to be advanced.

8. **The ground infrastructure at Kennedy Space Center is undergoing significant development to support the SLS/Orion launches.**
   a. **Do you believe that NASA's Ground Systems are making adequate strides relative to the progress being made on SLS and Orion?**
   b. **Are you confident that ground infrastructure improvements will not delay the overall progress on achieving EM-1 and EM-2 launch dates?**

8. I am sure the team at KSC is working diligently to prepare for SLS/Orion launches. I would defer to Mr. Dumbacher, since he has more recent direct knowledge on this subject. This effort is less publicly reported on than SLS and Orion. My concerns are that Launch Complex 39B is discussed by NASA as being a multi-purpose pad. I don't understand the practicality of this approach, and hope that it is not diluting the focus or compromising the design for launches of SLS/Orion. NASA originally said Launch Complex 39A was to be a multipurpose launch pad. When it was awarded to SpaceX, my understanding is SpaceX proposed to make the pad be for its exclusive use and NASA agreed to this. I just think that each vehicle is different, with different interfaces to the pad and that a multipurpose universal pad is not practical. I am concerned that NASA has apparently given away access to Launch Complex 39A. NASA has probably done this based on poor PBR budget projections and the resulting low flight rates. When Mars missions occur NASA will need higher flight rates of the SLS. As many as 6 or more flights will be needed. Apollo

needed and built 2 launch pads. Shuttle needed and used 2 launch pads (39A and B). I believe NASA will need 2 launch pads for Mars missions. Before that, NASA will need a second pad for SLS to support a more realistic higher launch rate.

Responses by Mr. Dan Dumbacher

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

"Deep Space Exploration: Examining the Impact of the President's Budget"

Questions for the record, Mr. Daniel Dumbacher, Professor of Engineering Practice, Purdue University; Former Deputy Associate Administrator, Human Exploration and Operations Mission Directorate, NASA

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

1. As a former member of a leadership team at NASA that managed human exploration programs under a variety of administrations. How would you characterize the priority this Administration puts on exploration?

RESPONSE: This Administration has shown a preference for the commercial cargo and crew activities at the expense of Orion, the Space Launch System, and the Ground Systems needed for humans to explore beyond Earth orbit. This is evident in the annual budget request and subsequent debates with Congress on the respective funding levels for these Programs.

It needs to be recognized that all of these Programs, along with funding for the International Space Station, are critical for humans to extend our presence into the solar system. For space exploration to be successful and sustainable in the long term, it is essential that commercial opportunities are encouraged and key steps are taken by the government to open new frontiers and markets, solve complex challenges, and reduce the investment risk for commercial enterprises to develop.

2. The expected low flight rate of Orion and the SLS has raised safety concerns. According to NASA's Aerospace Safety Advisory Panel, the current plan for one launch about every two to four years "would challenge ground crew competency."
   a. Based on your experience in human spaceflight, what flight rate would ameliorate this concern?
   b. What would you expect to be the annual cost of the additional flights?
   c. Are there other ways to address the safety concerns arising from a low flight rate? If so, what are they, and what are their cost implications?

RESPONSE: Based on my experience, I would request that SLS and Orion reach at least a 1 flight per year rate. This is needed to keep the team sharp and focused, and recognizies the budget constraints. As additional "customers' or users of SLS develop, the additional flight rate will improve the team efficiency and reduce the per flight costs.

It is also important from a mission success standpoint that as we travel further into space, with habitats, landers, and spacecraft, the multiple flights of SLS required to execute these missions will require flexibility and increased flight rate for reasonable mission success.

NASA has been developing the operational costs of Orion and SLS and I have not been involved in those calculations since July 2014. NASA can better respond to this question.

It is necessary in my opinion to keep the team focused and working toward an achievable, measurable common goal. Executing missions is the key way to focus the team on what needs to be done and staying focused on the real tasks to be accomplished.

3. Does the pace of development in the Orion program have any effect on NASA's plans for developing the SLS exploration upper stage (EUS)?
    a. Is it cost effective for the SLS program to forego human-rating the Interim Cryogenic Propulsion Stage for use in EM-2 and proceed directly into the development of the EUS for EM-2?
    b. How likely is NASA to fly crew on an EM-2 flight using an EUS that has never flown before? If NASA incorporated EUS into the SLS architecture for EM-2, would that have an effect on the date of the first crewed flight to EM-3?

RESPONSE: NASA's KDP-C for the Orion program was developed to meet a schedule for EM-2 The pace of Orion development should have no effect on the SLS upper stage. Those are separate issues. Proper funding is needed to assure that Orion is completed and the upper stage is ready for EM-2. In my opinion, it is an ineffective use of money to human rate any element of exploration that will only be used once or twice. Human rating the Interim Cryogenic Propulsion Stage is a significant cost that can and should be applied to the upper stage. This will provide increased exploration capability for less total cost. There are technical issues to be addressed in the development of the upper stage for the first crewed flight on EM-2; however, these can be addressed via ground testing of the propulsion systems and other subsystems. The important risk elements at the system and integrated levels can be significantly mitigated with appropriate ground testing.

4. NASA's KDP-C for the Orion program was developed to meet a schedule for EM-2 rather than EM-1. How does the NASA JCL model discern between those funds needed to support a first mission and those needed to support future missions?

RESPONSE: In the original planning, NASA established the KDP-C for Orion on the completion of the crewed flight capability, thus EM-2. The Orion configuration for

the EM-1 mission is planned to be uncrewed, primarily due to insufficient funding to achieve crewed capability on EM-1. NASA was forced into this position due to the OMB imposed cost constraints.

