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A REVIEW OF NASA'S EXPLORATION PROGRAM IN TRANSITION: ISSUES FOR CONGRESS AND INDUSTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

MARCH 30, 2011

Serial No. 112–8

Printed for the use of the Committee on Science, Space, and Technology

Available via the World Wide Web: http://science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

65–305PDF WASHINGTON : 2011

For sale by the Superintendent of Documents, U.S. Government Printing Office
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A REVIEW OF NASA'S EXPLORATION PROGRAM IN TRANSITION: ISSUES FOR CONGRESS AND INDUSTRY

WEDNESDAY, MARCH 30, 2011

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Steven Palazzo [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
CHAIRMAN

EDDIE BERNICE JOHNSON, TEXAS
RANKING MEMBER

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Subcommittee on Space and Aeronautics

A Review of NASA's Exploration Program in Transition: Issues for Congress and Industry

Wednesday, March 30, 2011

10:00 a.m.-12:00 p.m.

2318 Rayburn House Office Building

Witnesses

Mr. Douglas Cooke
Administrator, Exploration Systems Mission Directorate, National Aeronautics and Space Administration

Dr. Scott Pace
Director, Space Policy Institute, George Washington University

Mr. James Maser
Corporate Membership Committee, The American Institute of Aeronautics and Astronautics

HEARING CHARTER

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

A Review of NASA's Exploration Program in Transition: Issues for Congress and Industry

WEDNESDAY, MARCH 30, 2011
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

The subcommittee will examine 1) the accomplishments of the Constellation program, 2) NASA's transition toward development of the Space Launch System (SLS) and Multi Purpose Crew Vehicle (MPCV), and compliance with the FY2011 continuing resolution and the NASA Authorization Act, 3) the status of the 90-day SLS/MPCV report to Congress, and 4) examine the key challenges and risks in implementing the proposed changes including outstanding questions and issues for Congress from delays or other disruptions to the workforce or aerospace industrial base.

Witnesses

- **Mr. Douglas Cooke**, Associate Administrator, Exploration Systems Mission Directorate, National Aeronautics and Space Administration
- **Dr. Scott Pace**, Director, Space Policy Institute, George Washington University
- **Mr. James Maser**, Chairman, Corporate Membership Committee, The American Institute of Aeronautics and Astronautics.

Comparison of the NASA Authorization Act of 2010 (P.L. 111-267) with the FY2012 Budget Request

(millions of $)	FY10 enacted / FY11 C.R. *	Auth. FY12	Budget Request FY12	Request vs. Auth. FY12	Auth. FY13	Budget Request FY13	Request vs. Auth. FY13	Auth. Total FY12-13	Budget Request Total FY12-13	Request vs. Auth. FY12-13	Request vs. Auth. FY12-13
Human Exploration Capabilities	**3,287**	**4,050**	**2,810**	**(1,240)**	**4,050**	**2,810**	**(1,240)**	**8,100**	**5,620**	**(2,480)**	**-31%**
MPCV	*1,435*	*1,400*	*1,010*	*(390)*	*1,400*						
SLS/HLLV	*1,387*	*2,650*	*1,800*	*(850)*	*2,640*						
Integr'n & Ops	*465*										

* Values are for reference. Under the CR some numbers may vary slightly.

Issues

Exploration Capabilities in Transition; Issues for Congress and Industry

At issue is NASA's compliance with Congressional direction on extending and modifying the Constellation contracts, and the implications of NASA's actions for the continued, uninterrupted progress on the Multi Purpose Crew Vehicle (MPCV) and Space Launch System (SLS). Congressional intent, as reflected in authorization and appropriation language seek to utilize the existing workforce and assets in order to limit the damage to the nation's industrial base and workforce.

As the budget comparison above indicates, the FY2012 budget request does not adhere to the funding guidance in last year's authorization bill (PL 111-267). The administration's FY2012 budget request for Exploration systems is $1.24 billion below the amount specified in the Act. Exploration systems is **$2.5 billion below when comparing both FY2012 and FY2013.** In FY2013, the administration does not identify the funding specified for the two main components; the MPCV and the SLS.

In spite of the $2.5 billion reduction over two years in proposed funding for Exploration Capabilities, Administrator Bolden said, *"I am committed to try to make sure that the funding levels remain about the same, and one of the things is beginning in 2013 I have asked and I have been granted that we put human exploration in one budget line so that we can move the funds around as necessary in each successive year so that we marry those programs up when we need them, you know, that being the 2020 timeframe . . . "*

Yet, section 302 of the NASA Authorization Act directs the agency to develop the heavy lift system in a way that permits early flight testing of the "core" stage elements with a goal of an operational capability to orbit by December 31, 2016.

The U.S. space industrial base that has supported the Constellation - now MPCV and SLS effort - has waited while the agency settles on a plan for human spaceflight, and unless the uncertainty is eliminated in the near future, there could be serious disruptions to the aerospace workforce and industrial base as key suppliers begin to exit the market.

Report due to Congress

The Authorization Act directed NASA to report back in 90 days on the design of the vehicle envisioned, and to provide the assumptions and cost analysis to justify the systems selected. On January 10th NASA provided a *preliminary report* containing no detailed cost or schedule assessments, yet concluding nevertheless that, *"to date our studies have shown that none of those options thus far appear to be affordable in our present fiscal conditions, based upon existing cost models, historical data, and traditional acquisition approaches."*

According to NASA it will provide an independent (outside of the Agency) assessment of cost and schedule for the SLS and MPCV design options, and make those assessments public this Spring or Summer.

According to the *preliminary report*, NASA is considering various acquisition strategies for the MPCV and SLS which could have significant impacts to the workforce and industrial base. Thus far, Congress has directed the agency to continue to extend (and modify if appropriate), the Constellation contracts to the maximum extent practicable (see background below).

NASA's future acquisition decisions could have wide ranging repercussions. The preliminary report states, "While NASA will work as expeditiously as possible to meet the 2016 goal, NASA does not believe this goal is achievable based on a combination of the current funding profile estimate, traditional approaches to acquisition, and currently considered vehicle architectures."

When asked by Senator Boozman at the March 15th, 2011 Senate Commerce, Science and Transportation Committee hearing on The Challenges Facing NASA whether NASA was basing its analysis on the funding in the Authorization Act, or the much lower administration proposal Associate Administrator Doug Cooke replied, *"we are looking at, in these studies, the president's requested budget."*

A decision to re-compete significant elements of the MPCV or SLS could result in delays of as much as two years while the Agency issues Requests for Proposals (RFPs), evaluates the proposals, awards contracts, adjudicates protests, etc.

Background

The Constellation program consisted of the Ares 1 crew launch vehicle and Orion crew exploration vehicle, the Ares 5 heavy-lift launch vehicle, and associated lunar systems. Constellation architecture had been established since 2004 as a replace-

ment for the retiring Space Shuttle to deliver Americans and our International Partners to the International Space Station, and eventually to the Moon and other destinations beyond Earth orbit. Constellation was authorized in both the NASA Authorization Act of 2005 [P.L.109-155] and the NASA Authorization Act of 2008 [P.L.110-422] with a stepping-stone approach *"to ensure that activities in its lunar exploration program shall be designed and implemented in a manner that gives strong consideration to how those activities might also help meet the requirements of future activities beyond the Moon" and a range of future destinations "to expand human and robotic presence into the solar system, including the exploration and utilization of the Moon, near Earth asteroids, Lagrangian points, and eventually Mars and its moons."*

The administration has presented various - and often conflicting - statements and goals for the U.S. Exploration Program. In his April 15, 2010 remarks at Kennedy Space Center, President Obama said: *"Early in the next decade, a set of crewed flights will test and prove the systems required for exploration beyond low-Earth orbit. And by 2025, we expect new spacecraft designed for long journeys to allow us to begin the first-ever crewed missions beyond the moon into deep space. We'll start by sending astronauts to an asteroid for the first time in history."* But at the March 2, 2011 House Science, Space, and Technology Committee hearing on NASA FY2012 budget proposal, in response to a question from Rep. Dana Rohrabacher, Administrator Bolden said, *"The International Space Station is the anchor for all future exploration. That is our Moon right now."*

Congress has supported NASA's exploration program and authorized $10.8 billion over three years (FY2011-FY2013). The Constellation system that the administration proposed canceling is developing an array of technologies and heavy lift capabilities applicable to the goals of exploration beyond low Earth orbit. Sections 203(a)(1) and 301(a) of the 2010 NASA Authorization Act expressed the sense of the Congress that, *"the ISS, technology developments, the current Space Shuttle program, and follow-on transportation systems authorized by this Act form the foundation of initial capabilities for missions beyond low-Earth orbit to a variety of lunar and Lagrangian orbital locations," and "The extension of the human presence from low-Earth orbit to other regions of space beyond low-Earth orbit will enable missions to the surface of the Moon and missions to deep space destinations such as near-Earth asteroids and Mars."*

The NASA Authorization Act of 2010 directed the agency to develop a Space Launch System consisting of a heavy lift launcher (130 ton rocket, with 70-100 ton "core" capability that could be used to launch the crew capsule to the International Space Station by 2016) and multi-purpose crew vehicle (the Orion crew capsule). The system was envisioned to build upon the technologies and extensive capabilities of the Space Shuttle and Constellation systems, and to provide a backup capability to access the ISS by 2016 in case the Russian Soyuz, or commercial crew initiatives are unavailable. In order to limit termination liability costs and avoid disruptions to the workforce and industrial base, the 2010 Authorization Act directs NASA to, *"to the extent practicable, extend or modify existing vehicle development and associated contracts."*

FY2010 Appropriations Direction: Extend or Modify Constellation Contracts

In the Statement of Managers accompanying the FY 2010 Consolidated Appropriations Act, *"The conferees note that the Constellation program is the program for which funds have been authorized and appropriated over the last four years, and upon which the pending budget request is based. Accordingly, it is premature for the conferees to advocate or initiate significant changes to the current program absent a bona fide proposal from the Administration and subsequent assessment, consideration and enactment by Congress."* The Statement of Managers also states that *"Funds are not provided herein to initiate any new program, project or activity, not otherwise contemplated within the budget request and approved by Congress, consistent with section 505 of this Act, unless otherwise approved by the Congress in a subsequent appropriations Act. Funds are also not provided herein to cancel, terminate or significantly modify contracts related to the spacecraft architecture of the current program, unless such changes or modifications have been considered in subsequent appropriations Acts."* Similar language was included in the Act itself.

The Constellation program has racked up a series of impressive accomplishments including: 1) the full-scale Pad Abort Test of the crew escape system; 2) the near completion of the J2X rocket engine currently slated for testing at the Stennis Space Center in May or June; 3) the developmental test firings of five segment solid rocket

motors; 4) the Ares 1X test flight in October 2008. (Please see Appendix 1 for a comprehensive list of Constellation program's achievements to date.)

The Constellation program's Orion spacecraft was intended to serve as a back-up for commercial cargo services envisioned by the Commercial Orbital Transportation Services (COTS) program to service the International Space Station. NASA's FY2009 budget request stated, *"It [Orion] will be capable of ferrying up to six astronauts (plus additional cargo) to and from the International Space Station if commercial transport services are unavailable."*

Delays in Commercial COTS Cargo Systems Led to Additional Shuttle Flights

Significant delays in the COTS commercial cargo development fuel concerns that NASA will be unable to provide the logistics support necessary to maintain and utilize the International Space Station, or to fulfill U.S. obligations to our international partners. (Please see the SpaceX and Orbital Sciences COTS milestone charts in Appendix 2.)

Congress was aware as far back as 2008 that delays in the COTS cargo program would likely result in the need for additional Space Shuttle flights to assure that adequate spares would be aboard the ISS. Thus, section 611 of the NASA Authorization Act of 2008 [P.L.110-422] added two additional logistics flights, *"In addition to the Space Shuttle flights listed as part of the baseline flight manifest as of January 1, 2008, the Utilization flights ULF-4 and ULF-5 shall be considered part of the Space Shuttle baseline flight manifest and shall be flown prior to the retirement of the Space Shuttle, currently scheduled for 2010."*

As Congress debated the NASA Authorization Act of 2010 [P.L.111-267] in the Fall of last year, no COTS provider had yet accomplished an initial demonstration flight. (SpaceX launched the first of three COTS demonstration flights of a Falcon 9/Dragon on December 8, 2010, and the other two test flights are tentatively scheduled for late 2011 and early 2012.) As a result of these concerns, the NASA Authorization funded another Space Shuttle flight (STS-135 will be the last mission of the program), *"The Administrator shall fly the Launch-On-Need Shuttle mission currently designated in the Shuttle Flight Manifest dated February 28, 2010, to the ISS in fiscal year 2011, but no earlier than June 1, 2011, unless required earlier by an operations contingency."*

At the March 15th, 2011 Senate Commerce, Science and Transportation Committee hearing on The Challenges Facing NASA, Associate Administrator Bill Gerstenmaier explained how critical the STS-135 mission was given the concerns for commercial COTS schedule, *"We see that mission as extremely critical to us. What that mission provides for us is it gives us some margin that if the commercial providers are late and they don't fly in 2011 and 2012 as they plan, then we have got some time through 2012 that we will have enough supplies pre-positioned on Space Station that we can continue to do quality research, we continue to keep our crew size at six onboard station through that period of 2012 all the way until 2013. If we don't have that shuttle flight, then it's absolutely mandatory that the commercial cargo providers come on-line at the end of this year and early in 2012. I don't think that is a prudent strategy. We need some margin just as in the shuttle world, we thought we understood where we were going to go fly, then we had the tank problem that slowed us down a couple months. I would expect small problems to show up in the commercial providers as well. We need some margin to do that."*

Importance of MPCV and SLS as a Backup and as Assured Access to ISS

The impending retirement of the Space Shuttle and continuing delays in commercial COTS systems, reinforced the need for the backup assured ISS access capability envisioned for the original Exploration Systems development, as well as to lay the groundwork for exploration beyond low Earth orbit. Section 2(9) of the NASA Authorization Act of 2010 states, *"While commercial transportation systems have the promise to contribute valuable services, it is in the United States' national interest to maintain a government operated space transportation system for crew and cargo delivery to space."*

Many of NASA's international agreements with the Space Station partners were put in place before the decision to retire the Space Shuttle. As a result, even after the Space Shuttle has retired, NASA is still responsible for cargo delivery and transportation of our Canadian, European and Japanese partners to and from the International Space Station.

In Section 201(b) of the NASA Authorization Act of 2010, Congress, *"reaffirms the policy stated in section 501(a) of the NASA Authorization Act of 2005 (42 U.S.C. 16761(a)), that the United States shall maintain an uninterrupted capability for human space flight and operations in low-Earth orbit, and beyond, as an essential*

instrument of national security and of the capacity to ensure continued United States participation and leadership in the exploration and utilization of space."

Appendix 1

Key Achievements of NASA's Constellation Program

The Constellation Program achieved notable maturity as a flight system, as evidenced by the successful completion of a Preliminary Design Review in March 2010. This review, following the successful Preliminary Design Reviews of the Ares-I launch vehicle and the Orion spacecraft, signaled the completion of a coherent Program technical approach that aligned content, budget and schedule for Phase I Capability, or LEO missions to the ISS. Key development flight and ground tests helped the Program to gauge programmatic risk by providing hard data in areas having the most uncertainty, providing confidence in the Agency's ability to execute the Constellation Phase I Capability development within cost & schedule commitments. Associated with this review, the Constellation Program also successfully completed the Phase I Safety Review, addressing all hazards that would lead to loss of life or loss of mission for the integrated system including the launch vehicle, spacecraft, and ground systems. Technical studies continued on the Constellation Program Phase II content, which would enable missions to the Moon & beyond, with technology maturation, trade studies, and programmatic planning scenarios all under concurrent development for the Altair Lunar Lander, the Ares V heavy lift launch vehicle, and Lunar surface habitats. The overall feasibility of the Constellation Program Phase II architecture was successfully demonstrated at the Lunar Capability Concept Review conducted in 2008. A listing of key achievements for the projects comprising the Constellation Phase I Capability is provided below.

Key Achievements of the Orion Project

The Orion Preliminary Design Review (PDR) was successfully completed in August, 2009. Both the ISS and Lunar variants of the Orion spacecraft were examined during the review. The Orion Project also successfully completed the Phase 1 Safety Review of the spacecraft. The review addressed all catastrophic loss of crew and/or vehicle, and critical loss of mission hazards for both the ISS and Lunar Sortie missions. Orion safety analysis integrated the results of hazard analysis, probabilistic risk assessment, failure modes analysis, and engineering design assessments to provide an integrated design and safety assessment consistent with the latest NASA human rating requirements. As a result, the Orion design has been more fully optimized to minimize safety risk while carefully balancing other project cost, schedule, and technical constraints.

Fabrication of the Orion crew module Ground Test Article, the first full scale Orion article designed and manufactured to NASA's rigorous human spaceflight specifications, continues. Construction of this article has validated many of the advanced production processes, equipment and tools necessary to manufacture Orion spaceflight hardware. The crew module pressure vessel and primary structure were manufactured at the Michoud Assembly Facility in Louisiana using friction stir welding, an advanced welding process that yields stronger bonds resulting in optimal structural integrity. The article was subsequently shipped to a Lockheed Martin facility in Colorado where final outfitting, including installation of the thermal protection system, secondary structure and spacecraft subsystem simulators is underway. Assembly will be complete by July, 2011 at which time environmental testing, including mechanical vibration and acoustic testing will be initiated. The article will subsequently be shipped to NASA's Langley Research Center for high fidelity water landing testing. Fabrication of similar Orion service module and launch abort system ground test articles is now also underway.

The first developmental flight test of the Orion Launch Abort System (LAS) was conducted at the White Sands Missile Range, New Mexico on May 6, 2010. During this test, the Orion LAS accelerated the crew module from a standstill to over 500 miles per hour in less than 3 seconds in a real flight environment exactly as would be required during a real launch contingency in order to save the lives of a human crew. The Orion LAS includes three newly designed solid rocket motors (an abort motor, a jettison motor and an attitude control motor) developed to optimize vehicle performance and improve the range of survivable abort conditions.

A thermal protection system (TPS) advanced development project was undertaken to address the low maturity level of TPS materials suitable for the Orion heat shield. Since the end of the Apollo program, NASA's focus on reusable TPS materials such as those used in the Space Shuttle eroded NASA's in-house research and

development capability and left the ablative TPS industry in a state of neglect. The Orion project pursued a competitive phased development strategy with succeeding rounds of development, testing, and down selections. These efforts re-invigorated the ablative TPS industry, re-established a NASA competency to respond to future material needs, and transferred mature heat shield material and design options to the unmanned and commercial space industry, including TPS materials and technology information being used by the Mars Science Laboratory spacecraft and SpaceX Dragon capsule.

A new sensor technology has been developed that will allow easier and safer on-orbit rendezvous and docking. The Orion Vision Navigation System (VNS) is an advanced LiDAR based relative navigation sensor with performance specifications unmatched in today's relative navigation sensor market. A flight qualified version of the VNS is installed onboard the Space Shuttle Endeavour for the STS-134 mission. During the mission, the VNS will be operated in an experimental mode to characterize its performance and validate the technology for space operations. The VNS is a cross-cutting technology that has been developed in partnership with commercial vendors and is applicable for future spacecraft requiring rendezvous and dockings as well as other terrestrial commercial applications.

A new, high speed digital data bus protocol leveraging commercial developed standards while providing assured delivery of time critical data packets demanded by spacecraft command and control applications has been successfully developed for Orion. The protocol, referred to as Time Triggered Gigabit Ethernet, is an innovative technology employed that manages flight critical data as well as mission critical data, such as high definition video, over a single network to minimize weight and power. The Orion data bus network has been integrated and tested at the Honeywell labs in Phoenix, AR. The SAE approval of the Orion bus protocols is nearing completion, allowing for multiple vendors to supply this critical technology to a variety of commercial and government applications.

The Orion project successfully completed a Landing Systems advanced development project to trade, develop, test, and mature candidate systems to mitigate the loads imparted to the spacecraft and crew upon landing impact. Extensive analysis on the effectiveness of various technologies using sophisticated computer models and simulations was completed. The Project ensured the analysis was well-grounded by building and testing engineering development versions of the most promising alternatives, conducting a total of 117 drop tests. These efforts significantly advanced the state-of the art knowledge in this field and formed the basis for key Orion design decisions. These efforts have also provided the basis for the landing systems currently being considered by commercial human spaceflight efforts.

The Orion project successfully completed a formal Integrated Baseline Review to assess the adequacy of the integrated project baseline (cost, schedule, risk, and technical) following the system PDR.

Key Achievements of the Ares Project

The project completed its Preliminary Design Review in August 2008. Building on the successful Preliminary Design Reviews of the Upper Stage, Upper Stage Engine (J-2X), and First Stage, this review focused on integrated Ares-I launch vehicle design and performance. As a prerequisite for the Preliminary Design Review, the Ares Project successfully also completed the Phase 1 Safety Review. The review addressed all catastrophic (loss of crew/vehicle) and critical (loss of mission) hazards for the launch vehicle, integrating the results of hazard analysis, probabilistic risk assessment, failure modes analysis, and engineering design assessments to provide an integrated design and safety assessment consistent with the latest NASA human rating requirements.

In September 2009 and September 2010, NASA and ATK conducted successful tests of five segment development motors in Promontory, Utah. These tests were designated DM-1 and DM-2. Beyond validating the basic performance characteristics of the stage, the tests have enhanced modeling and understanding of key attributes that have historically been very difficult to predict analytically such as erosive burning, thrust oscillations and thrust tail off. Casting for DM-3 has been completed and the test is scheduled for later this year. This test will characterize and validate performance materials and processes applicable to future heavy lift launch systems utilizing solid propulsion stages.

In October 2009, the Ares I-X test flight took place at Kennedy Space Center in Florida. Data from more than 700 on-board sensors showed that the vehicle was effectively controlled and stable in flight. Thrust oscillation frequencies and magnitude data from the Ares I-X flight also were consistent with measurements from recent Shuttle flights that were instrumented, leading us to conclude that the oscil-

lation vibration on the Ares I would be within the bounds that the Ares I was being designed to. In the end, this test flight provided tremendous insight into the aerodynamic, acoustic, structural, vibration, and thermal forces that Ares I would be expected to experience. A final report, Final Flight Evaluation Report for Ares I Use of Ares I-X Data (APO-1041), was completed in January 2011.

The Ares Project successfully completed development and demonstration on September 30, 2010 of a core end-to-end avionics and software integration and test capability. This capability included the integration of upper stage software development unit flight computers, an initial version of the Upper Stage flight software, a single string of First Stage engineering avionics hardware, prototype First Stage rock and tilt thrust vector control (TVC) actuators, and a Kennedy Space Center-developed Ground System (GS) Launch Control System (LCS) interface emulator. The team demonstrated prelaunch checkout and commanding, a complete closed-loop Ares vehicle ascent, and descent of the recoverable First Stage. State-of-the-art systems modeling & simulation capabilities that include hardware integration have broad government and commercial launch systems applicability.

In early 2011, the Upper Stage Element successfully completed functional testing and delivery of three lithium-ion (li-ion) battery development test units (DTUs). A total of eight additional battery DTUs will be delivered to the Marshall Space Flight Center in FY11 for further evaluation and testing. The flight unit batteries are designed to power launch vehicle avionics and various other flight hardware components. Li-ion batteries are rechargeable batteries currently used in portable electronic applications. They are growing in popularity for military, electric vehicle, and now aerospace applications. The Ares I Project is working towards qualification of li-ion technology for human space flight.

The majority of the J-2X engine E10001 parts has been delivered to Stennis Space Center and engine assembly has begun with completion scheduled for May 2011. Static fire testing is currently slated to begin in the June/July 2011 time frame in Test Stand A2. J-2X Powerpack-2 Testing will begin in May 2011 in Test Stand A1. The J-2X offers a viable upper stage engine option in the development of government and commercial human and cargo launch systems.

Key Achievements of the Extra Vehicular Activity (EVA) Project

The EVA Systems Design Review was successfully completed in May of 2008. Successful completion of this review signaled completion of top-level EVA requirements and the associated technical feasibility of the design concept to meet the requirements.

In preparation for EVA Preliminary Design Review, the EVA Systems Project developed and delivered 5 prototype suits representing various design configurations and architectures to assess their respective merits in areas such as mobility, ease of donning and doffing, durability, reliability and safety.

The EVA Systems Project completed a formal Integrated Baseline Review in January of 2010.

Key Achievements in Ground Systems, Mission Operations, and Infrastructure

A two-year renovation of Kennedy Space Center's Operations & Checkout (O&C) building has been completed, resulting in a pristine new spacecraft "factory of the future." Built in 1964, the O&C building will continue its proud heritage of supporting every U.S. human spaceflight endeavor since the Gemini Program. Lockheed Martin and Space Florida partnered with NASA to create this state-of-the-art facility that will allow final assembly and checkout of the Orion spacecraft to be completed at the launch site.

At Kennedy Space Center in Florida, the deconstruction of Launch Pad 39B was initiated in October 2010 with the removal of the Rotating and Fixed service structures. Completion of the deconstruction is scheduled for April 30, 2011. These structures at the pad are no longer needed for NASA's Space Shuttle Program, so the pad is being renovated for future use. The new design will feature a "clean pad" for rockets to come with their own launcher, making it more versatile for a number of vehicles. The new lightning protection system, consisting of three lightning towers and a wire catenary system will remain.

In September 2010, four-year Launch Equipment Test Facility (LETF) renovation effort was completed at the Kennedy Space Center in Florida. The LETF includes a 600-ton test fixture used for tension and compression testing, a water flow test loop that tests valves, pumps and flow meters, two launch simulation towers and two 15,000-gallon cryogenic towers. The new Vehicle Motion Simulator, or VMS, simulates all the movements a vehicle will experience from rollout to launch.

At NASA's Kennedy Space Center in Florida, NASA's new mobile launcher (ML) support structure was completed in August 2010 and was moved from a construction site, north of the Vehicle Assembly Building (VAB), to the Mobile Launcher east park site. The base of the launcher is lighter than space shuttle mobile launcher platforms so the crawler-transporter can pick up the heavier load of the tower and a taller rocket. Once there, the ML can be outfitted with ground support equipment, such as umbilicals and access arms, for future rocket launches. It took about two years to construct the 355-foot-tall structure, which will support NASA's future human spaceflight program.

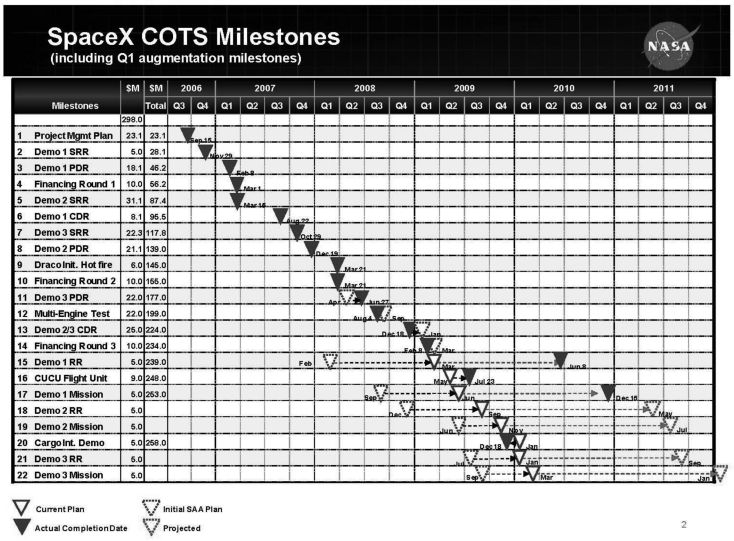
Construction of an advanced Space Environmental Test Facility (SET) at Glenn Research Center's Plum Brook Station in Ohio was initiated in 2007 and will be complete in the summer of 2011. Development of this facility will allow all Orion vehicle level qualification testing including mechanical vibration, acoustics, EMI and thermal vacuum testing to be accomplished in a single facility.

A hydro impact water basin was constructed at NASA's Langley Research Center in Virginia. This facility is available to support water landing impact testing of Orion and commercial spacecraft.

At NASA's Stennis Space Center in Mississippi, construction continues on a new engine test stand. The 300-foot-tall, steel-framed stand will be used to test the J-2X rocket engine. When completed in 2013, the A-3 test stand will allow engineers to evaluate the operating parameters of the J-2X engine by simulating conditions at altitudes as high as 100,000 feet. Construction on the stand began in August 2007At NASA's Johnson Space Center in Texas, architectures for the Mission Control Center-21 (MCC-21) project are being developed. The MCC-21 design features a modern architecture leveraging recent advances in technology to lower overall sustaining costs while increasing the flexibility and capability of the system. In concert with the MCC-21, the Training System (TS)-21 will provide a generalized simulation-based training capability for crew and flight controllers. This approach will support integration of a variety of future spacecraft rather than a single program or vehicle, develop simulation with integrated instructor tools that will provide common behavior across vehicle trainers; and create a simulation interface that supports a variety of vehicle-specific integration models. The Preliminary Design Reviews for MCC-21 and TS-21 will be held in the summer of 2011.

Several world-class manufacturing capabilities for liquid stage structures foaming, machining, and welding have been fabricated and installed at Alabama's Marshall Space Flight Center. These capabilities, the Vertical Milling Machine (the world's largest horizontal multi-axis milling machine), the Robotic Weld Tool, the Vertical Weld Tool, and the Spray-On Foam Insulation Booth, are adaptable and useful for a myriad of spacecraft applications.

Appendix 2


SpaceX COTS Milestones
(including Q1 augmentation milestones)
NASA
Milestones
$M
$M Total
2006
2007
2008
2009
2010
2011
Q1 Q2 Q3 Q4
298.0
1 Project Mgmt Plan 23.1 23.1 Sep 15
2 Demo 1 SRR 5.0 28.1 Nov 29
3 Demo 1 PDR 18.1 46.2 Feb 8
4 Financing Round 1 10.0 56.2 Mar 1
5 Demo 2 SRR 31.1 87.4 Mar 14
6 Demo 1 CDR 8.1 95.5 Aug 22
7 Demo 3 SRR 22.3 117.8 Oct 29
8 Demo 2 PDR 21.1 139.0 Dec 19
9 Draco Init. Hot fire 6.0 145.0 Mar 21
10 Financing Round 2 10.0 155.0 Mar 21
11 Demo 3 PDR 22.0 177.0 Jun 27
12 Multi-Engine Test 22.0 199.0 Sep
13 Demo 2/3 CDR 25.0 224.0 Dec 18
14 Financing Round 3 10.0 234.0 Mar
15 Demo 1 RR 5.0 239.0 Feb Jun 8
16 CUCU Flight Unit 9.0 248.0 Jul 23
17 Demo 1 Mission 5.0 253.0 Sep Dec 16
18 Demo 2 RR 5.0 Dec Sep May
19 Demo 2 Mission 5.0 Jun Nov Jul
20 Cargo Int. Demo 5.0 258.0 Dec 18 Jan
21 Demo 3 RR 5.0 Jul Jan Sep
22 Demo 3 Mission 5.0 Sep Mar Jan
Current Plan
Actual Completion Date
Initial SAA Plan
Projected
2

Orbital COTS Milestones
(including Q1 augmentation milestones)

	Milestones	$M	$M Total	2007 Q3	2007 Q4	2008 Q1	2008 Q2	2008 Q3	2008 Q4	2009 Q1	2009 Q2	2009 Q3	2009 Q4	2010 Q1	2010 Q2	2010 Q3	2010 Q4	2011 Q1	2011 Q2	2011 Q3	2011 Q4
		190.0																			
1	Program Plan Review	10.0	10.0			Mar 31															
2	Demo Mission SRR	20.0	30.0				Jun	Jul 17													
3	UCM PDR	10.0	40.0				Jul	Aug 14													
4	DELETED																				
5	COTS Int/Ops Facility	10.0	50.0					Sep 22	Oct												
6	PCM PDR	10.0	60.0					Oct 8	Nov												
7	DELETED																				
8	IP&CL Submission	10.0	70.0							Feb 18											
9	ISS Phase 1 SRP	10.0	80.0								Mar 27										
10	COTS System PDR	20.0	100.0					Sep		Apr	May 22										
11	PCM CDR	10.0	110.0									Jul 31									
12	Cygnus Avionics Test	10.0	120.0								Jun	Aug 13									
13	ISS Phase 2 SRP	10.0	130.0									Aug	Nov 06								
14	COTS System CDR	10.0	140.0								Mar	Sep		Mar 29							
15	SM Core Assy Comp.	7.5	147.5									Oct	Dec			Aug 30					
16	SM Test RR	7.5	155.0										Jan	Apr			Nov 17				
17	SM Initial CPT	5.0												Mar	Jul				May		
18	LV Stage I Assy Comp.	2.5													Sep	Oct				Jul	
19	Cargo Int. Demo	2.5	157.5														Dec 6				
20	Mission RR	2.5														Oct		Feb			Oct
21	System Demo Flight	2.5															Dec	Mar			Dec
22	Mission Concept Rvw *	20.0	177.5														Dec 14				

Current Plan
Actual Completion Date
Initial SAA Plan
Projected
* Augmentation Milestone

1

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

Good morning, everyone. Welcome to today's hearing entitled "A Review of NASA's Exploration Program in Transition: Issues for Congress and Industry." In front of you are packets containing the written testimony, biographies and truth in testimony disclosures for today's witness panel. I recognize myself for five minutes for an opening statement.

I would like to welcome everyone to today's Subcommittee hearing to review the transition of NASA's exploration programs as directed in last year's authorization act. We have a distinguished panel of witnesses who will give us the status of the capabilities that have been developed by the Constellation program, as well as the current status of the transition activities that have taken place over the past year, and the effect those changes are having on the aerospace workforce and industrial base.

I am happy that we are joined today by the Chairman of the Science, Space, and Technology Committee, Chairman Ralph Hall. I will keep my remarks brief so I can yield my remaining time to the Chairman for his opening statement.

During the previous three reauthorization cycles, including last year's bill, Congress has been clear about its desire to develop a government-owned launch system capable of taking astronauts to low Earth orbit and beyond. This Administration, on the other hand, has advocated an approach where NASA would rely exclusively on commercial companies to provide transportation to low Earth orbit. And while a government-owned capability to extend deeper in space is a "nice-to-have," the Administration seems to reason there is no rush to develop such a system, arguing that we aren't prepared nor can we afford to undertake a deep space mission in this decade. I disagree, and I think the law is clear: Congress expects NASA to develop a Space Launch System and Multi-Purpose Crew Vehicle in time to serve as a back-up to the commercial companies, who will likely encounter delays. And just as importantly, by building a follow-on system now, NASA will provide continuity for the skilled engineers and technicians who underpin our Nation's space capabilities. To not engage them would ensure a quick withering away of the skill base, and it would take years and billions of dollars to revive that capability. As Mr. Maser makes clear in his testimony, the Nation's aerospace workforce and industrial base is a perishable national asset that can disappear.

Many of my constituents have been working on the Constellation program at the Stennis Space Center for a number of years. The J–2X upper stage rocket engine should be completed in May, and is scheduled for testing at Stennis in June or July. The J–2X is one of many advanced capabilities developed over the past few years that could be applied directly toward a heavy-lift Space Launch System.

In the very tight fiscal environment we are in, NASA must make maximum use of every hard-won capability at its disposal. The decisions that NASA has made, and will make over the next few months, could have a profound effect on the future of the aerospace workforce and industrial base. These are important decisions affecting thousands of people and hundreds of millions of dollars of

investment in national capabilities, and it is vital that NASA proceed with care but not delay.

I look forward to the testimony of our witnesses.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF THE SUBCOMMITTEE ON SPACE AND AERONAUTICS
CHAIRMAN STEVEN M. PALAZZO

Good morning. I'd like to welcome everyone to today's subcommittee hearing to review the transition of NASA's Exploration programs as directed in last year's Authorization Act. We have a distinguished panel of witnesses who will give us the status of the capabilities that have been developed by the Constellation program, as well as the current status of the transition activities that have taken place over the past year, and the effect those changes are having on the aerospace workforce and industrial base.

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I now yield my time to the Chairman of the Science, Space, and Technology Committee - Ralph Hall - for his opening statement.

Chairman PALAZZO. I now yield my time to the Chairman of the Science, Space, and Technology Committee, Ralph Hall, for his opening statement.

Chairman HALL. I thank you, Chairman Palazzo, for holding this very important and timely hearing, and thanks to our witnesses for taking the time that they have taken to prepare, to travel here and to give us their time and to share their many years of very valuable experience and insight.

I have seen such great Americans, who are friends of mine and friends of many of us here like General Tom Stafford, Buzz Aldrin, Neil Armstrong, Gene Cernan and many, many others who risked their lives, and some give their lives, to explore space and demonstrate the strength and resolve of our country. They are real heroes. When they left to go to some of their destinations, they

weren't positive that they were going to come back. These men and women are really heroes.

Last year, I listened to their very strong testimony and I agreed with them that the President's plan took us absolutely in the wrong direction and took our country in the wrong direction. His decision on human exploration of space as set out absolutely undermined five years of broad bipartisan and bicameral support, Republicans and Democrats working together, and was made without clear direction or analysis. The President's action has spawned thousands of lost jobs and cast fear and doubt throughout the industry.

Last year, after careful consideration, and contrary to the President's objections, thank goodness, Congress laid out its plan and passed the NASA Authorization Act of 2010. The debate is over. This Act is the law. NASA has its direction. The Administration needs to acknowledge this and Act accordingly. They don't need to be going to Florida nor to Alabama nor to Texas threatening those people and telling them that they don't have to comply with acts of Congress. I just think Congress, both the majority of Democrats and Republicans in the House and Senate, are committed to ensuring that NASA follows the law. I expect them to. I think they will. I respect them.

We have heard favorable comments from those same astronauts who risked it all for our space program. They told us of the importance of continuing to develop these exploration systems for ensuring we can get back to the Space Station, and preparing for missions beyond low Earth orbit.

But as we have seen from the fiscal year 2012 budget request, the Administration is trying to ignore the thrust of this Act. We expect NASA to proceed with the uninterrupted development of the Space Launch System and Multi-Purpose Crew Vehicle that builds upon and takes maximum advantage of the significant work and capabilities that already exist. There is broad agreement on the importance of minimizing disruptions to an industrial base that is already reeling from the end of the space shuttle program.

NASA should make the most expeditious choices possible to minimize the adverse impact on the aerospace workforce and industrial base. If further bidding is required, and I am not suggesting that it is, NASA should ensure it has truly qualified bidders that should be called upon to demonstrate their financial strength and technical capabilities to give some assurance that they can follow through and finish what they begin.

In total, the NASA authorization provides $10.8 billion over three years to continue the exploration systems work. This is a significant commitment. NASA must not delay. Lengthy studies are no longer needed. Lengthy new starts will not be tolerated. We are well beyond that point. Congress has given clear direction and we expect NASA to comply.