For the SLS analysis, NASA limited the scope to only those activities required for EM-1 since EM-1 represented key launch capability. The team assessed funding line items for direct applicability to EM-1 and separated those items only addressing EM-2 and later missions from the JCL analysis. From the team's assessment of the funding line items, only those items needed for EM-1 were included in the JCL analysis.

5. Please describe the process for determining the JCL of a large NASA program like Orion or the SLS. Who does the engineering calculations? Who oversees that work? Who approves the final result?
    a. If the JCL is determined to be unacceptably low, what is the process for making changes to the program's scope, schedule, or budget?
    b. What is the process for recalculating the JCL following any such changes?
    c. Which of these processes are carried out internally by the staff of the program, and which are conducted independently by others?
    d. Would additional independent oversight help to ensure that the JCL is determined appropriately? Who would be best positioned to provide such independent assistance?

RESPONSE: The responsible Program team conducts the Joint Confidence Level (JCL) analysis. In the case of Orion and SLS, each Program team performed the needed analysis. The Program teams develop the schedule needed to achieve the required capability, identify technical and programmatic risks and the associated potential impacts to cost and schedule, and statistically assess the risks with the combined impacts to cost and schedule. These analyses are combined into the JCL top-level assessment. As the team assesses the JCL, options to improve schedule and cost are developed as necessary, with risk impacts assessed and understood. Changes to budget and schedule inputs require reassessment at the individual task level; this can result in significant rework.

The work performed by the Program teams is assessed by the NASA Standing Review Board process that addresses the technical, cost, and schedule analyses. This process provides constructive criticism to the Program teams. Given the dedication of the team to the effort, their recognition of the importance of the Agency commitment being developed, the significant taxpayer resources to perform these analyses, and the independent review by the Standing Review Board, additional independent oversight is not warranted, in my opinion. This assumes that NASA does not significantly alter the approach with the recent announcement to eliminate the Program Analysis and Evaluation (PA&E) Office. This Office provided the needed independent analyses.

6. NASA program management includes using Joint Confidence Level (JCL) exercises to predict the likelihood a program will meet predicted schedule. As you state in your testimony, this process is laborious and highly technical.
    a. In this model, how does the use of a lower set of budget numbers, such as the artificially low requests from the President, influence the JCL projections?

RESPONSE: The budget plan directly affects the JCL calculations. The lower the budget projections, the longer it will take to complete the work to achieve the stated capability, thus a later schedule for the same confidence level. Increased Congressional appropriations enhance NASA's ability to achieve the capability on an earlier schedule.

7. NASA's Cost Estimating Handbook (CEH) and GAO best practices advise that when constructing a JCL, the agency should first build a schedule and then cost-load that schedule. Can the JCL process be manipulated to presuppose a budget and then build a schedule to that budget?
    a. What are the negative effects of building a development schedule around a budget rather than letting the most logical schedule dictate the financial needs?

RESPONSE: To assess the risk of budget uncertainty, it is necessary to identify the changes to the cost loaded schedule resulting from a different budget projection. This was done by NASA on the SLS Joint Confidence Level Analysis. When assessing a budget risk, it is also imperative that the team assess the technical and programatic risks due to the different budget projection. This is necessary for the team and Agency leadership to understand the consquences of budget / schedule projections and how issues can result in the technical and program execution.

8. There is not always agreement between the President's budget requests and the enacted budget. For instance, SLS and Orion budget requests have been well below the annual enacted levels.
    a. How does the NASA JCL process address such budget discrepancies, given the well observed pattern of SLS and Orion funding above the President's request for the past five years?
    b. Are there changes that you would recommend to NASA's JCL model regarding the budget inputs to provide a more realistic prediction?

RESPONSE: Due to the visibility of these Programs, the "chain of command" relationship between the Agency and the Office of the President, and the nature of the public commitment of the Key Decision Point process, NASA has no choice but to plan the JCL around the President's budget request. In this analysis, NASA can, and should, address other funding scenarios, particularly given the recent history of

Congressional appropriations. The NASA JCL process addresses this issue as a budget or cost risk against the technical execution of the program.

Overall, providing the Programs the ability to plan based on historic funding levels up to Key Decision Point C would be an improvement. This would provide a more realistic view of the program future performance, provided the program planning, risks, and uncertainties are well understood. The recent IG report on the JCL process also calls into question the application of the JCL process to such large, single project Programs. I would add that JCL process for Programs that do not have defined end dates, as compared to a planetary mission launch, and over such long time horizons with the inherent uncertainties of future budgets, should be appropriately modified. The key value of the JCL process for SLS was the detailed understanding of the technical planning, risks, and known uncertainties.

9. The majority of NASA's high-cost development programs are single projects rather than ongoing development. As an example, NASA builds a single and unique scientific probe for each mission compared to multiple SLS and Orion builds to meet current and future exploration missions.
    a. Based on your experience with multiple build programs, are the current SLS and Orion budgets entirely dedicated to meeting only the objectives of their first mission?
    b. What are the implications to a multiple build program if all the allocated funds are directed to accomplish only the first mission?

RESPONSE: SLS and Orion budgets address objectives beyond just the first mission. Obviously, the majority of the funding is meant to complete the first mission. The SLS budget does address future planning for EM-2 and beyond- such as the upper stage, potential technology applications to future SLS product improvement, and investments to implement more efficient solutions for the Program. Orion's budget is developing crew systems necessary for EM-2. It is more appropriate to view the budgets as providing the building blocks for each mission, prioritized and sequenced so that the work is completed as efficiently as possible and to support expected mission objectives.

Given the current funding limitations, NASA can only implement a building block approach that focuses on the next step, with funding applied to the high priority items required for the follow-on steps. Each year the Programs must make priority decisions due to funding availability. Annual funding limits will affect these decisions and the ability to work on efforts beyond the near-term mission.