Before closing, I want to address a short statement to Mr. Cooke, and be clear this is not directed at you personally. This Committee did not receive your testimony until a little after 4 p.m. yesterday. We have had limited time to review your statements in any detail, which does a serious disservice to the hearing process. This isn't the first time that NASA's statements have arrived at the 11th

hour. Even in the prior Congress under Democratic control, NASA's testimony was prone to be late. So when you return to headquarters, I hope you will tell your folks there that is unacceptable practice and that we don't expect it to be continued. I want to work with you, I am going to work with you. Please let us work with you. I will not condone this type of bureaucratic behavior, and I don't think you would be proud of it.

If I have any time left, I yield it back.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF CHAIRMAN RALPH HALL

Thank you Chairman Palazzo for holding this important, and timely hearing. And thanks to our witnesses for taking the time to share their many years of valuable experience and insight.

I have seen such great Americans, who are friends of mine - like General Tom Stafford, Buzz Aldrin, Neil Armstrong and Gene Cernan - risk their lives to explore space and demonstrate the strength and resolve of America. They are real heroes. They didn't know if they would return.

Last year, I listened to their strong testimony and I agreed with them that the president's plan took our country in the wrong direction. His decision on human exploration of space undermined 5 years of broad bipartisan and bicameral support, and was made without clear direction or analysis.

The president's action has spawned thousands of lost jobs and cast fear and doubt throughout the industry. Last year, after careful consideration, and contrary to the president's objections, Congress laid out its plan and passed the NASA Authorization Act of 2010.

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But as we have seen from the FY2012 *budget* request, the administration is trying to ignore the thrust of this Act. We expect NASA to proceed with the uninterrupted development of the Space Launch System (SLS) and Multi Purpose Crew Vehicle (MPCV) that builds upon - and takes maximum advantage of - the significant work and capabilities that already exist. There is broad agreement on the importance of minimizing disruptions to an industrial base that is already reeling from the end of the space shuttle program.

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Before closing, I want to address a short statement to Mr. Cook, and be clear this is not directed at you personally. This Committee did not receive your testimony until a little after 4:00pm yesterday. We have had very limited time to review your statement in any detail, which does a serious disservice to the hearing process. This isn't the first time that NASA's statements have arrived at the 11th hour. Even in the prior Congress under Democratic control, NASA's testimony was prone to late arrival. So when you return to headquarters, I need you to tell your folks that this is an unacceptable practice and that I do not expect it to be continued. I will not condone this type of bureaucratic behavior.

Thank you, Mr. Chairman.

Chairman PALAZZO. Thank you, Chairman Hall.

The Chair now recognizes Mr. Costello for an opening statement.

Mr. COSTELLO. Mr. Chairman, thank you, and Mr. Chairman, I thank you for calling this hearing today, and let me associate myself with the remarks made by Chairman Hall, and Mr. Cooke, as Chairman Hall stated, it is not directed at you. I think we all realize that you are dealing with OMB but it is unacceptable and it is a disservice to this Subcommittee and to the full Committee and to the Members of this Committee, so I hope you take that back both to your bosses and to the Administration.

Mr. Chairman, I would like to start off by saying a few words about Congresswoman Giffords, a true champion of our Nation's space program. Ms. Giffords worked tirelessly during the 111th Congress to ensure NASA's human space exploration program remained the most innovative in the world. I am honored to serve as the acting Ranking Member today at this Subcommittee as we continue her work.

Through the 111th and 112th Congresses, this Committee has held several hearings to discuss the future of NASA's exploration program as it faced budget challenges and considered serious changes to its mission. Despite these ongoing discussions, we still have not received concrete answers on how NASA plans to transition away from the Constellation program and achieve the goals outlined by Congress in the 2010 Authorization Act. It is my hope that we receive specific information on four key issues here today from our witnesses.

First, I would like to know the status of the General Counsel's review of how existing Constellation contracts can be modified to carry out work on the crew capsule and heavy-lift launch vehicles as Congress intended in the Authorization Act.

Secondly, NASA has a preliminary baseline approach to developing a heavy-lift vehicle after completing several studies to select the most efficient and cost-effective design. I would like to hear an exact timeline and date for when NASA will start work on the new vehicle.

Third, during debate on the 2010 NASA Authorization Act, Congresswoman Giffords expressed serious concerns about NASA's ability to achieve the stringent exploration goals at the authorized funding levels. In view of her concerns, I would like to hear from each one of our witnesses if the heavy-lift vehicle and the Multi-Purpose Crew Vehicle have a real future at the current funding levels.

Finally, this Committee needs a clear understanding of NASA's mission for human exploration and the two vehicles it will develop under the authorization. Without concrete goals and benchmarks, we have no way of measuring the program's success.

I hope today's hearing will provide the opportunity for Members of the Subcommittee to understand how NASA will achieve the exploration mission and how Congress and the Administration can work together to reach these goals.

Mr. Chairman, I thank you again for calling the hearing. I welcome the panel of witnesses and I look forward to hearing their testimony and specifically addressing the four issues that I have raised in my opening statement. Thank you, and I yield back.

[The prepared statement of Mr. Costello follows:]

SUBMITTED STATEMENT OF ACTING RANKING MEMBER JERRY COSTELLO

Mr. Chairman, thank you for holding today's hearing to review the current status and the future of the National Aeronautics and Space Administration (NASA) exploration program.

I would like to start by saying a few words about Congresswoman Giffords, my good friend and a true champion of our nation's space program. Ms. Giffords worked tirelessly during the 111th Congress to ensure NASA's human space exploration program remained the most innovative in the world. I am honored to serve as Acting Ranking Member today as this Subcommittee continues her work.

Through the 111th and 112th Congresses, this Committee has held several hearings to discuss the future of NASA's exploration program as it faced budget challenges and considered serious changes to its mission. Despite these ongoing discussions, we still have not received concrete answers on how NASA plans to transition away from the Constellation Program and achieve the goals outlined by Congress in the 2010 Authorization Act.

Following your testimony, it is my hope to receive specific information about four key issues. First, I would like to know the status of the General Counsel's review of how existing Constellation contracts can be modified to carry out work on the crew capsule and heavy lift launch vehicles as Congress intended in the 2010 Authorization Act.

Second, NASA has determined a baseline approach to developing a heavy-lift vehicle after completing several studies to select the most efficient and cost-effective design. I would like to hear an exact timeline and date for when NASA will start work on the new vehicle.

Third, during debate on the 2010 NASA Authorization Act, Congresswoman Giffords expressed serious concerns about NASA's ability to achieve the stringent exploration goals at the authorized funding levels. Ms. Giffords is a champion of the human space exploration and she recognizes the importance of moving this program forward in a responsible way. In view of her concerns, I would like to hear from our witnesses if the heavy-lift vehicle and the multi-purpose crew vehicle have a real future at the current funding levels.

Finally, this Committee needs a clear understanding of NASA's mission for human exploration and the two new vehicles it will develop under the Authorization. Without concrete goals and benchmarks we have no means of measuring the program's success.

I hope that today's hearing will provide the opportunity for Members of the Subcommittee to understand how NASA will achieve its exploration mission and how Congress and the Administration can work together to reach those goals.

I welcome our panel of witnesses and look forward to their testimony. I yield back the balance of my time.

Chairman PALAZZO. Thank you, Mr. Costello.

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

At this time I would like to introduce our witness panel. Our witnesses today are Mr. Doug Cooke, NASA's Associate Administrator for the Exploration Systems Mission Directorate. Mr. Cooke has experience with the space shuttle, Space Station, and exploration programs during his distinguished 37-year career at NASA. Dr. Scott Pace is the Director of the Space Policy Institute at George Washington University and a former Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy. Mr. Jim Maser will testify today as the Chairman of the Corporate Membership Committee of the American Institute of Aeronautics and Astronautics. Mr. Maser is also the President of Pratt and Whitney Rocketdyne and is well prepared to give us an industry perspective on the state of the aerospace industrial base and the uncertainty surrounding NASA transition plans.

I want to thank all of you for taking the time and effort to appear before us today. As our witnesses should know, spoken testi-

mony is limited to five minutes each after which the Members of the Committee will have five minutes each to ask questions.

I now recognize as our first witness, Mr. Doug Cooke, Associate Administrator of the Exploration Systems Mission Directorate at NASA. Mr. Cooke.

STATEMENT OF DOUGLAS COOKE, ADMINISTRATOR, EXPLORATION SYSTEMS DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. COOKE. Chairman Palazzo and Members of the Subcommittee, thank you for the opportunity to appear before you today to talk about the future of human spaceflight and exploration and in particular to talk about the next generation of human spaceflight vehicles known as the Space Launch System, or SLS, and the Multi-Purpose Crew Vehicle, or MPCV. Before beginning, I would like to express my thoughts on a couple of matters.

Last year, I appeared before this Subcommittee, which was chaired by Congresswoman Giffords. My wife, Renee, and I met with her beforehand and I was very impressed with her as a person and by her strong support for human spaceflight. I would just like to acknowledge her as a colleague of yours and a member of the NASA family and extend my very best wishes for her recovery.

Second, I want to thank all the NASA and industry team who support exploration programs and activities. They continue to work tirelessly to further exploration beyond low Earth orbit even through challenging and uncertain times that we have experienced. I am constantly in awe of their dedication and drive. It is very obvious that exploration is a passion for them and not just a job. I personally owe them my best efforts to get us on a stable path through the efforts we have underway, and I think you share that objective. And now onto the business at hand.

Let me assure you that NASA is aggressively addressing the specifics required in the NASA Authorization Act of 2010 and to providing a path forward in the coming months for the SLS and MPCV in terms of specific designs that are within budget constraints. We are also compelled to apply the capabilities, lessons learned and knowledge gained through the Constellation program to SLS and MPCV efforts.

At the same time, we are committed to continuing with our successful human research program and to furthering demonstrations of maturation of capabilities through commercial cargo as well as new investments in commercial crew capabilities for low Earth orbit and to support the Space Station. We will augment the work on SLS and MPCV by initiating in-house development of concepts and prototypes of advanced systems and vehicles also needed for exploring the various destinations. The Space Station will provide an opportunity to test many of these capabilities as we prepare for the future. Therefore, our civil servants across the agency should feel confident there is exciting, meaningful work for them following retirement of the shuttle and transition from the Constellation program as we focus on a more capability-driven exploration architecture.

Moving forward, one thing is very clear. Developing a heavy-lift capability and a deep-space crew vehicle are the first, most impor-

tant steps needed to send crews to multiple destinations of interest in human exploration. Therefore, the SLS and MPCV will and must be capable of transporting astronauts to multiple destinations beyond low Earth orbit. Destinations could include Lagrange points lunar surface, visits to near-Earth asteroids and travel to the premier destinations of Mars and its moons, Phobos and Deimos. All these places hold incredible information for us with discoveries that we probably can't even imagine at this point.

In a constrained budget environment, we know how important it is to search for ways to make our programs and projects more efficient through our contracting and management approaches, and we are embracing this challenge. We have stepped up activities in-house and in collaboration with our current industry partners to implement cost-saving measures.

After passing of the Authorization Act, NASA immediately began studying potential SLS and MPCV configurations based on the requirements of the Act. We have selected a reference design vehicle for the MPCV and SLS, both of which are consistent with the Act and are supported with our past study results.

For MPCV, NASA has chosen the beyond-low Earth orbit version of the Orion crew vehicle as that design. The Orion development effort has already benefited from significant investments and progress to date and the Orion requirements closely match MPCV requirements as defined in the Authorization Act.

For the SLS, we have selected an Ares shuttle-derived vehicle as our reference vehicle design. This system will provide 130-metric-ton capability described in the Authorization Act. We would begin with a scaled-back version of the same components to provide initial capability of 70 to 100 metric tons to achieve the earliest possible deployment that fits within budget constraints. We have NASA study teams that are also looking at liquid oxygen/kerosene vehicle, a modular vehicle approach, and are looking at affordability of these various design approaches. We have awarded 13 study contracts to industry to have them help provide their best ideas and innovative approaches toward a heavy-lift vehicle. In parallel, we have procurement teams tracing requirements between MPCV and SLS to the current shuttle and the Constellation designs to understand how much the new work is within scope of those contracts.

Although much work remains to be accomplished over the next months, we are committed to developing programs and places that are executable both in terms of schedule and cost. We are continuing to work on Constellation contracts consistent with directions in law and are prioritizing work that has a high likelihood of being applicable to SLS and MPCV. We also are in the process of setting up program offices at three centers, one at Marshall for SLS, one at JSC for MPCV, and one at KSC for commercial crew development office.

In conclusion, I believe that throughout history countries have led an exploration of the uncharted and unknown, and these countries have been great world leaders of their time. Today our country through NASA is at the beginning of a new adventure in space travel, one that presents challenges that are appropriate for the talents and resources of our Nation, both now and for generations

to come. Our new adventure will build on sacrifices and achievements of the past and will contribute to and reinforce our place in world leadership. With your help, together we can and will create a bold legacy for future generations.

I thank you for your interest and I welcome your questions.

[The prepared statement of Mr. Cooke follows:]

PREPARED STATEMENT OF DOUGLAS COOKE, ASSOCIATE ADMINISTRATOR FOR THE EXPLORATION SYSTEMS MISSION DIRECTORATE

Chairman Palazzo and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the future of NASA's human spaceflight program, and in particular the progress NASA is making on developing the next-generation human spaceflight transportation systems, currently known as the Space Launch System (SLS) and the Multi-Purpose Crew Vehicle (MPCV), as well as their associated mission and ground support elements and other programs of the Exploration Systems Mission Directorate.

With passage of the NASA Authorization Act of 2010 (P.L. 111-267) on October 11, 2010, NASA has a clear direction for our human spaceflight programs, and we are aggressively moving forward with our next-generation human spaceflight system development efforts. NASA appreciates the significant effort made in advancing this important bipartisan legislation, and we look forward to working with you to shape a promising future for our Nation's human spaceflight programs.

The President's FY 2012 budget request continues to focus Agency efforts on a vigorous path of innovation and technological development leading to an array of challenging and inspiring missions to destinations with an incredible potential for discovery, increasing our knowledge of our solar system, developing technologies to improve life, expanding our presence in space, increasing space commerce, and engaging the public. Within the human spaceflight arena, our foremost priority is our current human spaceflight endeavor and the safety and viability of our astronauts. The request also maintains a strong commitment to human spaceflight beyond low Earth orbit (LEO) via a capability-driven architecture that will focus on increasingly complex destinations as we develop the technical expertise for those expanding missions ever-deeper into our solar system. It focuses on utilization and operation of the International Space Station (ISS), and on establishing a U.S. commercial crew and cargo capability to reach this National Laboratory to maintain our national human space flight capability rather than rely on foreign-bought services. It establishes critical priorities and invests in the technologies and excellent science, aeronautics research, and education programs that will help us win the future. The request supports an aggressive launch rate over the next two years with about 40 U.S. and international missions to the ISS, for science, and to support other agencies.

NASA is excited about moving ahead with this work. We are eager to find ways to leverage investments made in technology and through progress made by the Constellation Program. My testimony will outline how NASA is working to build a bridge between the past program and the future by transitioning previous and ongoing development work, best practices and lessons learned from the Constellation Program to the SLS and MPCV programs and by transitioning and leveraging hardware and technology investments, wherever possible.

While NASA has not yet finalized its development plans for the SLS and MPCV, NASA is working expeditiously to ensure we have a credible and integrated plan with which to move forward. We understand and appreciate the direction provided by the NASA Authorization Act of 2010, and we are honoring those requirements as we implement the Act. The President's FY 2012 budget request for Exploration, for example, reflects all of the major elements of the Authorization Act.

In moving forward on the SLS and MPCV, we will ensure that we have efficient contracting and management approaches so as to ensure affordability in the near term and over the long run. We will also build an evolvable and interoperable human spaceflight transportation system that will serve us for decades to come as we explore multiple compelling mission destinations. In a constrained budget environment, we know how important it is to look for ways to make our programs and projects more efficient, so finding and incorporating these efficiencies is a primary goal for us. Therefore, NASA has embraced the challenge to deliver human spaceflight systems for lower cost, and the opportunity to become more efficient, innovative and agile in our Programs. For example, we are revising the management of our requirements, contracts, and projects and incorporating approaches to ensure affordability in the near term and over the long run. This includes the use of fo-

cused insight/oversight, specifying, where appropriate, to industry what we need instead of how to build it, designing for cost-effective operations, increasing the use of common components and parts, and smartly consolidating infrastructure. Therefore, my testimony today will address progress made to date on the SLS and MPCV programs, as well as outlining the work ahead of us in order to ensure that we develop systems that reflect the NASA Authorization Act of 2010 using an affordable, sustainable and realistic approach.

But before I explore those topics, I would like to personally recognize the thousands of NASA civil servants and industry team members who have worked selflessly for countless hours, often under difficult circumstances and in a turbulent environment, to make the Exploration programs and projects productive and successful. I am constantly in awe of their dedication and agility in making progress through changing circumstances. I am personally indebted to them. Over 37 years at NASA, I have served through many transitions in human spaceflight programs, so I speak from personal experience when I say that change is never easy, especially for those who have devoted much of their professional and personal time and energy to programs they love. Today, the NASA Exploration team has much to be proud of . and much to look forward to.

Our civil servants across the Agency should feel confident that there is exciting and meaningful work for them to do following the retirement of the Shuttle and the transition from Constellation, and the shift from assembly of the ISS toward ISS operations. Turning our focus toward a more capability-driven exploration architecture will offer far-ranging opportunities for our creative and skilled civil servant workforce across the Agency. There will be opportunities for them to apply their cross-cutting talents to new challenges such as developing and demonstrating prototypes for human capabilities needed for beyond-LEO exploration. Here are just a few examples of enabling capabilities that must be developed before we can send crews beyond LEO - work that will be managed by our new Advanced Exploration Systems (AES) Program:

- Developing a ground-based test bed for demonstrating life support systems needed to enable long-duration crewed missions based on lessons learned from operation of the life support systems currently in use on the ISS;
- Developing and testing components for an advanced spacesuit to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the Moon, Mars and asteroids;
- Developing design concepts for future space exploration vehicles and deep-space habitats; and
- Conducting ISS and ground-based analog testing to validate operational concepts for long-duration missions.

We have already employed this teaming approach quite successfully, as exemplified by the NASA in-house efforts with Robonaut2 (R2), which was delivered to the ISS on the last Space Shuttle flight. This robot was developed in partnership by a joint NASA-General Motors team. Another example is the Lunar Electric Rover, which is a pressurized surface rover to provide astronaut mobility for exploring a planetary body in a shirtsleeve (or non spacesuit) environment. The prototype, developed at low-cost, has already been demonstrated and matured through field testing at sites on Earth that resemble the lunar terrain, for example. The rover, along with some of NASA's astronauts, also participated in President Obama's Inaugural Parade. In sum, both of these examples highlight the substantial benefit we will continue harnessing from our highly creative, competent and mission-focused workforces across the Agency and at all Centers.

It is clear that NASA has a bright future. The future will bring new destinations to explore, and a new generation of future astronauts, scientists and engineers to inspire. Clearly, there is much work ahead of us, but I am confident that NASA's incredible and talented employees working with our industry and international partners will continue to do whatever it takes to make sure that the United States remains the world's leader in human spaceflight. After all, they do not know how to commit to less.

The SLS and MPCV: Moving Forward

On January 10, 2011, NASA provided to Congress an interim report on our SLS and MPCV efforts, with a commitment to provide more extensive details in the FY 2012 President's budget request and in a follow-on report to Congress in the spring/summer timeframe of 2011. We recognize that Congress wanted more information than we were able to provide in the interim report. The report was due to Congress

90 days after the NASA Authorization Act of 2010 was signed into law, thereby formally authorizing NASA to move out on the SLS and MPCV programs. After passage of the Authorization Act, NASA immediately began studying potential SLS and MPCV configurations based on the requirements of the Act and began analyzing current Constellation contracts and their flexibility. However, the final FY2011 appropriation remains unknown, and the evaluation process entailed a longer timeframe to come to a comprehensive design and acquisition approach for these large and complex projects. Therefore, in an effort to be as responsive to Congress as possible, NASA developed an interim report which noted the progress we had made at that time, with a commitment to provide a follow-on report with more extensive details later this year.