10. NASA's KDP-C for the Orion program was developed to meet a schedule for EM-2 rather than EM-1. How does the NASA JCL model discern between those funds needed to support a first mission and those needed to support future missions?

RESPONSE: Please see question 4 for this response.

11. The Agency Baseline Commitments made for the SLS and Orion programs were made based on the President's budget request, rather than historical favorable Congressional Appropriations. In your opinion, do the President's budget requests reflect the needs of the program to keep to the Management Agreements for earlier launch dates, or will they require launch readiness delays?

RESPONSE: Based on my experience with the SLS KDP-C, the recent Congressional appropriations levels are required to keep SLS on track for the Management Agreement. Future technical issues and hurdles are likely ahead for SLS that can also affect the ability to meet the Management Agreement. Past Congressional Appropriations levels are needed to provide the team with necessary resources to address technical issues in a timely manner and increase the probability of meeting the Management Agreement. I would expect Orion to be in a similar position with the Congressional Appropriations levels serving to increase the probability of meeting the Management Agreement.

12. The Management Agreement for SLS and Orion uses a JCL that is lower than 70 percent. What is the main driver of this lower JCL?
    a. How does the maturity of the SLS system compare to other major NASA development programs?
    b. What other major NASA programs of similar maturity have used a JCL less than 70 percent in their management agreement?
    c. What was the outcome of those programs and how were the programs affected by using a lower JCL?

RESPONSE: From my perspective, the Management Agreement provides the schedule incentive to the team to address needed issues and develop the flight hardware as efficiently as possible. It is important to keep the schedule focus on the technical team, up to the point where poor technical / programmatic decisions can result. An example of keeping the schedule focus is NASA and the Industry partners are subject to losing key personnel and facility resources from other competing programs if there is a perceived slip in the schedule. Some industry partners have already experienced this issue.The Management Agreement serves this purpose and is a key program management tool.

The fact that this results in a lower JCL estimate is immaterial. The real goal is to get space exploration hardware developed as efficiently as possible, as safely as possible, and to learn from the exploration as quickly as possible.

There are no Programs of the magnitude of SLS and Orion that have been through a similar JCL process. The JCL process has been successfully applied to the NASA Science missions, and is only now being applied to the large, long – term human exploration programs.

13. The Orion and SLS programs have already spent more than $10 billion despite only recently being given authority to proceed to the implementation phase of the program. To a lay person, it might seem that these programs were being "implemented," not just "formulated," long before they reached KDP-C. How would you respond to that perception?

RESPONSE: Since the cancellation of the Constellation Program, Orion has undergone significant restructure, and the team's concerted efforts have led to the first Orion flight test in December 2014. The turmoil and uncertainty caused by the Constellation debate resulted in inefficient use of taxpayer dollars. The NASA / industry team managed to keep the needed hardware flowing that allows NASA to work toward the current schedule dates within the exisitng constrained budget environment. The funding to date has resulted in a spacecraft that will take humans further than ever before and significant development efficiency.

The Space Launch System has resulted from the national space exploration policy debate, and is making good progress toward its first flight. The funding spent to date on this program is entirely appropriate to assure that NASA is ready for full scale implementation. This key decision is based on demonstrated performance, and a thorough understanding of what is needed for such a large task. History tells us that when taking on such unique, large-scale, important challenges, it is better to invest up front for this thorough understanding so that key decisions are based on sound data, rather than rushing into implemetation unprepared.

14. When the Administration slipped the recent Orion launch schedule, NASA was quick to point out that they were still planning to the original launch date. If NASA program managers believe that the earlier launch readiness date could be kept on track with historical Congressional appropriations, why doesn't the agency commit to those earlier dates?

RESPONSE: NASA has committed internally to the earlier dates based upon the recent Congressional Approriations levels, as noted by the press conference following the Orion KDP-C announcement. Given the annual budget debates between Congress and the Administration, NASA must also recognize the potential lower funding levels. This, combined with the Agency policy for a 70% Joint Confidence Level, led to the public commitment as required by the Nunn – McCurdy legislation.

15. If NASA managers are running the programs based on the Management Agreement, despite the public Agency Baseline Commitment, what tools does NASA have to monitor schedule delays or funding increases as a result of technical issues in these programs if they are planning to a budget request that is not realistic?
    a. How does this bifurcated management system affect the management of the programs?
    b. What could the Administration do to alleviate this issue?

RESPONSE: As stated in Question 12's response, working to the Management Agreement is a key management tool for an efficient program. NASA monitors the technical, schedule and cost status on a weekly, monthly, and annual basis through reviews at all levels of the organization. It is correct that the difference between the internal Management Agreement and the external Agency Baseline Commitment can create some level of confusion among the team.

The best way I can see to address the issue is to provide stable funding at the Congressional Appropriations levels, cease the annual budget debate between Congress and the Administration, increase these levels with inflation and provide the growth in funding necessary to minimize the risk. This would result in the teams clearly working to one schedule. Also, the internal and external stakeholders would all be clear on the cost and budget goals.

16. The KDP-C review for Orion last month and the KDP-C review for the SLS last year both resulted in the announcement of unexpected schedule slips.
    a. To what extent is a formal KDP-C review necessary to identify schedule issues in programs of this magnitude?
    b. Conversely, to what extent should such issues be apparent on a continuous basis as part of NASA's ongoing program oversight and management?
    c. What changes could NASA make to its project life-cycle procedures to reduce the likelihood of schedule surprises at this point in a major program?

RESPONSE: The detailed JCL process forced the teams to critically address the detailed technical planning, schedules, risks, and uncertainties. This proves to be beneficial in a more thorough understanding of the program prior to committing to full scale implementation. It is always useful to thoroughly assess a program status prior to making a large commitment. This is similar to a company performing the "due diligence" necessary before a large investment.

NASA and its Industry partners assess their performance on a periodic basis, and must continue to do so. These processes will identify issues, and drive resolution in a timely manner when implemented properly. Also, the JCL analysis is the appropriate "due diligence" prior to the large investment commitment.

NASA should consider modifying the JCL approach for the large scale, one of a kind program such as SLS, Orion, and JWST to account for their unique nature, greater technical risks, budget risks, and inherent uncertainties.

17. In July 2015 GAO reported that the SLS program's earned value management system provided limited insight into progress relative to the program's agency baseline commitment because it tracks performance relative to the program's internal management agreement.

a. What are the other effects, both positive and negative, of managing to internal targets rather than to committed baselines?
b. How do the programs track and report progress relative to committed baselines?
c. Is the difference between NASA's management agreements and baseline commitment for SLS and Orion in effect just funded schedule necessary to allow the programs to satisfy the 70% confidence level guidance?

RESPONSE: The difference between the internal Management Agreement and the external Agency Baseline Agreement should be considered schedule / budget margin. With this approach, NASA works to increase its probability of success and increase efficiency, while maintaining a realistic need for margin on these large, one of a kind programs. This provides the needed focus within the program team to achieve results efficiently and address issues as quickly as possible.

The programs track and report progress relative to the internal Management Agreement, thus providing margin for achieving the Agency Baseline Commitment. It is essential that programs of this magnitude be permitted some level of margin in order to properly manage the programs and provide the needed value to the US Government.

18. Over the past five years there have been significant disconnects between the Administration's budget requests for SLS and Orion compared to NASA Authorizations and Appropriations. This is not the case for the majority of NASA's programs. Despite the budget uncertainties caused by the Administration budget requests, these programs continue to make stable and predictable progress with the appropriated funds.
    a. Can you give the Committee a brief overview of how these budget requests are developed?
    b. How does the program influence these requests to reflect the needs of the program?

RESPONSE: The budgets are developed with a "bottoms-up" approach, followed by a leadership review and prioritization process. The Orion, SLS, and Ground Systems Programs gather overall budget guidance in terms of capability content, schedule requirements, and budget assumptions. The Programs develop budget submittals to meet these requirements and assumptions. The budgets are reviewd at the Mission Directorate level, then reviewed at the Agency level. Any changes are negotiated with the Programs. OMB then reviews the Agency budget request making changes as they believe appropriate, resulting in the Presidents Budget Request (PBR).

19. The expected date of the first test flight of Orion and the SLS (EM-1) has slipped from 2017 to 2018. In discussing the budget for Exploration Systems Development, NASA's position has been that it would be difficult to bring the

launch date of EM-1 forward, even with additional funding, because the schedule depends on technical requirements such as engineering design and manufacturing schedules and the need for adequate testing.

a. In retrospect, how likely is it that additional funding earlier in the program could have accelerated the date of EM-1?
b. Even if bringing EM-1 forward would have been difficult, how likely is it that additional funding would have prevented the schedule from slipping as it has?

RESPONSE: Additional funding early in the program would not have been able to accelerate the EM-1 launch schedule due to the technical work that needed to be accomplished prior to first flight. If additional funding had been provided, EM-2 could have been accelerated, and possibly still could be accelerated, or EM-1 possibly made a crewed mission, and provided needed margin to maintain the schedule. Funding limits clearly established the uncrewed limitations on EM-1, and caused the long time delay between EM-1 and EM-2.

20. The President's budget request does not reflect the needs of the program while Congress continues to provide proper funding. The result is inefficiencies in how the program is managed. You address this oscillation in your testimony; could you expand more on the topic?

RESPONSE: The inefficiencies caused by the annual budget debate between Congress and the Administration, along with the annual realities of continuing resolutions, late appropriations, and threats of government shutdown, results in multiple planning scenarios and confusion among the NASA/ industry team. Budget instabilty of all forms takes important resources away from the already challenging task of managing the complex Orion, SLS, and Ground Systems development.

Each year the team is required to prepare a plan at the President's Budget Request level, develop planning options for possible appropriations levels, carefully craft communication strategies internal to the team, and separate communication strategies external to the team - all to be consistent with Administration direction. Managers must also spend important leadership time, at all levels, assuring that all members of the team understand the strategy. In addition, they must work with their industry team partners to assure understanding of the plan. All of these actionsrequire significant resources of time and money. Much time is spent developing and implementing the communication, and then actually communicating with all team members. This valuable time and money could be better spent on executing the Programs. Team morale is also negatively affected by the continuous, annual uncertainty. This all results in very inefficient use of U.S. taxpayer dollars.

There is also a secondary effect when GAO auditors, or other independent reviews, are intiated due to perceived lack of performance by the NASA / Industry team. In fact, the issues are the result of the budget instability. It is imperative that the entire

team (Adminsitration, Congress, NASA, and Industry) work together on such large, complex, and important National Programs.

21. Orion has completed several highly successful tests so far. Pad Abort-1 successfully test the crew escape system, and EFT-1 tested many the crew module capabilities as well as mission operations. Please describe how additional funding might be utilized to accelerate crew capability for Exploration Mission-1

RESPONSE: At this point, additional funding will not help to achieve crew capability for EM-1. It is essential that Orion be funded at the recent Congressional Appropriations level to assure EM-2 in 2021. Additional funding above the Congressional Appropriations can help accelerate crewed capability, move EM-2 earlier in time, and provide needed margin to address technical and programmatic risks.