Much work remains to be accomplished over the next few months such as in-depth planning to synchronize the schedules and budgets for SLS, MPCV and Ground Operations efforts such that their developments are coordinated in order for each to deliver its capability in a planned timeframe. Since an integrated schedule for the SLS and MPCV vehicles is an essential product of our planning efforts, NASA required additional time to gain reliable information from on-going system trade studies, obtain a better understanding of budget requirements and constraints, and develop acquisition strategies that can put development on an affordable and sustainable path. Therefore, by summer, NASA expects to have completed several key analytical steps - information that will be contained in our follow-on report to Congress:

- The basic framework for a capability driven architecture and concept of operations that provides the strategic context for exploration of multiple destinations, a plan that applies the principles of affordability, sustainability, commonality, and interoperability, and a framework for expanded partnerships with the international, interagency, industry, and academic communities;
- Analysis of the current Ares and Shuttle contracts for their applicability to the future development program;
- Analysis of the cost and benefits of the Reference Vehicle Designs for the SLS and MPCV and alternate vehicle designs; and
- Analysis of potential initial acquisition approaches (in the case when contract changes or new procurements are indicated, NASA will follow applicable procurement regulations, including the March 4, 2009, Presidential Memorandum on Government Contracting).

As required by law, NASA's SLS and MPCV vehicles will be capable of providing crew and cargo transportation to the ISS as backup to our current international partners and future commercial crew transportation providers. However, the primary goal of SLS and MPCV development is exploration beyond LEO. As such, the SLS and MPCV will be capable of transporting astronauts to multiple destinations beyond LEO. Destinations could include cis-lunar space, such as Lagrange points between the Earth and the Moon, the lunar surface, visits to near-Earth asteroids, and eventually to Mars and its moons. All of these places hold incredible information for us - information that we probably don't even know exists at this point. Compelling missions such as satellite servicing, new discoveries and exploration advancement are all enabled by this approach. This journey begins with the SLS and MPCV as the first important core elements of the broader exploration evolutionary approach for accomplishing this broad spectrum of missions.

Consistent with direction in the NASA Authorization Act of 2010, the Agency has selected a Reference Vehicle Design for both the SLS and MPCV, giving us a baseline from which to start developing schedule, budget and requirements, as well as acquisition plans. Recently, NASA formally authorized the MPCV program office to stand up at Johnson Space Center (JSC) in Texas, and the SLS program office to be established at Marshall Space Flight Center (MSFC) in Alabama. As such, these teams will be charged with putting more detail on those designs so as to be able to help us answer the hard questions that will undoubtedly occur before we finalize our selections. In that spirit, we are continuing to look at alternative designs to challenge and/or validate those concepts so as to ensure our final vehicle choices will be the best value for the taxpayer in terms of cost, schedule and capability.

The Authorization Act specified that the initial vehicle performance would range from 70 to 100 metric ton[1] (mT) to LEO, evolvable to 130 mT and that it use, to the extent practicable, existing contracts, investments, workforce, industrial base,

[1] The Authorization Act specified vehicle performance in terms of "tons" but NASA develops capability in terms of "metric tons." Therefore, lift capability references in this testimony refer to metric tons.

and capabilities from the Space Shuttle and Orion and Ares I projects. Therefore, for the SLS, NASA has chosen a Reference Vehicle Design that is derived from Ares and Space Shuttle hardware. The current concept vehicles would utilize a liquid oxygen/liquid hydrogen core with five RS-25 Space Shuttle Main Engine-derived engines, five-segment solid rocket boosters, and a J-2X-based Upper Stage for the SLS as the 130 mT version of the heavy-lift vehicle - evolvable from the 70 to 100 mT version. This reference design would allow for use of existing Shuttle and Ares hardware assets in the near term, with the opportunity for upgrades and/or competition downstream for eventual upgrades in designs needed for affordable production.

For the MPCV, NASA has chosen the beyond-LEO version of the Orion Crew Exploration Vehicle design as the Reference Vehicle Design. The Orion development effort has already benefited from significant investments and progress to date, and the Orion requirements closely match MPCV requirements as defined in the Authorization Act, which include utilizing the MPCV as the primary crew transportation vehicle for beyond-LEO exploration, as well as being capable to serve as backup for ISS crew and cargo transportation.

NASA will evaluate the Reference Vehicle Designs and other alternatives this spring through in-house analyses and maturation of concepts and will incorporate results of industry studies that the Agency solicited earlier this fiscal year. In particular, one of the greatest challenges for NASA will be to reduce the development and operating costs (both fixed and recurring) for human spaceflight missions to sustain a long-term U.S. human spaceflight program. We must plan and implement an exploration enterprise with costs that are credible and affordable for the long term under constrained budget environments. As such, our development efforts also will be dependent on a realistic budget profile and sufficiently stable funding over the long term, coupled with a successful effort on the part of NASA and our eventual industry team to reduce costs and to establish stable, tightly-managed requirements.

NASA is exploring ways to transition the design and development efforts of the Constellation Program so that NASA will be able to capitalize on current investments and workforce, as appropriate. In the meantime, as will be outlined later in this testimony, NASA is taking steps to concentrate current spending on those aspects of the Constellation Program that will have the greatest applicability to the new SLS and MPCV programs.

Currently, NASA has procurement teams who are mapping SLS and MPCV requirements (those outlined in the NASA Authorization Act of 2010 and those we are currently developing) against the Ares and Orion contracts (and other Agency contracts) to determine if the new requirements fit the scope of the existing contracts. For the SLS, we are reviewing each element of Ares (First Stage, Upper Stage, Upper Stage J-2X engine and avionics) to determine whether the new SLS requirements are within scope of the current contract. For the MPCV, our review of the Orion contract indicates that the MPCV is within scope of the Orion contract.

The final acquisition plans for both vehicles are expected in the late Spring/Summer timeframe. The development of the SLS and MPCV and supporting capabilities must be planned by developing an integrated budget and schedule to understand how these programs collectively fit within budget profiles and to determine when preliminary flight dates are possible. In this timeframe, costs and schedule will be preliminary, based on pre-formulation information for these new programs.

NASA recognizes it has a responsibility to be clear with the Congress and the American taxpayers about our true estimated costs and schedules for developing the SLS and MPCV. NASA is committed to keep Congress informed about our planning efforts. To this end, NASA will acquire independent (outside of the Agency) cost and schedule assessments for SLS and MPCV design options as part of its decision process this spring or summer. Furthermore, NASA will make these assessments public.

Additionally, NASA is currently developing a list of major development and testing milestones planned for Exploration Systems over the next several years. However, it is important to note that these plans are contingent on many factors, including available funding; decisions about what work from Constellation will transfer to the SLS and MPCV programs and their associated supporting elements. It is also contingent on NASA's upcoming decisions regarding SLS and MPCV final designs and associated requirements and acquisition needs.

The SLS: Where We Are Today

The NASA Authorization Act of 2010 directs NASA to develop an SLS that is capable of accessing cis-lunar space and the regions of space beyond LEO. The Act also states that the SLS must be capable of lifting the MPCV, and that the SLS must be able to initially lift 70-100 mT to LEO, while ultimately being evolvable

to 130 mT or more. For the initial capability, the Authorization Act set a goal of achieving operational capability for the core elements no later than 2016.

NASA's SLS development effort is focusing initially on the 70 to 100 mT lift capability, so as to get as close to 2016 as possible in terms of initial operational readiness. We also are seeking ways to capitalize on synergies between the lower-range and upper-range lift capabilities, thereby allowing us to develop some of the upper-range capabilities at the same time as we are focusing on the 70 to 100 mT capability. Doing so is actually a fairly natural, evolvable progression in terms of developing these capabilities. However, before making any final decisions, we must first understand how our approaches to heavy-lift will fit within the budget profile, how they will fit into a future exploration architecture and how they might benefit other agencies to maximize the investment for the taxpayer. Knowing the amount appropriated for SLS and MPCV development efforts in FY 2011 and gaining increased clarity regarding future budget profiles will be an important factor in helping NASA to finalize plans for the SLS and the MPCV.

Recently, NASA concluded the first iteration of a Requirements Analysis Cycle (RAC), which was established to complete a preliminary analysis of high-level system requirements, to include initial development planning, design concept maturation, and preliminary programmatic requirements. By using techniques such as design-to-cost, the teams considered a balanced set of trades between capabilities and the price tag to implement them. The RAC teams also brought in ground processing and launch expertise from KSC so that the long term operational expenses of various designs could be assessed. The results will be informed by NASA analysis of the direction in the Authorization Act, SLS safety and performance, existing national capabilities and stakeholder priorities for SLS.

The RAC team is now preparing to brief its findings to NASA Administrator Bolden, and they will also be preparing to incorporate the findings of several independent, industry-led trade studies into their analysis. Thirteen of these six-month studies were initiated in November 2010 in order to provide a "fresh look" at innovative launch vehicle concepts, propulsion technologies, processes and affordability initiatives that can be infused into the development of the new human exploration missions - information that will be used to help inform the overall selection and development of the final SLS vehicle detailed design.

One of NASA's goals is for the RAC teams and the study contracts teams to develop ideas to come as close to the goal identified in the Authorization Act as possible, given budget realities and the need for the program to be affordable over the long-term. Our commitment will be to determine a flight date that has a reasonable probability of being achieved. Additionally, NASA believes that, all else being equal, utilizing heritage systems will help expedite the development process and flight dates, even though launch vehicle integration challenges will still exist as a schedule threat. On the other hand, starting with a clean sheet may provide a lower lifecycle cost. This is the subject of the current studies.

NASA is still in the process of developing the full acquisition strategy for the SLS. Given that the current Reference Vehicle Design utilizes heritage systems from Shuttle and Ares, NASA is evaluating existing Ares and Shuttle contracts -- and potential money saving improvements and modifications to them -- to determine whether those contracts could be used for development work on the SLS and whether doing so would be the most affordable and efficient option for developing the SLS. In the meantime, in order to maintain existing capabilities during this planning effort, NASA continues work on the elements of the Ares I Project that are most likely to feed forward into the SLS, as detailed later in this testimony.

Additionally, the SLS Program will continue to examine ways to increase efficiency and agility so as to be able to deliver an affordable and achievable heavy-lift system as soon as possible. Examples being considered in formulating SLS plans:

- Consolidating infrastructure smartly;
- Using common parts and common designs across the Government, so as to encourage bulk buys of heavy-lift vehicles;
- Ensuring requirements are appropriately specific and also that requirements applied to NASA crew launch vehicles are similar to those provided to our eventual commercial crew partners, thereby ensuring that NASA vehicles are not required to meet more substantial requirements than commercial crew vehicles and vice versa; and
- Conducting insight/oversight activities of our contract partners in a smarter way, thereby using our resources more appropriately to focus on the high-risk items, rather than watching over someone's shoulder, per say, on more mundane tasks.

NASA continues to review affordability initiatives proposed by our current industry partners, and where possible, we will incorporate those potential savings into SLS development processes.

The MPCV: Where We Are Today

The NASA Authorization Act of 2010 directs NASA to develop an MPCV that continues the advanced development of the human safety features, designs, and systems in the Orion Project. As such, the MPCV must be evolvable and capable of serving as the primary crew vehicle for beyond LEO exploration, and at the same time, it must be capable of providing an alternative means of crew and cargo transportation to the ISS as a backup to commercial crew or partner-supplied vehicles. The Act sets a full operational capability goal of 2016.

NASA's assessments show applicability of the Orion spacecraft design to the MPCV requirements specified in the NASA Authorization Act of 2010, which given the Authorization Act requirements, is why the Orion beyond-LEO version (known internally as "block 2") has been selected as the MPCV Reference Vehicle Design. For example, the MPCV must include basic capabilities and specifications for nominal, contingency and abort scenarios - all of which are traceable to MPCV requirements in the Authorization Act. In addition, the MPCV must also be capable of launching up to four crew members and carrying them to beyond-LEO destinations. It will have the capacity for over 21 days of active mission duration, and it will be capable of beyond-LEO re-entry velocities and return crews safely to a water landing off of the California coast. The Orion vehicle meets these requirements.

The MPCV design will be optimized for beyond-LEO exploration, and while contingency utilization for the ISS is a possibility, doing so would represent a highly inefficient vehicle usage. Additionally, the MPCV will be designed so that its capabilities are evolvable for other mission-specific design variations so as to enable supporting a variety of missions as described in the Authorization Act such as performing EVA, rendezvous and docking, and operating in conjunction with payloads delivered by the SLS or other vehicles in preparation for missions beyond LEO. This approach is critical to enable the commonality across the planned systems necessary to improve overall affordability.

NASA has evaluated the degree to which the existing Orion Project, including designs, facilities, infrastructure, organization, contract, and processes could be transitioned and continued under the MPCV Program. While the current designs have been shown to be a good match with the requirements specified in the NASA Authorization Act of 2010, affordability and sustainability are being re-examined and validated. Preliminary assessments indicate that environments and conditions driven by the Ares I vehicle, which drove the current Orion designs, tend to be more demanding than design-driving parameters of the SLS and therefore these new parameters will most likely not result in changes to Orion. This will, of course, be studied, verified, and tested as the designs for SLS mature. But at this point, NASA is confident that the robust design of the current Orion is such that integration with the SLS will not be a significant challenge. Such factors will have to be taken into consideration as the final SLS design matures. It is important to emphasize that no final decision has been made yet with regard to the current Orion contract.

NASA will endeavor to achieve the earliest possible operational readiness date for the MPCV within the available budget and in a way that leads to affordable operations over the long term. NASA will also strive to ensure that the MPCV design and schedule fits into a sustainable future exploration architecture Final decisions will be informed based upon technical analysis, as well as the combined SLS and MPCV cost and schedule phasing and use of infrastructure and facilities and will be formalized through NASA's required processes in the coming months. Knowing the amount appropriated for SLS and MPCV development efforts in FY 2011 and gaining increased clarity regarding future budget profiles will be an important factor in helping NASA to finalize plans for the SLS and the MPCV.

Once the final plan has been decided, NASA personnel will transition from the Orion Project to the MPCV Program, while also continuing to refine the requirements for the MPCV system. Orion will also transition affordability initiatives that are already underway to include streamlined government insight on high risk areas instead of day-to-day oversight, phased development, re-use of test facilities, and new opportunities for partnerships. Available funding will drive work that can be accomplished in terms of technical content and schedule milestones. Planned FY 2011 work is focused on continuing the design of core vehicle systems and performing planned testing of the Ground Test Article (GTA), which are tasks applicable to the MPCV Reference Vehicle Design. The GTA recently completed primary fabrication at the Michoud Assembly Facility in Louisiana, and is undergoing outfit-

ting and assembly in Colorado. Environmental testing, such as vibration and acoustic testing, is planned to begin in the summer, with drop testing at a new water basin facility at Langley Research Center (LaRC) in Virginia to follow.

An MPCV program schedule, which will be integrated with the SLS's program schedule that will include all major milestones from inception to achieving operational capability, will be developed in coming months and will be provided in the updated report to Congress.

Additionally, the MPCV Program will continue to examine ways to increase efficiency and agility so as to be able to deliver an affordable and achievable crew vehicle as soon as possible. Given that MPCV work is building upon the work performed as part of the Orion Project, numerous innovative affordability initiatives are already underway, including:

- Streamlining government oversight and insight activities to ensure we are focusing on the key-risk items;
- Implementing an incremental approach to building vehicle capabilities; and
- Planning a more innovative and cost-effective vehicle qualification plan, utilizing distributed test labs, for example.

In addition, in partnership with Orion's current contract and its subcontractors, NASA is also exploring other affordability measures including consolidating facilities and re-using test assets.

The Constellation Program and its Relevance to SLS and MPCV

NASA greatly values the contributions and efforts of the Constellation Program team. The Program had many challenges to overcome despite the hard work of the many talented people in the Program. There is much to build upon as we transition from the Constellation Program to the MPCV and SLS Programs.

The current implementation of the Constellation Program was initiated in 2005 with an assumption of increased funding to NASA and an aggressive development approach that would have the goal for Initial Operational Capability[2] (IOC) as early as 2012 to minimize the gap between the Shuttle and the Constellation elements. Fiscal realities -- both internal and external to NASA -- contractual realities and technical maturation and difficulties made this internal goal unrealistic. This resulted in a stretch out of the Program in 2008, leading to a 2015 IOC with an attendant increase in cost. (See attachment 1 and 2).

After an extensive review in 2009, the independent U.S. Human Spaceflight Plans Committee, also known as the Augustine Committee, concluded that the U.S. human spaceflight program in place at that time appeared to be on an unsustainable trajectory, and that it was pursuing goals that did not match allocated resources. One key element of this analysis was a conclusion that there were insufficient funds (based upon the budgetary resources likely to be provided for NASA's human spaceflight activities) to support both the Constellation Program and the likely extension of the ISS beyond 2016 in a suitable manner. Therefore, based in part on the Augustine Committee's report, the President's FY 2011 budget request proposed cancellation of the Program and instead proposed a budget that focused on developing new technologies needed for the long term and fundamental investments to prepare for Exploration in the future.

Throughout 2010, NASA continued work on various Constellations systems as Congress reviewed the President's FY2011 budget request. This work was conducted consistent with relevant appropriations law and was aimed at optimizing those projects considered most applicable to NASA's future activities. Following the passage of the 2010 NASA Authorization Act, NASA was in a position to further tailor its effort on Constellation systems consistent with the direction in the Act.

As of February 2011, NASA had spent $12.7 billion on the Constellation Program, which includes money spent on labor, infrastructure, acquisition, and testing of hardware elements and software systems etc. While some may consider Constellation's investment to date to be wasted and sunk costs, much of what Constellation has accomplished is indeed transferable to the SLS and MPCV programs, not just in terms of hardware, validated requirements and infrastructure elements, but also in terms of less tangible items such as knowledge and experience gained by our team with the Constellation Systems being developed. Therefore, as we work to close out the Constellation Program, we are also taking care to capture and build upon Program accomplishments (see attachment 3), especially those technologies that have a high likelihood of feeding forward into the SLS and MPCV programs.

[2] IOC is defined as the first crewed flight of Orion to the ISS, enabling fight test astronauts to fly the Orion on its maiden voyage.

From the beginning, the Constellation Program used electronic records and a centralized database to capture and manage all data, risks and knowledge learned, including information from test flights, hardware and software tests and programmatic reviews. Therefore, there is a wealth of information that the Program will be able to pass on to future human spaceflight developers, including those at NASA and those in the U.S. aerospace industry, when allowable by law. Since completing the technical portion of the Program-level Preliminary Design Review (PDR)[3] in March 2010[4] and after previously having completed the Project-level PDRs for Ares and Orion in 2008 and 2009 respectively, the Program has been working to finalize its technical library, thus ensuring that historical data from Constellation work is documented, preserved and made accessible to future human spaceflight designers.

The Constellation Program also can be credited with helping to reinvigorate NASA's technical base. Following the development of the Shuttle, NASA's human spaceflight community focused on operations rather than development in that we were no longer a robust developmental Agency in terms of developing crew-launch systems, but rather an operationally-focused human spaceflight Agency. As such, the Constellation Program enabled us to re-learn how to build a crew launch system, beginning from the earliest stages of viewgraphs and trade space and advancing through multiple key project review checkpoints and ultimately to the point where NASA, along with its industry partners, had built hardware and integrated systems that were used on two major test flights, the Ares I-X flight and the Pad Abort 1 (PA-1) flight for the Orion Launch Abort System (LAS) -- both of which resulted in substantial data that will be of great use to the MPCV and the SLS programs.