22. The Government Accountability Office (GAO) has found that NASA's cost estimates do not capture the full life-cycle cost of developing and operating the SLS and Orion. In particular, the baseline cost estimates for the SLS and for associated ground systems omit the cost of EM-2 and none of these estimates, including the Orion estimates, include the cost of operational missions after EM-2.
    a. Based on your experience managing human spaceflight programs at NASA, would you expect the cost of these programs to increase or decrease after they transition from development to operations?
    b. What factors are most likely to affect that outcome?22. Costs should decrease when transitioning from development to operations.

RESPONSE: That is the typical experience in a commercial environment. Government program costs tend to stay flat in the operational phase, as needed technical modifications are implemented to address flight issues, and product improvements are put in place. Flat or increasing government program costs can also be caused by political pressure for maintaining work at specific locations - without consideration of the future potential use of resources to achieve the critical next steps of exploration.

Given the budget reality that precludes an Apollo-like funding level for the forseeable future, and the need for long term sustainability of the Exploration enterprise, I believe it is essential that operational cost targets be implemented. Target costs need to be included in design requirements in the development phase. And, in the operational phase, meeting them would provide needed funding for the next elements (habitats, landers, etc.) required for exploration. This approach will minimize "requirements creep", require space hardware developers to be better stewards of the taxpayer dollars, and free up funding for the future space exploration activities.

23. As members of the senior executive service at NASA, you were both engaged in budget formulations and pre-decisional submissions to the Office of Management and Budget under this administration. NASA has indicated that these programs are receiving the funding they need to achieve the programs' goals and milestones. Was that your experience during your tenure at NASA?
    a. Is it your opinion that the exploration systems development budget at NASA is sufficient to achieve NASA's exploration goals? Why or why not?
    b. In your opinion, what difference would additional funding make to the proposed launch dates for EM-1 and EM-2?

RESPONSE: In 2011, NASA was asked by OMB to plan within an annual $3B cost constraint, with no inflation. Subsequent budget requests have been consistently below $3B, and held flat -or decreased- annually. Congressional Appropriations alleviated this issue, but only to the point of assuring that SLS and Orion achieved EM-1 as quickly as possible. The second major issue with the budget is a flat annual profile. Typical major hardware development programs work best with a development cost curve over the life of the program and stable funding projections.

To achieve NASA's goals, my experience tells me that the exploration budget needs to be; stable for efficient planning and execution, increased to account for the additional elements such as habitats, testing and research on the ISS, provide funding for preparing and carrying out risky human missions, and grow with inflation to maintain purchasing power.

Additional funding at the appropriate level would provide the needed capability of the SLS upper stage, accelerate the Orion crewed capability to an earlier flight date, and is needed to provide a sustainable mission cadence of one to two flights per year. Four to five years between missions is unsustainable, as manpower capability diminishes. Current funding levels put NASA at the 4-5 years between missions pace.

At this point, additional funding would help assure the SLS flight date of 2018. It is too late to accelerate the EM-1 date. Additional funding could help accelerate EM-2, however, we are quickly coming to the time when EM-2 is in a similar situation as EM-1.

24. Major NASA development programs typically have a development curve where funding increases during the course of development and then funding decreases during integration and test.
    a. Do you have any concerns with NASA's continued flat funding requests for the Orion and Space Launch System (SLS) programs?
    b. What sort of funding curves are optimal for development programs?
    c. What are some of the likely impacts of flat annual budgets on development programs?

d. Do the planned budgets for SLS and Orion support the development schedule and retirement of risks?

RESPONSE: The prescribed flat funding levels require unique program execution. A typical development program funding curve increases as the program proceeds to the detailed design phase and the staff is increased to complete the detailed analyses and design drawings. As the program proceeds into assembly, integration, and test, the funding requirements reduce unless significant technical issues must be resolved. This type of funding profile is the most efficient manner to execute SLS, Orion, and Ground Systems.

The flat funding profile imposed on SLS, Orion, and Ground Systems results in work being executed in an inefficient manner. Work that can be completed in parallel is now replanned to be serial, technical decisions needed early are delayed, with consequences to the product quality. Continuous management oversight is needed to assure the appropriate planning is properly executed. Overall, this approach driven by the budget adds to the inefficiency, as well as the technical risk of the program. My experience plainly tells me that this is not the appropriate manner in which to execute these important, complex programs.

Congressional Appropriations levels support the execution of SLS and Orion toward the internal Management Agreement dates. Undobtedly, risks and issues will arise due to the complex technical nature and scale of SLS, Orion, and Ground Systems. It is important that these funding levels be maintained and improved. This will get us beyond earth orbit quicker and demonstrate the continued U.S. leadership in space exploration. The U.S. must be present and estabish the key "rules of the road" in space exploration.

25. 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. Did NASA consider using this clause during your tenure? If not, can you explain why not?
    a. Could NASA use uncosted or unobligated funds from other programs to cover the highly unlikely event of a termination for convenience on these national priority programs?
    b. Is this how other mission directorates currently handle this unlikely possibility?

RESPONSE: This clause was considered, however, it was not approved at the Agency level. Following Constellation, Agency policy changed, at least for SLS / Orion. Termination liability had to be included as part of the annual funding content. The funding designated for termination liability was therefore unusable - from a program execution standpoint. The policy was implemented even though it was clear that any cancellation discussion for SLS and Orion would require significant time and coordination within the Administration and with Congress. This would provide sufficient time for the termination liability to be included in the funding and

the execution content adjusted. It was also clear that the change in NASA policy directly affected the corporate risk assessment strategies of team contractors, leading them toward "less risk" planning.

How the Agency would choose to address termination liability is purely speculative at this point. The overall Agency budget picture would affect any decision made, as would, policy discussions among NASA, the Administration, and Congress. Best use of available resources, for any given Program, would be necessary to provide tangible results. In short, this would need to be a complete portfolio management issue.

I cannot speak to how other NASA Mission Directorates may address the issue. That is a question for NASA.

26. The NASA Authorization Act of 2010 requires NASA to build the Orion crew vehicle with the minimum capability requirement to provide backup crew transfer services to the ISS in the event that commercial contractors are unavailable. This does not require Orion to be launched on SLS. The Administrator has said in the past that the Orion will not be used for this purpose. The law is clear that Orion should be capable of serving that purpose.
    a. In the event that both Commercial Crew contractors experience failures similar to the Commercial Cargo program, do you believe it would be a bad idea to use Orion rather than rely on Russia?

RESPONSE: NASA can better answer this question. In my opinion, Orion and SLS could serve in an emergency situation to deliver or rescue crew from the ISS. This mission is well within the design requirements of both vehicles, however, it is not an efficient use of these vehicles. Orion is only able to be launched on SLS, due to its weight, and driven by its design as a long-term exploration vehicle with 4 crew members. I do not believe Orion's weight permits the Delta IV heavy launch vehicle to lift the Orion spacecraft -properly configured for crew return- to the International Space Station. NASA would need to verify this assertion.

Use of a Russian spacecraft to return ISS crew to earth depends on the nature of the circumstances (i.e an emergency need) and the overall crew rotation at the time. NASA would need to make situational assessments and decisions.

27. Please explain how the agency budget is developed and how the negotiation process between NASA and OMB is conducted.
    a. In your opinion, how effective is the current presidential budget request process?
    b. How could the presidential budget request development and negotiation process be improved to ensure that programs are complying with Congressional direction and operating as efficiently and effectively as possible?

RESPONSE: Budgets are developed at NASA by the respective Programs - based on overall Agency guidance that has been coordinated with OMB. The Programs provide their budget requests to the cognizant Mission Directorate. The Mission Directorate assesses the input and integrates the Program requests within its purview for submission to the Agency. The Agency then assesses and integrates the budget, across the entire Agency portfolio, for submission to OMB. As part of the OMB review, the Agency is provided the opportunity to respond to OMB requests and modified guidance. Final decisions are made by OMB and reflected in the President's Budget request for the specific fiscal year. This budget request includes the current execution year, the upcoming fiscal year, and the budget horizon over the next four years. In total, the budget request is a five-year budget horizon. Since 2010, OMB has typically considered the budget horizon, beyond the fiscal year in question, as "notional" -- thereby implying that it is not meant for solid program planning purposes. The "notional" nature of the out-year budgets increases confusion, and is in addition to the consistent request for SLS, Orion, and Ground Systems - below the previously appropriated Congressional levels.

Given the importance and the large scope of the national budget as a whole, the budget process provides input from the executing Programs, and the requisite integration and assessment to meet the Agency commitments as defined by the Authorization and Appropriations laws. As with all large government processes, there is always room for improvement. With the size of the SLS, Orion, and Ground Systems efforts, coupled with teams that have not done development of this scale in over a generation and the tight fiscal constraints compared to Apollo, plus the need to efficiently and effectively utilize taxpayer dollars, it is imperitive that these Programs be permitted to plan and execute properly. The annual budget debate between the Administration and Congress, coupled with the continual budget debate resulting in Continuing Resolutions (CR's), plus the constant threat and periodic implementation of government shutdowns, the teams are forced to plan and execute in a highly inefficient manner. The result is confusion among the teams, loss of focus on very technically challenging and complex programs, increased risk, and ultimately, schedule delays. These all affect the ability of the United States to maintain leadership in space exploration.

In my opinion, it is essential that Congress and the Administration stop the annual specific debates on SLS, Orion, and Ground Systems and agree on a long-term plan. The 2010 Authorization Act clearly defines the goals and objectives. Congress and the Administration have signed the Act, and NASA should be allowed to execute these agreed upon goals and objectives. I also believe that it is essential for Congress to assure that appropriations bills are in place prior to the beginning of the fiscal year, thus ending the annual budget debates that can cause government shutdowns, and stop the inefficiencies brought on by Continuing Resolutions.

28. Please explain the benefits that come from passing a reauthorization bill before the beginning of the next Administration.

RESPONSE: Authorization Act, would provide clear direction from Congress and the Administration to NASA on the goals and objectives, schedules to be met, and the available funding. I recognize the need for the next Administration to have the ability to influence decisions. The next Adminsitration must also have buy-in to the Programs, or the current situation will continue, and possibly become worse. A repeat the 2009 – 2011 space exploration upheaval would dramatically affect the ability of the United States to lead in space exploration.

29. After the Apollo program took us to the moon, three landing missions were cancelled: Apollo 18, 19, and 20. How can similar exploration programs, like a Mars exploration program, avoid termination after the first several human landings?

RESPONSE: Space exploration must be sustainable and viable. It cannot, and must not, soley be performed with U.S. taxpayer dollars. Space exploration must provide commercial space development opportunities, include International partners, provide an avenue of economic growth for citizens on Earth, and help improve life for everyone on the planet.

It is essential that space exploration work to include the needs of the various stakeholders, and educate people on the benefits, possible approaches, risks, and potential outcomes of space exploration. The 2014 National Research Council report on the Pathways of Exploration provides a sound starting point for this work, and is formed with input from across the stakeholder base. This report should be the touchstone for planning, including budget levels.