Additionally, the Constellation Program allowed us to incorporate new technologies and testing methods that will certainly become the norm as we move forward with SLS and MPCV. Historically speaking, during the Apollo era, NASA had comparatively little experience with in-flight aborts and limited computational capability. Today, however, flight tests are being combined with advanced simulation tools and advanced computers, thereby allowing NASA to conduct a more thorough analysis of hardware and software elements and operating processes. The Orion integrated abort system's effectiveness can now be calculated using computer models of the blast environment by employing more realistic, physics-based, simulations of abort conditions with remarkable speed and accuracy, given NASA's evolved engineering expertise and the computation power of modern computers. In comparison, during the Apollo era, abort effectiveness was estimated by comparison to escapes from high-performance military aircraft combined with the results of a few escape system tests.

In fact, our computer modeling scenarios are so accurate, that we had been able to forgo more expensive ground tests in some cases, and we expect to see this trend continue with the SLS and MPCV programs, whenever possible without sacrificing safety. For example, designing the Ares I allowed NASA to make an important technology leap in the design process. By transitioning from a 2-D, paper-based vehicle design and verification process to a 3-D model-based design environment, NASA was able to gain valuable experience with state-of-the-art design system that can reduce costs while also increasing system reliability - benefits that will feed forward into the SLS.

Other examples of work / accomplishments that will feed forward include:

- On May 6th 2010, Orion conducted the PA-1 flight test at White Sands Missile Range in New Mexico. This test flight demonstrated a development version of the Orion LAS by simulating an abort during an emergency occurring before the launch vehicle has left the pad. The test demonstrated all three of the LAS' solid rocket motors (Abort Motor, Attitude Control Motor, and Jettison Motor) working in conjunction. It also demonstrated an early version of the parachute and forward bay cover deployment design. Data gathered from PA-1 proved the overall design concept and LAS architecture

[3] PDR is a crucial milestone during a program's or project's development cycle in t hat it is the first major review of the detailed design and is normally held prior to the preparation of formal design drawings. During PDR, the program verifies that the preliminary design meets all requirements within acceptable risk limits and within the cost and schedule constraints. The completion of the PDR and the closure of any actions generated by the review become the basis for the start of the detailed drafting and design effort and the purchase of parts, materials, and equipment needed.

[4] The Constellation Program did not complete the cost portion of its Systems-level PDR, NASA never established a formal baseline cost for each Constellation Project and the Program as a whole

are feasible, and the data gathered will also improve computer design and analysis models and tools and reduce risks and uncertainty in the MPCV's production design - or that of commercial crew partners, should they choose to use this technology.

- The Orion GTA: NASA validated advanced-production processes, equipment and tools such as friction-stir welding) to manufacture this structural and thermal prototype of the Orion crew module. The GTA is now in final assembly at the Lockheed Martin facility in Denver, and will undergo a series of ground-based environmental tests to validate the Orion design and computer models. It will undergo structural load testing later this spring; vibration and acoustic testing during the summer; and drop testing at LaRC this fall. Given that the MPCV will be based on the Orion crew module, data collected from testing the GTA will be incorporated into MPCV development efforts so as to result in a safe, reliable and affordable human-rated crew capsule.
- On Oct 28, 2009, NASA successfully completed the Ares I-X test flight at KSC. Data from more than 700 on-board sensors showed that the vehicle was effectively controlled and stable in flight and that the vehicle had met all of its test objectives. Moving forward, this test flight is important in that it validated the accuracy of NASA's design tools, models and processes for inline crew launch vehicle configurations, allowing significant economies in integration and testing to be assumed for SLS development. For example, the test flight provided tremendous insight into the aerodynamic, acoustic, structural, vibration, and thermal forces that Ares I or other inline launch vehicles would be expected to experience. In particular, aero-acoustic forces were measured at key locations along the stack, which has highlighted differences between the predicted loads and the actual loads for the Ares I. Therefore, the adjustments to computer models made possible by this Ares I-X data may significantly reduce uncertainty and risk in future launch vehicle designs.
- In 2009 and 2010, two successful ground tests of the Ares I First Stage were conducted. In each test, a five-segment solid rocket motor was tested at a contractor facility in Utah, thereby demonstrating two temperature cases (normal and cold) for motor operation. During the full-duration ground test, also called a "cold motor" test, the motor's overall temperature was lowered to validate the motor's performance in cold weather and data was gathered to evaluate thrust, roll control, acoustics, motor vibrations, nozzle modifications and insulation upgrades. These tests validated performance of advanced designs and materials in upgrading solid rocket motor technology and eliminating obsolescence. Beyond validating the basic performance characteristics of the engine, the test resulted in enhanced modeling and a better understanding of key attributes that have historically been very difficult to predict analytically such as erosive burning, thrust oscillations and thrust tail off. As such, data from this test will help advance the safety, technology and knowledge of solid rocket motors in general - work that will likely be applicable to the SLS or other human spaceflight systems.

It is also important to note that there are Constellation technologies that are transferable to the U.S. aerospace industry. For example, one of our commercial cargo partners, Space Exploration Technologies (SpaceX), has already incorporated the Orion's Thermal Protection System and its parachute development technologies into the company's Dragon capsule, which was successfully launched last year.

Going forward, SLS and MPCV will continue to focus on a risk-informed design approach, as Constellation has done, thus helping the Agency achieve its goal of increasing astronaut safety on the next-generation human spaceflight system, relative to Shuttle missions. As such, NASA will continue to design systems with an overriding priority given to crew safety at every stage of the design and operational process. In doing so, we will design systems to be as inherently safe as we can make them; we will eliminate known risks and hazards; and then we will add backup such as an abort system to mitigate residual risks. In addition to leveraging heritage systems, when feasible, NASA will continue to utilize improved computer modeling to help identify, reduce and eliminate or mitigate hazards and risk. Additionally, we will continue to tightly interweave design and safety team members into the decision-making process, thereby allowing them to work with design engineers to provide expertise and feedback via various assessments and analysis techniques from the very beginning of the design process. At the same time, a prudent risk system will result in better cost/benefit assessments to improve overall affordability without sacrificing safety. Finally, NASA will continue to utilize its active risk-management process to identify technical challenges early in the process and aggressively work solutions.

Consistent with the provisions of the FY 2010 Consolidated Appropriations Act (P.L, 111-117), NASA is continuing to implement the Constellation Program and associated projects while we also work on the SLS and MPCV programs in parallel. Therefore, we have not terminated any Constellation contracts. However, NASA does have the legal flexibility to prioritize Constellation funding, and as such, we have deliberately prioritized Constellation funds to maximize their use in support of transition to SLS and MPCV in the NASA Authorization Act, thus maximizing the effective use of taxpayer dollars. For example:

- Ares has worked closely with SLS planning team to focus our development efforts on technologies and processes that could be utilized in the eventual SLS configuration. This includes vehicle avionics, J-2X Engine testing, First Stage Engine testing (Development Motor-3), and installation of Upper Stage tooling applicable to large diameter tanks. At the same time, we deferred activities that were highly vehicle configuration dependent including a ground vibration test article and design of Upper Stage component hardware such as the reaction control system.
- Orion has focused our development efforts on crew safety, targeting an orbital test flight mid-decade to validate 10 of the top 13 analyzed crew safety risks in the real flight environment -- risks primarily in the regimes of entry, descent, and landing. At the same time, we deferred efforts in areas posing relatively small risk to crew safety such as life support, communications, crew support systems and the LAS. NASA has deferred further work on the LAS for the near-term since it is ahead of other Orion systems in its design and testing.
- EVA has coordinated with Orion to focus our development efforts on suit architecture trades in light of the new beyond-LEO mission timetable, and including modified Advanced Crew Escape System (Shuttle launch and entry suit) in launch and entry suit trade study. At the same time, we have deferred efforts on beyond-LEO suit design and commonality with the launch and entry suit.
- Ground Operations has coordinated with the SLS team and focused our Ground Operations work on items that would mostly likely be needed by heavy-lift launches - works such as launch pad construction, launch control center construction and crawler overhauls (the crawler is the vehicle that transports a launch vehicle stack from an integration building to the launch site.) At the same time, we deferred Vehicle Assembly Building modifications at KSC until we know the dimensions of our new heavy-lift vehicle.
- Mission Operations has coordinated with Orion to focus our efforts on activities required for general human spaceflight mission support, with efforts concentrated on Mission Control Center and Training Systems. At the same time, we have deferred efforts on highly configuration dependent activities such as a high-fidelity Orion mockup or docking adapter trainer.

It is important to note that even though NASA currently has the legal flexibility to prioritize funding, NASA would prefer for Congress to remove the funding restrictions imposed by the FY 2010 appropriation. Doing so would allow the Agency to terminate unnecessary Constellation work that is not required for the new SLS and MPCV. As such, NASA agrees with the NASA Inspector General, who in a Feb. 2, 2011 report to Congress, stated: ". as NASA moves closer to making final decisions regarding how best to move forward in designing and building the next generation space system, it will become increasingly more difficult for the Agency to continue to juggle the inconsistent mandates of the Authorization Act and the appropriations legislation so as to avoid wasting taxpayer funds." Therefore, it is important to be able to move out with new programs in pace and the flexibility to plan and fund work in the most effective way.

The Commercial Orbital Transportation Services (COTS) Projects

Both of NASA's funded COTS partners -- SpaceX and Orbital Sciences Corporation -- continue to make progress in developing their cargo transportation systems, based in part on NASA's financial and technical assistance. NASA sees no reason to doubt either company's ability to achieve its desired objectives - that of demonstrating commercial cargo delivery to and from LEO. While each has experienced milestone delays, this is not unexpected, since both partners have aggressive, success-oriented schedules, and are facing challenges typical of a space flight development program. (See attachment 4.) These delays have not required any additional NASA funding of specific milestones, since the partners are paid only fixed amounts

for achieving milestones. Additional development costs have been borne by the companies and/or other investors. NASA has added augmentation funding of $300M for additional milestones for additional risk reduction such as additional testing, as authorized by the NASA Authorization Act of 2010.

To date, NASA has invested $529 million in the COTS effort, which includes funding invested toward the two current funded partners, as well as funding that was invested toward another partner that was terminated for failure to perform in 2007. By the conclusion of the COTS effort, NASA anticipates it will have invested $800 million in the COTS program, which does not include reimbursable work NASA has performed and infrastructure support that NASA has provided to the COTS partners. The $800 million includes the original $500 million authorized for COTS milestone payments in the NASA Authorization Act of 2005, as well as $300 million in augmented milestone payments authorized by the NASA Authorization Act of 2010 to help accelerate technical development, conduct flight tests and develop ground infrastructure.

In total, NASA anticipates providing SpaceX and Orbital $128M each in augmented funding via modifications to their respective funded COTS Space Act Agreements (SAAs) and via the Commercial Resupply Services contract during FY 2011. To date, NASA has executed two SAA amendments (known as Quarter 1 and Quarter 2 augmentations) for each company with respect to the augmentation milestones authorized by the NASA Authorization Act of 2010. Payments for the Q1 and Q2 augmentations were made using Exploration funds under the FY 2011 continuing resolution. The remaining augmentations for Q3 and Q4 are in negotiation with the companies and are contingent on available funding at the time the agreements are finalized, which NASA hopes to be in the near future. As with any SAA milestone, NASA will not pay for a milestone until the work has been completed successfully.

SpaceX signed its SAA with NASA in August 2006. Since then:

- To date, NASA has paid SpaceX $258 million out of the original SAA amount of $278 million, and $20 million for meeting its Q1 augmentation milestones. To date, SpaceX has completed 22 of 29 negotiated milestones.
- On December 8, 2010, SpaceX successfully completed the first COTS demonstration flight, thereby demonstrating launch of the Falcon 9 booster, separation of the Dragon spacecraft and completion of two orbits, orbital maneuvering and control, reentry, parachute decent and spacecraft recovery after splashdown in the Pacific Ocean.
- SpaceX's remaining demonstration flights for NASA are scheduled for July 2011 and January 2012. NASA is reviewing a SpaceX proposal to accelerate the third demonstration flight test objectives, which include berthing to the ISS, during the second demonstration flight. If accepted, the combined mission could be flown as early as November 2011.
- The augmentation milestones improve the chance of mission success by adding ground and flight testing, accelerating development of enhanced cargo capabilities, or further developing the ground infrastructure needed for commercial for commercial cargo capabilities. More specifically, the additional SpaceX milestones include rendezvous and proximity operations sensor testing, system level thermal vacuum and electromagnetic interference testing, and infrastructure improvements at the launch, production and test sites.

Orbital signed its SAA with NASA in February 2008. Since then:

- NASA has paid Orbital $157.5 million out of the original SAA amount of $170 million, and $40 million for meeting its Q1 and Q2 augmentation milestones. To date, Orbital has completed 18 of 22 negotiated milestones.
- Recently, Orbital began integration and testing of its Cygnus Service Module and Taurus II launch vehicle.
- Orbital is expected to complete its demonstration flight for NASA in December 2011.
- The Orbital augmentation milestones will lead to an additional test flight of the Taurus II which significantly reduces the risks associated with a new launch vehicle development thereby separating risks associated with the development of a new spacecraft. The milestones also enable additional software and control system testing.

Conclusion

Americans and people worldwide have turned to NASA for inspiration throughout our history - our work gives people an opportunity to imagine what is barely pos-

sible, and we at NASA get to turn those dreams into real achievements for all humankind.

With the passage of the NASA Authorization Act of 2010, NASA has a clear direction and is making plans for moving the Agency forward. Today, we have a roadmap to even more historic achievements that will spur innovation, employ Americans in fulfilling jobs, and engage people around the world as we enter an exciting new era in space. NASA appreciates the significant effort that has gone into advancing this bipartisan legislation.

In conclusion, let me assure you that NASA is committed to meeting the goals and requirements of the NASA Authorization Act of 2010. As such, we are committed to developing an affordable, sustainable, and realistic next-generation human spaceflight system that will enable human exploration, scientific discovery, broad commercial benefits, and inspirational missions that are in the best interests of the Nation. We look forward to working with you and other Members of Congress as we finalize our strategy for achieving human spaceflight to many destinations in our solar system.

Chairman Palazzo and Members of this Subcommittee, I would like to conclude my remarks by thanking you again for your continued support for NASA and its human spaceflight programs. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

BIOGRAPHY OF DOUGLAS R. COOKE, ASSOCIATE ADMINISTRATOR FOR EXPLORATION SYSTEMS MISSION DIRECTORATE

Doug Cooke is Associate Administrator for the Office of Exploration Systems Mission Directorate. The Exploration Systems Mission Directorate is responsible for managing the development of flight hardware systems for future human exploration beyond low Earth orbit, including the moon, near Earth asteroids, Mars and its moons and other destinations. This includes development of critical technologies, new capabilities, and human research to support future human spacecraft and exploration missions. It also includes partnering with industry to develop commercial capabilities for cargo and crew transportation to and from low Earth orbit.

Mr. Cooke has over 37 years of unique experience in the Space Shuttle, Space Station, and Exploration Programs. He has been assigned significant responsibilities during critical periods of each of these, including top management positions in all three programs.

Mr. Cooke's first major challenge began in 1975 when he was tasked with defining and implementing an entry aerodynamic flight test program for the Space Shuttle. This program was successfully implemented during the Approach and Landing Tests in 1977, and early orbital flights of the Space Shuttle beginning in 1981 through 1984.

Mr. Cooke was asked to lead the Analysis Office when the Space Station Program Office was first organized in 1984. He accepted the challenge and led the work that defined the Space Station configuration and many of its design details and technical attributes.

Following the Space Shuttle Challenger accident, Mr. Cooke was assigned to the Space Shuttle Program Office. He helped lead a Civil Service and contractor team to provide the system engineering and integration function that resulted in the return of the Space Shuttle to flight on September 29, 1988. He reached the position of Deputy Manager of the NSTS Engineering Integration Office.

Mr. Cooke has played a pivotal role in planning for future space exploration beginning in 1989. He helped to lead a NASA team that produced the "90 Day Study" on lunar and Mars exploration. Mr. Cooke was subsequently assigned to the Synthesis Group led by Lt. General Tom Stafford, Gemini and Apollo Astronaut. The team produced a report for the White House entitled "America at the Threshold: America's Space Exploration Initiative." Mr. Cooke was selected to be the Manager of the Exploration Programs Office under then Exploration Associate Administrator Michael Griffin, where he initiated and led NASA agency-wide studies for the human return to the Moon, and exploration of Mars.

In March of 1993, the agency undertook the redesign of Space Station Freedom. Mr. Cooke was assigned the responsibility of leading the engineering and technical aspects of the redesign. He was subsequently chosen to serve in the Space Station Program Office as Vehicle Manager, leading and managing the hardware development and systems engineering and integration for the International Space Station. From April to December of 1996, Mr. Cooke served as Deputy Manager of the Space Station Program.

Prior to his current appointment to NASA Headquarters, Mr. Cooke served as manager for the Advanced Development Office at the Johnson Space Center, Houston. Mr. Cooke provided leadership for the planning of human missions beyond Earth orbit; including the Moon, Mars, libration points, and asteroids. This team developed integrated human and robotic mission objectives, defined investment strategies for exploration technologies, and managed NASA exploration mission architecture analyses.

Mr. Cooke was detailed to NASA headquarters during portions of this period to contribute to headquarters level strategies for human exploration.

Mr. Cooke served as NASA technical advisor to the Columbia Accident Investigation Board from the time of the accident to the publishing of the report.

Prior to his current assignment Mr. Cooke served as Deputy Associate Administrator for the Exploration Systems Mission Directorate. He has made significant contributions to the structuring of its programs, defining the program content, and providing technical leadership. He initiated and led the development of the Global Exploration Strategy activity that led to defined themes and objectives for lunar exploration. International, science, industry, and entrepreneurial communities were engaged, and they contributed to the development and shaping of these themes and objectives. He led and guided the development of the planned lunar exploration mission approach and architecture. Mr. Cooke has also led the efforts to define long term NASA field center assignments for hardware development and operational responsibilities. He has been the Source Selection Authority for the major exploration

contract competitions. In this role he has successfully selected the companies who are currently on contract.

Mr. Cooke is a graduate of Texas A&M University with a Bachelor of Science degree in Aerospace Engineering.

Major Awards: SES Presidential Distinguished Rank Award- 2006, SES Presidential Meritorious Rank Award- 1998, NASA Exceptional Achievement Medal- 2003, NASA Exceptional Achievement Medal- 2002, NASA Outstanding Leadership Medal- 1997, NASA Exceptional Achievement Medal- 1993, NASA Exceptional Service Medal- 1988, JSC Certificate of Commendation- 1986, JSC Certificate of Commendation- 1983.

Chairman PALAZZO. Thank you, Mr. Cooke.

I now recognize our second witness, Dr. Scott Pace, Director of the Space Policy Institute at George Washington University.

STATEMENT OF SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Dr. PACE. Thank you, Mr. Chairman, and thank you for providing an opportunity to discuss this topic.

The transition away from the space shuttle to a new generation of vehicles is perhaps the most critical task facing the U.S. space program today. In this regard, I think it is appropriate and timely the Committee examine the accomplishments of the Constellation program and the prospects for the Space Launch System and Multi-Purpose Crew Vehicle.

The Committee posed a series of four questions that I will try to briefly answer in turn. The first one is the requirement to use the existing Constellation contracts was, in my opinion, an effective and prudent measure. Continuation of the contracts enabled time for industry, Congress and, I believe, NASA to think more carefully about next steps. This enabled continued development of the Orion Crew Exploration Vehicle to include a successful pad abort demonstration and completion of a ground test article. It enabled completion of the five-segment Ares solid rocket motor including static test firings, continued structures technology testing with a successful shell-buckling test that was recently in the news, and continued development assembly of the J2–X upper stage engine and the A–3 test stand, the only new cryogenic engine development in the United States today.