In addition, we must make every effort to find, develop, and grow new commercial opportunities in space transportation. We must find and utilize space resources and assets, and gain the knowledge and experience of living and working in space. As we are learning from the International Space Station about health issues related to long-term space habitation, we are also gaining key knowledge on the effects of the aging process on humans. We are researching new pharmaceuticals, only achievable in space, to eliminate diseases on Earth. Our exploration of the solar system and beyond is providing a better understanding of how planets evolve and change, the possible consquences of this evolution, and thereby giving us new knowledge to use on Earth. Overall, there must be commercial and International "skin in the game" to assure long-term viability.

The United States has demonstrated leadership with the Mercury, Gemini, Apollo, the Space Shuttle, the International Space Station, Voyager, Mars Science Lab, Opportunity and Pathfinder, and now SLS and Orion missions. We must continue this leadership if we are to be primary contributors in space exploration, as other nations continue to grow in their capability and desire.

30. This most definitely is a pressing need that must be pursued now. The United States must continue its leadership in space exploration, to be part of establishing the "rules of the road" in space. Other nations are working toward this leadership.

The importance of space exploration to economic development, demonstrated technical prowess, and leadership is recognized by China, India, Europe, Russia, and Japan. The United States must lead this endeavor or become a follower to other countries. A better life for our citizens and the future of our economy both rely on the new technologies and knowledge that arise from taking on the hard challenges in space exploration.

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

"Deep Space Exploration: Examining the Impact of the President's Budget"

Questions for the record, Mr. Daniel Dumbacher, Professor of Engineering Practice, Purdue University; Former Deputy Associate Administrator, Human Exploration and Operations Mission Directorate, NASA

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

1. How should NASA structure its human space exploration program so that it continues to make progress despite constrained budgets? What in your view would be the most important things for Congress to do to help NASA sustain progress on its exploration programs?

NASA must continue to work toward efficiencies in management and execution of the human space exploration programs. The current lean management structure should be encouraged, and at the same time, tested to assure that the safety, technical, cost and schedule requirements are achieved. During my tenure, NASA made great improvement in the management practices for SLS and Orion, as compared to other human spaceflight programs. The overall executive leadership was placed at NASA HQ to allow for a more balanced decision approach when addressing competing priorities and interests that crossed Center and Program (SLS, Orion, Ground Sys) lines. This also provided a more direct connection to the NASA exploration strategy development - having the people responsible for the strategy development in close proximity with the leadership level. Another improvement was to provide the Programs with funding reserves at their Center's level, rather than holding all the reserves at the HQ level. This eliminated the requirement that Programs request from HQ each penny of reserve. We purposely wanted to get the funding as close to the decision makers most knowledgeable of the hardware, status and risks. This allowed for dramatically improved, "decision velocity" and is a key aspect of the progress to date.

On systems integration, the Programs were purposely held accountable to work with each other, and not rely on the larger, overall organization to direct the Programs. This resulted in almost an order of magnitude reduction in the funding required for systems integration. With this approach, safety and technical performance were not sacrificed. Tasks were kept on track to support the schedule and technical decisions, and key issues were addressed with independent analysis, based on risk to the overall system. The team diligently worked across all the Programs to optimize for the integrated system. Each month, NASA HQ Exploration Systems conducted reviews with all the Programs, and the Systems Integration Team, to measure progress, address issues, and communicate among the team. Each Program held internal reviews monthly, bi-weekly, or weekly depending

on the need. A key element of the management approach was direct and personal interaction with the teams across the Country. This enabled the team to quickly address issues and concerns. Since safety is paramount, and schedule drives cost, all levels of the NASA exploration team work rigorously to assure that design and operations are safe, while as cost efficient as possible. I understand that these approaches continue today across the Exploration Systems NASA / Industry team.

The most important things Congress can do to sustain progress in space exploration are: provide a stable budget and provide the needed appropriations in a timely manner. It is essential that Congress and the Administration stop the annual specific debates on SLS, Orion, and Ground Systems. The 2010 Authorization Act clearly defines the goals and objectives. Congress and the Administration have signed the Act, and NASA should be allowed to execute to meet these agreed upon goals and objectives. I also believe that it is essential for Congress to assure that appropriations bills are in place prior to the beginning of the fiscal year, discontinue the annual budget debates that often lead to government shutdowns, and stop the inefficiencies brought on by Continuing Resolutions.

In addition to budget stability, Congress and the Administration should periodically reinforce the space exploration goals and ojectives, schedule expectations, and available funding levels via Authorization Laws. These should be modeled on the 2010 Authorization Act.

2. To what extent is the Joint Confidence Level a suitable tool for managing the SLS and Orion programs at this point in their development? What, if any, alternatives exist and do they provide a benchmark to which Congress can measure progress?

RESPONSE: The analysis process that each Program conducted proved valauable, giving a more thorough understanding of the program status, issues, risks, and uncertainties. The true value comes from the understanding and agreement grasped by all on the Program teams. This aids their execution and decision processes. The JCL analysis, applied to smaller missions with defined launch or mission dates, has also shown to be useful. The key value of the JCL process for SLS was the detailed understanding of the technical planning, risks, and uncertainties.

The recent IG report on the JCL process documents its successful application in the planetary missions, and also calls into question the application of the JCL process to large, single-project Programs. I agree that the JCL process for Programs that are long-term, without defined end dates and uncertain future budgets should be appropriately modified.

Alternatives demonstrated in the past include periodic reviews with Members of Congress and staff on the Program status, issues, and efforts in place to address

issues. These reviews have included the appropriate metrics used by the Programs to assess progress, status and issues. Most important is the need for transparency and trust among NASA, Congress, and the Administration when discussing these important and highly visible Programs.

3. The EFT-1 test generated excitement around the world in sending the Orion test vehicle farther into space than any human spaceflight mission since the Apollo era. Given the long gaps between the EFT-1, EM-1, and EM-2 flight tests, what can NASA do to sustain the enthusiasm that EFT-1 created?

RESPONSE: It is important to not only sustain, but also increase the enthusiasm for space exploration. NASA cannot do this on its own. NASA is a key player, along with Congress and the Administration. Congress and the Administration can aid NASA in maintaining and improving the enthusiasm by appropriating the needed funding, providing and allowing public outreach opportunities wherever possible. NASA should be permitted by law to better educate and connect with the public. Enthusiasm is derived from the actual performance of exciting missions, while recognizing the risk involved. Mars Science Lab's video, "7 minutes of Terror" and the flight of EFT-1 demonstrate this reality.

The delay between EM-1 and EM-2 is purely a funding limitation. Additional funding above the current appropriations levels can accelerate the implementation of crew systems needed for EM-2 on Orion. Orion is quickly advancing to the point in the Program where additional funding will *not* help, and technical limitations will take over. NASA should be able to provide the information necessary to address acceleration of EM-2, unless OMB should decide to limit the conversation.

4. How important is it to have a defined mission for the Space Launch System (SLS) and Orion beyond EM-2 at this point in time? What are the implications for the programs of not having a defined mission?

RESPONSE: It is important for an initial, top-level space exploration strategy to be in place as quickly as possible. A sustainable exploration strategy should include top- level objectives for Exploration Missions beyond EM-2, and clarity on how to achieve these objectives. The strategy must also be sufficiently flexible, and able to be modified based on what is learned with each mission., It should pave the way for commercial opportunities and International partnerships.

The SLS, Orion, and Ground Systems Programs need definition for missions and launch rate. These are needed to provide efficient planning and execution. Timely manufacturing and production planning, technical modifications, and definition of the schedule and budgets all depend on knowledge of the near-term, upcoming missions.

5. In its 2015 Third Quarterly Meeting Report, the Aerospace Space Advisory Panel (ASAP) indicated that NASA's approach to developing SLS, Orion, and

Ground Systems is in essence "capabilities-based management", which ASAP characterized as a slower and more flexible approach to building the systems (characterized as "parts" by ASAP) needed for the future. ASAP noted, without further explanation, that there are challenges in NASA's "parts" approach, both in program management and in integration.

a. Having now been away from the program for some time, does the capabilities-based management approach still make sense? If not, what other approach should be taken and how would NASA transition to the new approach?
b. What are the program management and integration challenges associated with the current approach?

RESPONSE: The current capabilities based management approach is consistent with the existing budget environment, and the need for a flexible exploration strategy. This approach provides flexibility, as learning occurs through exploration efforts, and can work in parallel to the expected budget environment. There are challenges with the capabilities-based management approach, however, these are outweighed by its flexibility and capability to maintain progress within a constrained budgetary environment. The uncertainty introduced in the Program planning and execution is managed by the Program teams with diligent oversight and communications, and clear involvement in the exploration strategy plans.This is preferable to a specific destination approach. A specific destination approach can result in successfully reaching a prescribed destination, but then have no planned follow-on, similar to the Apollo experience following Apollo 17.

6. Given the challenges of sending humans on future long-duration missions to Mars or other deep space destinations, such as radiation exposure and the need for generating food and water, do we need to consider developing an advanced crew transportation system based on nuclear-electric propulsion to reduce travel times? In your opinion, what are the risks associated with nuclear-electric propulsion, and how can they be mitigated?

RESPONSE: It is clear from past exploration strategy analyses that decreased trip times can benefit in multiple ways. Reduced trip times can help decrease radiation exposure, and have beneficial impacts on other human health aspects of space travel. It can also lessen the exposure to hardware and software failure modes, thereby decreasing the probability of failure.

Nuclear propulsion options, including nuclear-electric propulsion, can provide shorter trip times. The risks include the development of the nuclear propulsion capability to meet the expected operational requirements, and addressing the public environmental concerns. Current nuclear propulsion research efforts would need to be funded. Increased funding is needed to develop operational nuclear propulsion systems, develop these propulsion systems as power sources for exploration activities, in addition to addressing the public environmental risk concerns.

7. During this Subcommittee's hearing on the SLS and Orion programs in December of 2014, Mr. Gerstenmaier, NASA's Associate Administrator for the Human Exploration and Operations Mission Directorate, said, "I would say the biggest technology areas that we need to work on are...radiation for the human being and look at radiation shielding." Do you agree? What are the most promising approaches for addressing the risks of radiation exposure in future human exploration of deep space? What is your view of the status of work on radiation shielding or technological approaches to this area of risk?

RESPONSE: Mr. Gerstenamier is correct. Radiation exposure, and shielding, is a key technology area to be addressed for human space exploration. The NASA Human Research Program (HRP) is addressing these risks and is a better source to discuss the status of the effort, and the technological approaches. The overall human health aspects for living and working in space, and long-duration spaceflight require significant effort and investment. The human helath aspects are at least as important as the hardware systems needed for long-duration spaceflight. There are significant technologeis to be addressed in terms of Mars entry and descent, advanced in-space propulsion, advanced life support, advanced power systems, and others.

8. The ground infrastructure at Kennedy Space Center is undergoing significant development to support the SLS/Orion launches.
    a. Do you believe that NASA's Ground Systems are making adequate strides relative to the progress being made on SLS and Orion?
    b. Are you confident that ground infrastructure improvements will not delay the overall progress on achieving EM-1 and EM-2 launch dates?

RESPONSE: Based on the information available to me, the Kennedy Space Center is making great progress toward preparations for the EM-1 and EM-2 launch dates. The Ground Systems Program team should be commended for its dedicated and professional efforts in assuring that the needed ground systems for SLS and Orion are available to meet the schedule commitments.

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