NASA's efforts, however, to transition from the Constellation program designs to the SLS can be seen as incomplete and possibly inadequate, and in particular don't appear to make progress toward one of the CAIB's—Columbia Accident Investigation Board—central recommendations on dramatically improving crew safety. The CAIB observed that the design of the system for next-generation human launch should give overriding priority to crew safety rather than trade safety against other performance criteria such as low cost and reusability or against advance space operations capabilities other than crew transfer.

To these ends, the Constellation Ares I set a goal of for probability of loss of crew in excess of one in a thousand, with design estimates over one in 2,800. In comparison, the space shuttle's probability of loss of crew has been estimated at less than one in 150. No other vehicles including the Ares V design and existing EELV designs are expected to reach the one in 1,000 standard. This is not to say they cannot do so in the future but only after

accumulating flight heritage comparable to the shuttle solid rocket motors or the Russian Soyuz.

Now, the Committee also asked about the greatest risks arising from this transition. Well, the greatest risks, in my view, are those arising from policy instability and the lack of a basis for predictable decision-making by NASA and industry. There was a decline of human-rated launch vehicle and spacecraft development experience, while shuttle operations continued and various R&D programs came and went. We atrophied for some decades. The rebuilding of expertise that was occurring under the Constellation program, notably with the Ares I–X flight test, that progress has not been followed up on. Again, progress has been made in the last year but it has not been exploited to the degree it should have been.

NASA's plans prior to the Ares I–X testing of the Ares I and Orion spacecraft could be, I think, fairly characterized as largely a ground test program that would have avoided committing the actual flight until a predominant amount of risk had been retired. The experiences of the Ares I–X and of the pad abort I think helped teach NASA industry teams how to finish a product and fly it to really their great benefit. The experience base could have led to a more prominent role for incremental flight testing and a means of risk reduction if funding had continued.

With the kind of programmatic and budgetary redirection that NASA has received in recent years, it is hard to expect a positive outcome for workforce productivity and the health of the space industrial space. The cumulative reductions in future support for human space exploration have been dramatic over the last several years.

The Committee asked what are some key indicators that could help Congress judge the success of transition programs. Well, the most important consideration is always people, both inside NASA and in industry. Government and industry cannot have coherent workforce transition plans if they cannot define what skill mixes they need today or in the future. Skill mixes cannot be defined absent a clear understanding of government roles and responsibilities, what work is to be done in-house and what will be contracted out, and a stable set of mission requirements is a part of a large exploration and architecture strategy. Congress should be looking for updated workforce transition plans with reports on the identification of key skills and how they will be retained. Congress should look to ensure that NASA and industry are creating and strengthening their internal intellectual capital for developing new human spaceflight capabilities, and this can be most directly observed if there is frequent and increasingly ambitious tests and flights of actual hardware.

Finally, Congress should be asking for progress on the definition of an internationally recognized and accepted human space exploration architecture that supports U.S. national space policy goals and principles because the stability and predictability we need is not just with industry but also with our industry and international partners who are trying to make decisions also in this very difficult environment.

The transition away from the space shuttle and towards new human spaceflight capabilities while ensuring independent U.S. access to the International Space Station is, I stress, the most immediate and critical task for human spaceflight. In this regard, the upcoming flight of STS–135, I believe is absolutely crucial but we also need to look beyond that and say what is going to be coming next.

Major policy questions remain unanswered that I think complicate the transition efforts and perhaps foremost among them is whether or not there is a need for independent U.S. government access to space, and if not, the identification of those entities upon which we are willing to depend for such access. In my view, the U.S. government should have its own means of assuring access to space even as it makes increasing use of commercial services or international partners. One of my analogies is, just as a diversified portfolio needs bonds as well as stocks, a public option is an important, crucial part of a diversified portfolio for strategic national capability like human spaceflight. It is the existence of the Constellation program that enabled a prudent risk-taking in commercial cargo services and contemplation of eventual procurement of commercial crew services.

The technical complexities and risks of human spaceflight make it an activity distinct from buying normal commercial goods and services. A policy that pretends or assumes that it is not distinct is unlikely to succeed, just as unrealistic flight rates planned for the shuttle in 1970s or large commercial markets planned for EELVs in the 1990s did not succeed. Merely because something is attractive doesn't mean it will be true.

The government has several proper roles to play in the next generation of human space exploration, and those roles can and should evolve over time. It is time, in my view, to push carefully for greater reliance on commercial cargo services to the International Space Station. It will then subsequently be possible to define a path for commercial crew services that operate in addition to but not to the exclusion of U.S. government capabilities. To fully rely on commercial or government approaches to the exclusion of the other would place, in my view, all human spaceflight by the United States at risk, both public and private.

And with that, thank you very much for your kind attention and I would be happy to answer any questions you might have.

[The prepared statement of Mr. Pace follows:]

PREPARED STATEMENT OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Thank you, Mr. Chairman, for providing an opportunity to discuss this important topic. The transition away from the Space Shuttle to a new generation of vehicles for human access to space is perhaps the most critical task facing the U.S. space program today. In this regard, it is appropriate and timely that the Committee examines the accomplishments of the Constellation program and prospects for a Space Launch System and Multi-Purpose Crew Vehicle as contained in the most recent 2010 NASA Authorization Act.

Specifically, the Committee has posed four questions that I will address in turn:

1. Has the use of existing Constellation contracts to prioritize the work on the Space Launch System been an efficient and effective approach?

The FY 2010 Emergency Supplemental Appropriations bill contained a provision cosponsored by Senator Richard Shelby (R-AL) and Robert Bennett (R-UT) that said:

> "Provided further, that notwithstanding any other provision of law or regulation, funds made available for Constellation in Fiscal Year 2010 for 'National Aeronautics and Space Administration Exploration' and from previous appropriations for 'National Aeronautics and Space Administration Exploration' shall be available to fund continued performance of Constellation contracts, and performance of such Constellation contracts may not be terminated for convenience by the National Aeronautics and Space Administration in Fiscal Year 2010."

Approval of this provision was, in my view, an understandable response to the many uncertainties faced by the Congress last year. Two previous NASA Authorizations, in 2005 and 2008 had approved clear efforts to transition the Space Shuttle, extend operations of the International Space Station, and explore beyond Earth orbit. As part of the Fiscal Years 2007, 2008, and 2009 NASA budgets, the Constellation program became a consistent and well-understood approach for implementing exploration objectives. The Obama Administration had sought to cancel the Constellation program and terminate existing contracts with the Fiscal Year 2011 NASA budget. However, this dramatic change of course was not accompanied by a clear explanation of what would replace Constellation. In particular, there were no concrete explanations of how the transition away from the Space Shuttle would be implemented, support for the International Space Station assured, or human explorations beyond Earth orbit conducted.

In light of this situation, the requirement to use existing Constellation contracts was an effective and prudent measure. It is difficult to say that such a requirement was efficient as it would almost certainly have been preferable if the Administration and Congress could have found a common approach on human space exploration before the release of the FY 2011 President's Budget Request. It is the prerogative of any Administration to review and reorder priorities for NASA, and it is possible to imagine a dialogue with Congress that would have resulted in a reordering of the Constellation program (e.g., placing greater emphasis on demonstrating new technologies). However, the disruption that would have resulted from the wholesale cancellation of the Constellation contracts would have been harmful to the U.S. space industrial base. The existing contractors would have certainly been harmed and other potential contractors would not have benefited if for no other reason than the time it would have taken to define, compete, and award new contracts. The lack of a clear alternative to the Constellation program meant that contract cancellation at that time would largely have resulted in a waste of public funds.

Continuation of the Constellation contracts enabled time for industry, Congress, and I suspect NASA, to think more carefully about next steps. This enabled continued development of the Orion Crew Exploration vehicle to include a successful pad abort demonstration and completion of the ground test article. It enabled completion of the five-segment Ares solid rocket booster, including static test firings, continued structures technology testing with a successful shell-buckling test, and continued development assembly of the J2-X upper stage engine and A-3 test stand - the only new cryogenic engine development for the United States.

2. How do NASA's recent efforts to transition from the Constellation program to the Space Launch System and Multi Purpose Crew Vehicle align with the recommendations of the Columbia Accident Investigation Board?

One of the most important observations from the Columbia Accident Investigation Board (CAIB) for steps to take after the Space Shuttle was the following:

> "It is the view of the Board that the previous attempts to develop a replacement vehicle for the aging Shuttle represent a failure of national leadership. The cause of the failure was continuing to expect major technological advances in that vehicle. With the amount of risk inherent in the Space Shuttle, the first step should be to reach an agreement that the overriding mission of the replacement system is to move humans safely and reliably into and out of Earth orbit."

Furthermore, the CAIB offered the admonition that:

> "The design of the system should give overriding priority to crew safety, rather than trade safety against other performance criteria, such as low cost and reusability, or against advanced space operation capabilities other than crew transfer."

To these ends, the Constellation Ares 1 set a goal for probability of loss of crew (PLoC) in excess of 1:1000 with design estimates for reaching over 1:2800. In comparison the Space Shuttle's PLoC has been estimated at less than 1:150. No other vehicles, including the Ares V design and existing Evolved Expendable Launch Ve-

hicles (EELVs), are expected to exceed the 1:1000 standard. This is not to say they cannot do so in the future, but only after accumulating flight heritage comparable to the Shuttle solid rocket motors or the Russian Soyuz.

With regard to the CAIB's recommendations, NASA effort to transition from Constellation program designs to the Space Launch System can be seen as incomplete and arguably inadequate. They do not appear to make progress toward the CAIB's central recommendation on dramatically improving crew safety. The transition of Orion to a Multi-Purpose Crew Vehicle looks to be in better shape, in particular with progress on a Launch Abort System, but it is the fully integrated combination of launch vehicle, crew vehicle, and escape system that must be considered.

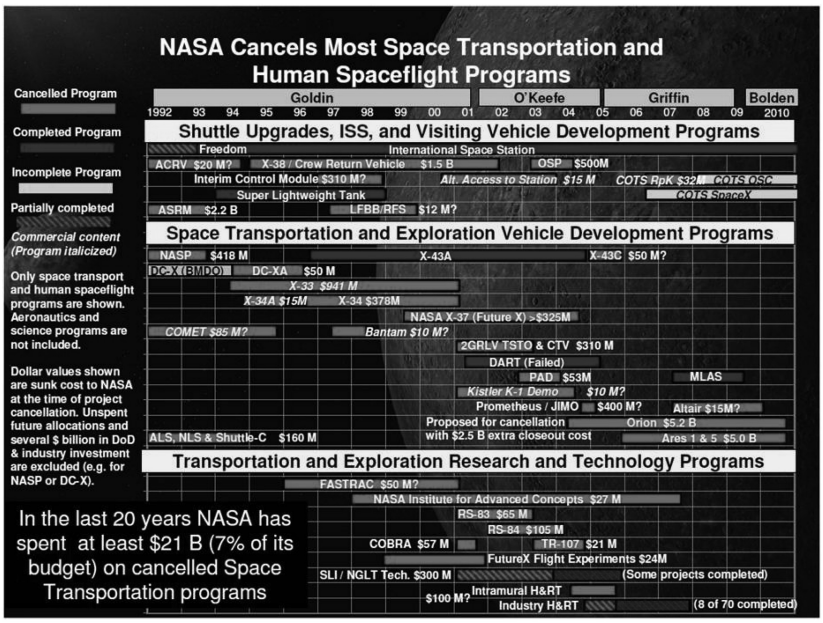
The CAIB also commented on the need for stability of purpose in the development of new launch vehicles:

> "NASA plans to make continuing investments in "next generation launch technology," with the hope that those investments will enable a decision by the end of this decade on what that next generation launch vehicle should be. This is a worthy goal, and should be pursued. The Board notes that this approach can only be successful: if it is sustained over the decade; if by the time a decision to develop a new vehicle is made there is a clearer idea of how the new space transportation system fits into the nation's overall plans for space; and if the U.S. government is willing at the time a development decision is made to commit the substantial resources required to implement it."

As discussed in response to the following questions below, none of the conditions cited by the CAIB appear to be met by current proposals before the Congress.

3. What are the greatest risks to the aerospace industrial base and workforce associated with the transition from Constellation to the Space Launch System program?

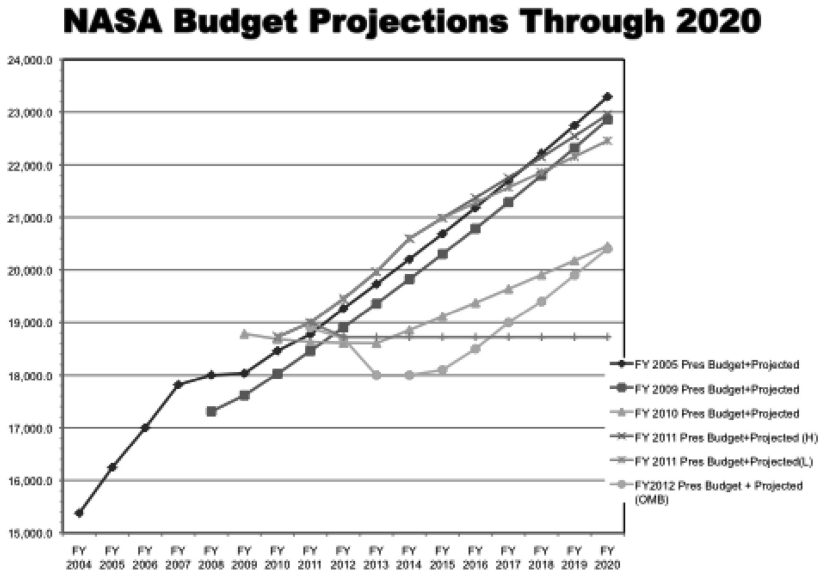
The greatest risks are those arising from policy instability and the lack of a basis for predictable decision-making by NASA and industry. Such instability has very real costs as the chart below indicates:



The history of U.S. human spaceflight over the past two decades is one of continual turbulence with occasional episodes of progress. There are many sources of policy instability - some internal to NASA, some embedded in the relationship between successive Administrations and Congresses. The net result has been a lack of human-rated launch vehicle and spacecraft development experience while Shuttle operations continued and various R&D programs came and went. Unlike the scientific community at NASA, there was not a steady progression of spacecraft development programs in which both NASA and industry could gain and maintain expertise. The rebuilding of expertise was occurring on the Constellation program, notably with the Ares 1-X flight test, but that progress has not been followed up on.

NASA's plans prior to Ares I-X for testing of the Ares I rocket and Orion spacecraft could be characterized as largely ground test programs that would have avoided committing to actual flight until a predominant amount of risk had been retired. The experiences from Ares I-X and Pad Abort I helped teach the NASA-industry teams how to 'finish' a product and fly it - an experience base that would have led to a more prominent role for incremental flight testing as a means of risk reduction if funding had continued.

Through its budget proposals, the current Administration has contributed to policy instability for NASA as a whole, not just in human space flight. The chart below shows proposed and projected top-line NASA budgets back to FY 2005 when the Vision for Space Exploration was proposed and through 2020 when the first human return to the Moon was planned.

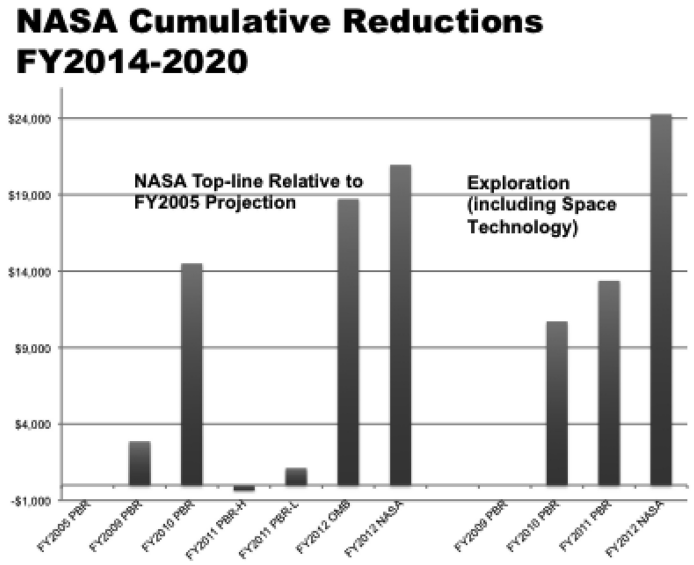


The FY 2005 NASA budget projection was expected to remain flat in terms of purchasing power and thus it t increased at only 2.4% in the out years. The FY Y 2009 NASA budget shows that NASA received slightly less funding that it had planned for in FY 2005 and this resulted in the schedule slip of Ares 1/Orion first flight to 2 2014 or possibly later. The first Obama Administration budget for FY 2010 projected a large reduction, due to placing $3 billion in exploration funding "on hold" while reviews of NASA's human spaceflight p programs occurred. In addition to those funds directly affected, the projection of out year spending was reduced to 1.36%. If inflation levels experienced by NASA were more than that, the agency would experience a d decline in real purchasing power.

In the FY 2011 proposal for NNASA, the Administration added funds back such that the NASA top line returned to where it would have been in continuing the spend ding levels of the Bush Administration. However, the composition of spending had changed significantly, with exploration spending dropping and science and technology-related spending increasing sharply. In FY 2012, the pendulum continues to swing w with NASA expecting at best a flat budge et in nominal terms (and thus a reduction in real terms) while OMB seems to envision even sharper reductions in the near term with possible restoration of some funds in the out years.

With the kinds of programmatic and budget redirection that NASA has received in recent years, it is hard to expect a positive outcome for workforce productivity or the health of the space industrial base.

The chart below show the cumulative reductions experienced in the overall NNASA budget and the exploration budget respectively for the years FY 2014-2020. This was the time period that had been targeted d for conducting the first human missions beyond d low Earth orbit since Apollo. Even if all of the Administration's space technology fund ding is counted toward "exploration," the cumulative reductions in future support for human space exploration remain dramatic.



4. Can you suggest some key indicators that would help Congress judge the success of NASA's transition efforts?

There are many ways to monitor transition efforts, from workforce plans, to completion of hardware milestones. However, the most important consideration has always been people, both inside NASA and in industry. Government and industry cannot t have coherent workforce transition n plans if they cannot define what skill mixes they need today or in the future. Skill m mixes cannot be defined absent a clear understanding of government roles and responsibilities (e.g., what work is to be done in-house e and what will be contracted out) and a stable set of mission requirements that are part of a larger architecture and exploration strategy.

The lack of a U.S. focus on h human lunar return and an associated architecture is one of the most serious programmatic gaps that make transition planning difficult. Efforts to find a feasible and attractive mission to a Near Earth Object (NEO) have not been successful and likely await the completion of a more complete survey of such objects. Sending humans to Mars remains too technically difficult and expensive at our current level of development. The Moon was and continues to be the logical focus for efforts to move humans beyond low Earth Orbit as well as being vital to future commercial developments. For example, the logistics requirements of a sustained lunar base offer perhaps the only near term source of significant new demand for cargo mass to low Earth orbit (LEO). Commercial service to the International Space Station (ISS) is an important first step, but ISS supply needs are limited and unlikely to attract major new investment by itself. If the Administration is truly supportive of stimulating commercial space transportation beyond LEO then it needs to consider where future demand might come from. It's not a question of choosing between government and commercial approaches, but of government first and then commercial in a well-considered transition.

This does not mean that the Constellation approach to the Moon is the only one possible - one can envision precursor missions to Lagrangian points in the Earth-Moon system and tele-presence experiments prior to a human landing. In a similar vein, one can imagine missions to NEOs as part of precursor efforts to send human to orbit Mars. The crucial point is that individual missions should not be one-time highly dangerous stunts, but should be careful steps in the continual expansion of human deep-space capabilities that can address important human exploration questions. The international space community has developed a lunar architecture as part of a large Global Exploration Strategy with strong U.S. technical participation. We should consider making greater use of international partners through existing international mechanisms to create a more rational approach for our own plans.

The Congress should be looking for updated workforce transition plans, with reports on the identification of key skills and how they will be retained. Next, the Congress should look to ensure that NASA and industry are creating and strengthening their internal "intellectual capital" for developing new human spaceflight capabilities. This can be most directly observed in through frequent and increasingly ambitious tests and flights of actual hardware. Finally, the Congress should be asking for progress on the definition of an internationally accepted human space exploration architecture that supports U.S. national space policy goals and principles.

Summary

The design, development, and operation of major space systems reflect the strategic engineering capacity of the United States. This capacity is being tested today by the technical and managerial challenges of developing new human-rated space systems. The transition away from the Space Shuttle and towards new human space flight capabilities, while assuring independent U.S. access to the International Space Station, is the most immediate and critical task for U.S. human spaceflight.

Planning for and successfully executing this transition has been made significantly more challenging by the policy, programmatic, and budget instability of the past two years. As a result, the United States does not have at present a plausible architecture and strategy for conducting human missions beyond LEO for the next two decades. In addition, a plausible architecture and approach for international cooperation in human space flight beyond the International Space Station no longer exists. This has been a particular problem for many countries that had started development of lunar robotic and human space flight plans based on the Constellation program structure.

Major policy questions remain unanswered that complicate transition efforts. Perhaps foremost among them is whether or not there is a need for *independent U.S. government human access to space*, and if not, the identification of those entities upon which we are willing to depend for such access. In my view, the U.S. government should have its own means for ensuring human access to space even as it

makes increasing use of commercial services or international partners. Just as a diversified portfolio needs bonds as well as stocks, a "public option" is an important and crucial part of a diversified portfolio for a strategic national capability like human space flight. Complete reliance on commercial or international services is an excessively risky approach that can deter innovation in those areas as they become "too important to be left alone." It was the existence of Constellation that enabled prudent risk taking in commercial cargo services and contemplation of eventual procurement of commercial crew services.

A corollary question is: what is the proper role of NASA for the human expansion into space, given NASA's disparate functions as "innovator and technology developer" vs. "designer/developer/smart buyer" of new systems, and "system operator" vs. "service customer"? The Administration's proposals for human space flight appear to have a clear policy theme - that there is no compelling need for a U.S. government human space flight program and that all necessary objectives and risks can be meet by private contractors using government funding with reduced if not minimal oversight. The technical complexities and risks of human space flight make it an activity distinct from buying normal commercial goods and services. A policy approach that pretends or assumes that it is not distinct is unlikely to succeed - just as the unrealistic flight rates planned for the Shuttle in the 1970s or the large commercial markets for EELVs in the 1990s did not succeed.

The government has several proper roles to play in the next generation of human space exploration and those roles can and should evolve in parallel over time. It is time to push carefully for greater reliance on commercial cargo services to the International Space Station. It is subsequently possible to define a path for commercial crew services that operate in addition to, but not to the exclusion of, U.S. government capabilities. To fully rely on commercial or government approaches, to the exclusion of the other, would place all human space flight by the United States at risk, public and private.

Thank you for your attention. I would be happy to answer any questions you might have.

BIOGRAPHY OF DR. SCOTT PACE, DIRECTOR, SPACE POLICY INSTITUTE, GEORGE WASHINGTON UNIVERSITY

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of Practice in International Affairs at George Washington University's Elliott School of International Affairs. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the U.S. Department of State's Group Superior Honor Award, GPS Interagency Team, in 2005, and the NASA Group Achievement Award, Columbia Accident Rapid Reaction Team, in 2004. He has been a member of the U.S. Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the U.S. Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997-2000. He is a past member of the Earth Studies Committee, Space Studies Board, National Research Council and the Commercial Activities Subcommittee, NASA Advisory Council. Dr. Pace is a currently a member of the Board of Trustees, Universities Space Research Association, a Corresponding Member of the International Academy of Astronautics, and a member of the Board of Governors of the National Space Society.

Chairman PALAZZO. Thank you, Dr. Pace.

I now recognize our final witness, Mr. Jim Maser, Chairman of the Corporate Membership Committee at the American Institute of Aeronautics and Astronautics.

STATEMENT OF JAMES MASER, CORPORATE MEMBERSHIP COMMITTEE, THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Mr. MASER. Thank you, Chairman Palazzo and distinguished Members of the Committee. I want to thank you for the opportunity to address a subject of critical importance to the aerospace industry and to our Nation as a whole, which is a need for a clear national strategy for space.

It is true that we face many other significant challenges, and that our country is going through a period of transition. However, we must not lose sight of the fact that the aerospace industry overall directly employs more than 800,000 people across the country and supports more than two million middle-class jobs and 3,000 suppliers from all 50 States, with total industry sales in 2010 exceeding $216 billion. As a result, the health of the aerospace engineering manufacturing base in America is a crucial element of our continued economic recovery and employment growth. But in addition to that, the aerospace industry is unique in its contribution to national security, and if the highly skilled aerospace workforce in the United States is allowed to atrophy, it will have widespread consequences for our future well-being and success as a Nation.

However, the U.S. space community is at a crossroads and facing an uncertain future that is unlike any we have seen in decades. This uncertainty significantly impacts our Nation's ability to continue exploring space without being dependent on foreign providers. It also has implications for our national security in the U.S. industrial base.

Thirteen months ago, NASA Administrator Charlie Bolden called me, as well as several other aerospace manufacturers to tell us that the Constellation program had been canceled. In the 13 months since that call, NASA has yet to identify a strategy to replace the space shuttle. There does not appear to be a consensus within the Administration regarding the need for the Space Launch System and Multi-Purpose Crew Vehicle, and clearly there is not consensus between Congress and the Administration on NASA priorities. This uncertainty has our industry partners and suppliers very concerned about how we can position our business to meet NASA's needs while retaining our critical engineering and manufacturing talent. It is creating a gap which our industry will not be able to fill.

When the Apollo program ended in 1975, there was a gap of about six years prior to the first flight of the space shuttle program. However, the shuttle program had been formally announced in January 1972, so although there was a gap in U.S. human spaceflight, there was not a gap in the work on the next-generation system. Clearly, this transition was difficult for industry. NASA budgets were reduced but the industry adapted to this new reality.

During the space shuttle era, we saw NASA budgets flattening, declining to less than one percent of the federal budget, and although space industry would have liked to have seen overall increases, we knew how to plan our business, how to invest, how to meet our customers' needs and how to compete, but the situation now is much worse. It poses a much greater risk to the U.S. space community. To the engineering workforce and to the U.S. leader-

ship in space. The difference between the Apollo-shuttle transition and the shuttle-next generation space exploration system transition is the perilous unknown. We simply do not know what is next.

Congress passed an authorization bill that directs NASA how to move to the next-generation program, but NASA has said that due to the Constellation contractual obligations, they are limited in moving forward with the authorization bill. This situation is creating a host of problems and it urgently needs to change. If NASA is going to be relieved of Constellation obligations, we need to know how the workforce will be transitioned, and how the many financial investments will be utilized for future exploration efforts. Whereas the Apollo-shuttle transition created a gap in U.S. human access to space, this next transition is creating a gap in direction, purpose, and in future capabilities.

In order to adequately plan for the future and intelligently deploy resources, the space community needs to have clear goals. Up until two years ago, we had a goal. We had a national space strategy and a plan to support it. Unfortunately, at this point, that plan no longer exists. This lack of a unified strategy coupled with the fact that NASA transition is being planned without any coordination with industry leaders, makes it impossible for businesses like mine to adequately plan for the future.

How can we right-size our business and work towards achieving greatest efficiency if we can't even define the future need? This is an impossible task. So faced with this uncertainty, companies like mine continue fulfilling Constellation requirements pursuant to Congressional mandate to capitalize on our investment in this program but we are doing so at significantly reduced contractual baseline levels. Forcing reductions in force at both prime contractor and subcontractor level.

This reality reflects the fact that the space industrial base is not facing the crisis. We are in a crisis and we are a losing national perishable asset: our unique workforce. The entire space industrial base is currently being downsized with no net gain in jobs. At the same time, we are totally unclear as to what might be the correct levels needed to support the government. Designing, developing, testing and manufacturing the hardware and software to explore space requires highly skilled people with unique knowledge and technical expertise, which takes decades to develop. These technical experts cannot be grown overnight, and once they leave the industry, they rarely return. If the United States develops a tremendous vision for space exploration five years from now but the people with these critical skills have not been preserved and developed, that vision will disappear. We need that vision, that commitment, that certainty right now, not five or ten years from now; if we are going to have a credible change of bringing it to fruition.

In addition to difficulties in retaining our current workforce, the uncertainty facing the U.S. space program is already having a negative impact on our industry's ability to attract new talent from critical science, technology, engineering, and mathematics. Young gradates who may have been inspired to follow STEM education plans because of their interest in space and space exploration, look at industry now and see no clear future. This will have implications on the space industrial base for years to come.

Access to space plays a significant part in the Department of Defense's ability to secure our Nation. The lack of a unified national strategy brings uncertainty in volume, meaning the fixed costs will go up in the short term across all customers until actual demand levels are understood. Furthermore, the lack of a space policy will have ripple effects in the defense budget and elsewhere, raising costs when it is in everyone's interest to contain costs.

It is of course true that there are uncertainties about the best way to move forward. This was true in the early days of space exploration and in the Apollo and shuttle eras. Unfortunately, we do not have the luxury of waiting until we have all the answers. We must not let best be the enemy of the good. In other words, selecting a configuration we are absolutely certain is the optimum configuration is not as important as expeditiously selecting one of the many workable configurations so that we can move forward. This industry has smart people with excellent judgment, and we will figure the details out but not if we don't get moving soon. NASA must initiate SLS and MPCV efforts without gapping the program efforts already in place intended to support Constellation.

The time for industry and government to work together to define future space policy is now. We must establish a policy to recognize the synergy among all government space launch customers to determine the right sustainable industry size and plan on funding it accordingly. The need to move on with clear velocity is imperative if we are to sustain our endangered U.S. space industrial base, to protect our national security and to retain our position as a world leader in human spaceflight and space exploration. I believe that if we work together, we can achieve these goals. We are ready to help in any way that we can but the clock is ticking.

Thank you again for the opportunity to address the Committee today. I look forward to responding to any questions you may have.

[The prepared statement of Mr. Maser follows:]

PREPARED STATEMENT OF MR. JAMES MASER, CHAIRMAN, CORPORATE MEMBERSHIP COMMITTEE, THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Chairman Palazzo and distinguished Members of the Committee:

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It is true that we face many other significant challenges and that our country is going through a period of transition. However, we must not lose sight of the fact that the aerospace industry directly employs more than 800,000 people across the country, and supports more than two million middle class jobs and 30,000 suppliers from all 50 states, with total industry sales in 2010 exceeding $216 billion.

As a result, the health of the aerospace engineering and manufacturing base in America is a crucial element of our continued economic recovery and employment growth. But in addition to that, the aerospace industry is unique in its contribution to national security. And if the highly skilled aerospace workforce in the United States is allowed to atrophy, it will have widespread consequences for our future wellbeing and success as a nation.

The U.S. space community is at a crossroads and facing an uncertain future that is unlike any we have seen in decades. This uncertainty significantly impacts our nation's ability to continue exploring space without being dependent on foreign providers. It also has implications for our national security and the U.S. industrial base.

Thirteen months ago, NASA administrator Charlie Bolden called me, as well as several other aerospace manufacturers, to tell us that the Constellation program had been can celled. In the 13 months since that call, NASA has yet to identify a strategy to replace the Space Shuttle.

There does not appear to be consensus within the Administration regarding the need for the Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV), and clearly there is not a consensus between Congress and the Administration on NASA's priorities.

This uncertainly has our industry partners and suppliers very concerned about how we can position our businesses to meet NASA's needs, while retaining our critical engineering and manufacturing talent. It is creating a gap which our industry will not be able to fill.

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Clearly this transition was difficult for industry. NASA budgets were reduced but the industry adapted to this new reality.

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But the situation now is much worse. It poses a much greater risk to the U.S. space community, to the engineering workforce, and to U.S. leadership in space. The difference between the Apollo-Shuttle transition and the Shuttle-next generation space exploration system transition is the perilous unknown.

We simply do not know what is next.

Congress passed an authorization bill that directs NASA how to move to the next generation program. But NASA has said that due to the Constellation contractual obligations they are limited in moving forward with the Authorization bill. This situation is creating a host of problems, and it urgently needs to change.

If NASA is going to be relieved of Constellation obligations, we need to know how the workforce will be transitioned and how the many financial investments will be utilized for future exploration efforts.

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So, faced with this uncertainty, companies like mine continue fulfilling Constellation requirements pursuant to the Congressional mandate to capitalize on our investment in this program, but we are doing so at significantly reduced contractual baseline levels, forcing reductions in force at both the prime contractor and subcontractor levels.

This reality reflects the fact that the space industrial base is not FACING a crisis; we are IN a crisis.

And we are losing a National Perishable Asset ... our unique workforce.

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In addition to difficulties in retaining our current workforce, the uncertainty facing the U.S. space program is already having a negative impact on our industry's ability to attract new talent from critical science, technology, engineering and mathematics. Young graduates who may have been inspired to follow STEM education plans because of their interest in space and space exploration look at the industry

now and see no clear future. This will have implications on the space industrial base for years to come.

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Now, it is of course true that there are uncertainties about the best way to move forward. This was true in the early days of space exploration and in the Apollo and Shuttle eras.

Unfortunately, we do not have the luxury of waiting until we have all the answers. We must not "let the best be the enemy of the good." In other words, selecting a configuration that we are absolutely certain is the optimum configuration is not as important as expeditiously selecting one of the many workable configurations, so that we can move forward.

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The need to move with clear velocity is imperative if we are to sustain our endangered U.S. space industrial base, to protect our national security, and to retain our position as the world leader in human spaceflight and space exploration. I believe that if we work together we can achieve these goals.

We are ready to help in any way that we can. But the clock is ticking.

Thank you again for the opportunity to address the committee today. I look forward to responding to any questions you may have.

BIOGRAPHY OF MR. JIM MASER, CHAIRMAN, CORPORATE MEMBERSHIP COMMITTEE
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

Jim Maser is President of Pratt & Whitney Rocketdyne (PWR) Inc. a division of Pratt & Whitney. Jim became President on December 4, 2006, and is responsible for the design, manufacturing and performance of power and propulsion systems. Pratt & Whitney Rocketdyne is the world's premier liquid rocket propulsion technology company, with a foundation that extends to the beginning of the U. S. space program. PWR products power the space shuttle, and have powered missions to nearly every planet in the solar system.

Prior to his current position, Maser served as President and General Manager of the Sea Launch Company, an international partnership that launches commercial communications satellites. Under his leadership, Sea Launch emerged as one of the premier heavy-lift launch services in the world, earning the company a reputation of reliability and affordability in a challenging international market.

Following Sea Launch, Maser took his launch vehicle and entrepreneurial leadership experience to Space Exploration Technologies, as President and Chief Operating Officer of the start-up firm, which was selected by NASA to demonstrate delivery and return of cargo to the International Space Station.

Maser has a strong background as an aerospace engineer with extensive experience in program management, design and engineering leadership. Beginning with the Boeing Delta and Evolved Expendable Launch Vehicle programs in structural design, he became lead of advanced studies in systems integration and was one of the key architects of the evolution of Delta II to Delta IV. In 1998, Maser transitioned from Chief Engineer of Delta III to Chief Engineer of Sea Launch. Before joining McDonnell Douglas (now Boeing) in the 1980s, he was a research fellow at NASA/Lewis (now Glenn) Research Center.

Maser graduated *magna cum laude* from the University of Akron with a bachelor's degree in Engineering, followed by a master's in Engineering. He later received a master's degree in Business Administration from the University of California at Los Angeles. In 2000, the American Institute for Aeronautics and Astronautics honored Maser with its George M. Low Space Transportation Award.

Chairman PALAZZO. Thank you, Mr. Maser. I thank the panel for their testimony, reminding Members that Committee rules limit questioning to five minutes.

The Chair will at this point open the round of questions. The Chair recognizes the chairman of the full Committee on Science, Space, and Technology, Mr. Hall, for five minutes.

Chairman HALL. I thank you, Mr. Chairman, and I hope that none on this Committee nor within the audience or anywhere mistake my opening remarks as an indication that I am not very pro-NASA or that I am not an admirer of the Administrator and each person working there and I am grateful to you for coming here today, but had I had your opening statements, I would have had some questions for Mr. Maser when he says you need instructions. You do have instructions, and we will have some questions to send to you and to Doug Cooke. I have a question for Doug, but I will have some questions for you and for Dr. Pace and we will hope you send them back to us timely. I think the Chairman is going to instruct you to send them back within two weeks. but just so we have them to go down the road.

Mr. Cooke, I thank you for your hard work and your leadership. You have been operating for years using the previous Constellation contracts that were awarded through the competitive bidding process, a process that has been voted upon by Republicans and Democrats alike here. Have you been able to successfully extend or modify these contracts to reorient work to support the Space Launch System and the Multi-Purpose Crew Vehicle?

Mr. COOKE. Chairman Hall, absolutely. We are modifying the work on these contracts and making sure that they are focused on our direction ahead toward the SLS and MPCV.

Chairman HALL. Have you found that to be a reasonable and efficient way to keep the work moving along?

Mr. COOKE. It is——

Chairman HALL. And if not, tell us about it.

Mr. COOKE. Okay. Within the constraints of the laws, we are able to vector the work. Obviously the contracts that we have are for the Orion spacecraft and they are for the Ares I launch vehicle. The Ares launch vehicle, of course, was designed to carry the crew capsule. The SLS will be a heavy-lift vehicle so there are differences in the requirements. But many of the components of Ares I are functionally the same. We are able to continue work on the solid rocket booster, which was designed initially as a five-segment booster that could be used on a heavy-lift vehicle. The work on the Orion vehicle and the requirements that they are working to are in line with MPCV requirements that are called out in the authorization act, and upper-stage work for Ares I includes the J–2X engine, which was chosen originally to be common with an upper-stage engine that could be restarted for a heavy-lift vehicle. Manufacturing techniques that we have developed on the upper-stage tanks have been very valuable to us and something that we have learned quite a bit about. The avionics unit is functionally very similar to what would be needed on a heavy-lift vehicle. A lot of the functionality is the same, some of the parameters are different but there are similarities in function with all these and potentially lead directly to use in the heavy-lift vehicle, so we have done every-

thing that we know how to continue work on long-lead items to specifically put tasks in place that are consistent with where the act has guided us, and in the case of the MPCV, the requirements are mapping very closely.

Chairman HALL. I thank you, and my time is almost up. I just want to tell you that I am very hopeful that we can preserve our position in space, can keep our word with our foreign partners, and realize that we do need our space station and need our leadership. We need our missions beyond Earth orbit, but I think we need to limit those to a time that the economy might dictate. I have heard it said at home we don't want you guys going to the moon or to Mars or to some other mark out there, wherever, until we can go to the grocery store, and I guess that is what is going to guide us here, the economy.

But we thank you for your hard work and appreciate your input, and I yield back my time.

Chairman PALAZZO. Thank you, Mr. Chairman. I now recognize the Ranking Member, Mr. Costello.

Mr. COSTELLO. Mr. Chairman, thank you.

Mr. Cooke, to follow up on Chairman Hall's question about existing or modified Constellation contracts, Congress, to my knowledge, has not seen a final ruling from the General Counsel on whether NASA can use those contracts. I guess, one, the first question is, has the General Counsel made a decision, and number two, if so, what is the decision that was made by the General Counsel? If not, when will the ruling be made?

Mr. COOKE. Where we stand on working with the current contracts goes along the lines of we have been mapping the requirements that are for the MPCV and SLS against our current contracts. For instance, in the case of the MPCV, we have a procurement determination from the procurement office in Houston that MPCV requirements are within scope of the Orion contract. That has been concurred on by my office and with General Counsel as well as Procurement Officer for NASA. So that work has gone on. We are doing the same activity with the SLS in terms of the contracts that we have there including first stage, including upper stage, J–2X engine and the avionics unit, so procurement officials at Marshall Spaceflight Center are mapping those requirements. We have not gotten to determinations on those. They are a little more complex because we are moving from the crew launch vehicle to a heavy-lift vehicle but that work is ongoing. All of this will be brought forward in the next couple of months as we finish off our studies that are leading this, and in order to understand the best approach to fit within the budget with our acquisition and the actual design.

Mr. COSTELLO. So the bottom line is, some issues have been resolved internally, others may not have been, but is there a final ruling on some but not others, and if so, tell us which ones and which ones have not had a final ruling.

Mr. COOKE. The determination we have is only currently on the Orion contract. We are still working on the others, and we will have to go through an acquisition process to work through the details of those and make sure we understand what we can do legally.

Mr. COSTELLO. And what are we looking at as far as the timeline when Congress can expect a final ruling?

Mr. COOKE. Our plan is to complete this work in the spring and early summer and get back in that time frame.

Mr. COSTELLO. When can we expect to get an exact timeline and date when NASA will start work on the new vehicle?

Mr. COOKE. That will be determined at the same time frame. We are trying to bring all these decisions together through a plan that we have laid out for the next couple of months that lay out decision time frames that complete work that we have in contracts supporting the design decisions and also incorporating the industry studies that we have out that are contributing to our heavy-lift studies.

Mr. COSTELLO. So the answer is in a few months?

Mr. COOKE. Yes, sir.

Mr. COSTELLO. Let me ask you a final question and ask the other witnesses the same question. I mentioned in my opening statement that Congresswoman Giffords had very serious concerns about current funding levels, and her concerns were if the current funding levels in fact could accomplish both the heavy-lift and the Multi-Purpose Crew Vehicle, if they really had a future at current funding levels, and my question to you is, do they have a future with current funding levels?

Mr. COOKE. That is the subject of these studies as well, to understand how these design concepts lay out, what they will cost, and how the work can be phased within the funding levels that we are looking at in order to understand when we can produce hardware and lay out the program plans. We need an integrated program plan, and that is what we are developing now.

Mr. COSTELLO. Dr. Pace, based upon what you know now, I would ask you the same question.

Dr. PACE. Well, I read with interest the report that NASA provided saying that they would have difficulty meeting the Congressional time schedule at current funding levels, and as someone who used to deal with cost estimations and probabilities associated with cost estimations, I think they were exactly correct. They cannot meet the schedule with sufficient confidence with the funding levels that they have. I think that is fairly straightforward. And this is not, I should say to be fair, not a new problem. Lack of funding from the Administration, the previous Administration, in which I served, also led to cost increases in the program. So inefficient costing and funding schedules create overall costs to rise, so I don't think they are there now and I think that if they continue to be underfunded, the overall cost to the Nation if we continue on that path will be higher. So they need more funding now to make schedule, and if they don't get it, you will see costs go up.

Mr. COSTELLO. Mr. Maser?

Mr. MASER. It is a complex question, and ultimately NASA is the one who has to execute under the budget provided, and in my opinion, it depends on whether they extrapolate business as usual into the future or truly move out on what they are saying is a more efficient approach. Mr. Cooke in his testimony stated that NASA is working on stepped-up cost savings and measures that are supposed to be more efficient both internally and externally. It is not

clear how quickly that can be put into systems and processes, so I would argue that extrapolation of the past with the current budget would make it challenging with the timeline but that it could be achieved with an extended timeline and the right architecture.

Chairman PALAZZO. Thank you, Mr. Costello. I now recognize myself for five minutes.

Mr. Cooke, NASA's preliminary report seems to indicate that you intend to design a smaller vehicle, around 70 to 100 tons, than what was envisioned in the authorization. The authorization assumes a launch vehicle that is designed from inception as a 130-ton vehicle with an upper stage, but one that could make use of the core first stage for early flight testing of the crew capsule. Could you clarify for us how NASA envisions the design of the space launch vehicle?

Mr. COOKE. Yes, Chairman Palazzo. I realize there is some confusion over some of this. Actually, in our teams we are studying design concepts and we really have to design from the inception for the full capability of 130 metric tons, and our approach would be—so there is the design aspects and you have to understand where you are going, which is 130 metric tons. There is also a discussion in the act about something evolvable from 70 to 100 metric tons. So basically starting with 130, you can assemble the components to get the lower-level capabilities, and if we do that, we can potentially field a capability earlier at the lower levels of 70 to 100. But certainly you have to work on the 70- to 100-metric-ton implementation considering its ultimate capability at the 130-metric-ton level.

Mr. MASER. I would like to give an industry perspective on some of the confusion we have around that whole topic. In a recent March 25th Space Transportation Association luncheon, Administrator Bolden was quoted as saying "NASA does not need 130-metric-ton vehicle probably before the next decade." He also was quoted at the Center for Strategic and International Studies in March saying, "We are not going to build 130-metric-ton vehicle; we can't. We continue to negotiate and discuss with Congress why that is not necessary."

So in industry what we hear is a lot of discussion about what we can't do and what we don't want to do, and okay, so what can we do, what do you want to do and why aren't we being explicit now, and why aren't we being transparent now. From an industry perspective, all I know is the shuttle ends in June. The Constellation is can celled. Tomorrow will be 14 months with nothing that I would characterize as other than platitudes on innovation, inspiration, technology, infrastructure, education but no plan and no direction with a true ominous gap. The authorization bill is into law. We need to define the vehicle. It needs to be something that can go beyond low Earth orbit right from the get-go and we need to get started now.

Chairman PALAZZO. Thank you, Mr. Maser.

Now, this question can be for all of you. We understand the importance of maintaining our aerospace industrial space. For purposes of today's discussion, how much of that industrial base is driven by NASA, and if NASA chooses to reduce its commitment to the Space Launch System and capsule, what happens to the peo-

ple who build these systems? To what degree can the Defense Department and other civil customers absorb these people and facilities?

Mr. MASER. Okay. Well, from my perspective, I can't speak for all of AIAA because it varies in terms of the types of businesses people are in, etc., so as part of United Technologies and Pratt and Whitney Rocketdyne, from our perspective, historically NASA has been a majority of our industrial base, and in fact, not so far ago, maybe 5 to ten years ago, 75 to 80 percent of our industrial base, and over time that has reduced down to, say, 50 or 60 percent of our entire workload industrial base, and we have been working to build what I would call a mixed portfolio of business. It not healthy for a business to have that much tied to one single customer in any way.

But I will say for a Nation from the national standpoint, that NASA contribution to the industrial base has benefited the entire Nation's access to space, and we have a chart that shows that relative to DOD access to space, and we provide the majority of propulsion for that, but NASA carrying a large portion of the fixed costs of that industrial base has benefited DOD in terms of what I would characterize as subsidies to their costs and have afforded them relatively attractive pricing in the past. As we look at what the future looks like, our ability to adjust our fixed costs and industrial base quickly is somewhat limit, and what happens in the short run is that we will have to shift some of those costs to DOD over time. So there is still a net total cost of U.S. access to space, and I think there is not an integrated view being looked at that. But to be clear, NASA has supported a large portion certainly of the liquid propulsion industrial base, and that is in jeopardy right now.

Chairman PALAZZO. Would anybody briefly like to wrap up? I am over time.

Dr. PACE. Sure. And I think during the Constellation program when I was at NASA, there was a certain amount of advocacy for use of EELVs and we were advocates of it and we did those sorts of trades with the architecture studies. One of the things that was important to note about the Constellation architecture was the large use of RS–68 engines built by Pratt and Whitney Rocketdyne, and that the combination of large buys for the Constellation program was beneficial to the DOD side. One of the largest costs in a launch vehicle is the first-stage engine. The second largest cost in the vehicle is the second-stage engine. So even though we weren't buying EELVs that would benefit, I think, parts of DOD, we were supporting the industrial base. Again, that kind of integrated thinking, I think, is absolutely necessary, and it is really hard to do it if we don't have an architecture or direction as to where we are going. So it is not just a matter of building vehicles, it is a matter of saying where are they going to go, and what schedule are they going to be on so you can then get down to planning what actually makes sense for the industrial base.

Chairman PALAZZO. We have a limited amount of time and a lot of Members have some questions. Thank you all for that. I will now recognize Mrs. Fudge.

Ms. FUDGE. I thank you, Mr. Chairman, and thank all of you for being here today.

Mr. Cooke, during the Constellation program, the Glenn Research Center contributed significantly to the success of various activities including developing, designing and constructing the 110-foot upper-stage simulator. That simulator successfully flew on the Ares I–X. Though I am supportive of the President's budget and new direction for NASA, I feel that it is important for Glenn to have a role. So my question, what Space Launch System and Multi-Purpose Crew Vehicle project management responsibilities are envisioned for Glenn?

Mr. COOKE. In terms of the past, I agree with you, the Ares I–X effort was very significant, the work was excellent, and the upper stage was incredible. The Glenn Research Center continues to have service module responsibilities for the crew vehicle. In terms of the launch vehicle, those assignments will be worked by Marshall Space Flight Center. There have been on Ares I assignments at Glenn and the work that was done on Ares V in the Constellation program, was there as well. So as we get to final decisions on these vehicles and understand how the final designs work out, we will be working those assignments.

Ms. FUDGE. As you talk about Marshall, let me just ask, have any other center-specific assignments for SLS or MPCV been made?

Mr. COOKE. The assignments that we currently have are for the MPCV leadership at Johnson Space Center, which is where Orion has been worked from, and the Space Launch System will be at Marshall Space Flight Center. Those are the primary assignments that have been made so far. It will depend on final designs in the future but we will be working with centers across NASA.

Ms. FUDGE. So if those assignments have been made, then when do you anticipate that the other assignments will be made?

Mr. COOKE. As we get to our final designs and we begin our implementation phase of the work for the SLS and MPCV, those assignments will be negotiated as they have been in the Constellation program, and that will be following the results of the work that we are currently doing that should end up this summer.

Ms. FUDGE. Lastly, Mr. Cooke, how is Glenn involved in current trade analysis leading to the final report on the Space Launch System and the MPCV?

Mr. COOKE. I will have to take that for the record. I am not sure exactly their participation in that.

Ms. FUDGE. And you would get me that information at what point?

Mr. COOKE. That is a fairly simple request, I think, so it should be soon.

Ms. FUDGE. Thank you very much, Mr. Chairman. I yield back.

Chairman PALAZZO. Thank you. I now recognize Mr. Rohrabacher.

Mr. ROHRABACHER. Well, at times like these, two stories come to mind which of course many of us already know these stories, and that is, the first about the gentleman who takes his son to the Air and Space Museum and is pointing out the Spirit of St. Louis. He tells his son that this is where Charles Lindberg, this is the craft

Charles Lindberg first was able to traverse the Atlantic from New York to Paris. The son asks, well, was it really difficult for him to do that all by himself, and the father answers it would have been more difficult with a committee. We have heard that, as well as the fact that a camel is nothing more than a horse that was designed by committee. What we have here is a space policy designed by committee, not just this Committee but the committee made up of the Senate and the Executive Branch and people in the private sector who are all trying to get together to design a horse, and it is turning out to be a camel and I am not even sure if it is a camel.

Let us take a look at what we are talking about here in terms of the billions of dollars that are being spent and have been authorized. Let me just ask, Mr. Cooke, is the heavy lift that has been authorized for $4 billion, is that heavy lift absolutely necessary and the money that is being spent in developing it for other options other than just the immediate option that is our immediate task of having a backup for taking people to the International Space Station?

Mr. COOKE. Yes, sir. The heavy-lift vehicle is a necessary step, probably the most important step in getting beyond low Earth orbit to other destinations.

Mr. ROHRABACHER. Right. But I mean, in terms of space exploration, are there other options to space exploration rather than just the building this heavy-lift vehicle or are we talking about the option that is driving the heavy-lift vehicle as a backup to manning the International Space Station?

Mr. COOKE. The role for the heavy-lift vehicle as a backup to transporting cargo or crew to Space Station, using it for that is inefficient actually. It is more needed for going beyond low Earth orbit.

Mr. ROHRABACHER. That is correct. But let us take a look now in terms of actual space exploration. Is it possible that perhaps developing refueling techniques and other such approaches to deep space exploration might be, let us say, a better use or a better method of getting to space exploration rather than just building a big booster like we did with the Saturn? After all, we did produce a huge vehicle like this before. Saturn carried 260 tons into orbit, which is much more than what we are even talking about now for this heavy lift, and that was 1950s technology. Is there something—haven't we progressed to the point that there is other technological alternatives rather than simply having a huge, dumb and expensive booster?

Mr. COOKE. There are many technologies that are needed for going beyond low Earth orbit to other destinations. Getting off the planet is the hardest part, step one, and we have done extensive studies over the years to look at various alternatives. Certainly, in-space fueling can augment what you would do, but ultimately you have to get fuel off the planet to go into outer space, and one of the biggest components of, say, a Mars mission is the fuel it takes to get there. So in-space transportation efficiencies are important but we have found that even when you sum up all the gains you can get in efficiencies that we know how to get to with technology, some of which we don't currently have in hand, it still may take six or seven heavy-lift boosters to get all the hardware——

Mr. ROHRABACHER. When you talk about fuel, we have had some great advances in nuclear technology that would not only save Japan from what it is going through right now but permit us to utilize very safe nuclear engines in space. These technological advances have been happening just in the last few years, so I would suggest that we—quite often these debates are taking place within the mental framework of what is and what is that was created by technologies of decades ago, and just a concept here that yes, NASA is really important to develop a workforce and it is important to our industrial base but we have to realize that today we also have a great deal of investment going on. Bigelow, Boeing, SpaceX, ATK, United Space Alliance, Orbital and many other companies are now emerging as entities that are investing in developing space technologies. I would hope that as we plan through this committee process that we have got our strategy for the future, that we have to realize that with the type of deficit spending that we now have taking place in this government, it behooves us to think with new thinking to bring as many resources into America's space effort as we possibly can and also make sure that we are cooperating. If we have three backups to supplying the Space Station, if we have three backups and one of them happens to be Russian and the others happen to be American commercial, I would hope hat we are not wasting billions of dollars simply to have a third backup which those billions of dollars could go to developing the technologies we need for new methods of getting into deep space.

Thank you very much, Mr. Chairman.

Chairman PALAZZO. Thank you. I now recognize Mr. Wu.

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

Dr. Pace, I notice from your CV that you have part of your portfolio in international issues, and I would like to address a question in that direction, and it is a question for both you and Mr. Cooke. Dr. Pace, on page 7 of your written testimony you state, "If the Administration is truly supportive of stimulating commercial space transportation, then it needs to consider where future demand might come from. It is not a question of choosing between government and commercial approaches but of government first and then commercial in a well-considered transition," and I just want to point out that this transition was rolled out by the Administration with no transition. Congress was surprised. I believe that NASA may have been surprised. I won't guess or speak for NASA. And I am very concerned about that. Further on page 7, Dr. Pace, you discuss the role of international partners in the future and you state, "We should consider making greater use of international partners."

I have heard from some of our international partners. I was surprised when I first got calls from the press in other countries and from some other folks in foreign countries and then it became apparent to me that we have these partners, I believe more than 15. I have heard from some of them. Have you heard from them, and what have you heard? Are they concerned? And do we run a risk of fracturing this multinational space coalition which was so painstakingly put together over a period of 30 years or so, which I view as very important to the future of human spaceflight. Dr. Pace, you first, then Mr. Cooke, then you.

Dr. PACE. Thank you for that. It is an excellent question, and the answer is yes, we are at a risky period. I mean, the Space Station continued assembly was done in part because we needed to preserve our international partner commitments. It was not clear we could finish the Space Station after the terrible Columbia accident. We did it in part to keep our commitments to our international partners and they are with us now on station. But what is happening is with the kind of drift in the policy approach with discussions of Mars and near-Earth objects and the Moon is not quite here and we are not sure what we are doing next. The partners are having to make their own decisions with their own governments. They have their own financial problems, their own budgetary issues, and if there is not clear leadership and direction for the United States, they each make their own decisions. This is happening in Japan. This is happening in Europe. Certainly India is making its own judgments about what to do next.

So there is a very coherent, I thought, international lunar architecture that had been created through consultations that have been done over the last several years, and one of the things that was great about it was that countries at different levels of capability could participate, yes, the really high-end countries with manned space capabilities but South Korea, Brazil, potentially South Africa, other countries could find small experiments, could find things to participate in. One of the problems with some of the ambitious statements that the Administration has made is that inadvertently, I think unintentionally, excludes a lot of those countries so I would urge a return to an international lunar architecture and focus for beyond low Earth orbit. Not only because I think that is great for the United States but I think it produces more opportunities than other alternatives for involving countries and continue to maintain the partnership and build upon the amazing partnership that has occurred over the last decade.

Mr. COOKE. I would like to add that in our work with the internationals, we have developed what is called the International Space Exploration Coordination Group, which does include 14 space agencies, That group has developed lunar architecture that Scott Pace mentioned. We are continuing to work with them on a weekly basis to develop roadmaps for other destinations. We also talk about potential for flying instruments on each others' spaceflight, to continue collaboration, and I have been in discussions with Bill Gerstenmaier of Space Ops to understand how we can work exploration-type activities together on Space Station to help with that coordination. So we are continuing to work with them.

Mr. WU. Thank you very much.

Mr. Chairman, if you will permit me the liberty of one more comment. I believe very strongly in a multilateral approach to human space exploration. I want to leave no doubt about that. But I don't think that this can occur without American leadership. My daughter, after attending the last shuttle launch, bought the book Apollo 13, and like the comment in that book, "In this endeavor, failure is not an option," and what is at stake is just as English is the language of air traffic control, I want English to be the language of

space, and that is what is at risk with this Administration's drifting human spaceflight policy. Thank you, Mr. Chairman.

Chairman PALAZZO. You are welcome. I now recognize Mr. Smith.

Mr. SMITH. Thank you, Mr. Chairman.

Dr. Pace, I would like to address first question to you as well as to the other panelists, and it is this. While the NASA Authorization Act of 2010 legislates that a heavy-lift launch vehicle and a Multi-Purpose Crew Vehicle be built, Mr. Maser contends in his testimony, I think it was page 3, "There does not seem to be a consensus within the Administration to build these systems," and it seems to me that the NASA Authorization Act is being ignored by the Administration. If you agree, what do you think Congress should do about it, perhaps short of holding the Administration in contempt of Congress? But what else can we do to get the Administration's attention and to get them to follow the laws Congress has passed?

Dr. PACE. Well, thank you very much. I can't really speak for the Administration or speak for NASA. I know that Doug Cooke's testimony was very detailed on the subjects of what they are doing with the Space Launch System and Multi-Purpose Crew Vehicle. What I know is what the Administration proposed in the fiscal year 2012 budget, and I look at that budget proposal and it reflects priorities, and their priorities are fairly clear in terms of additional technology, money that is not tied to any particular mission, funding for some important earth science efforts, funding for commercial crew capabilities, which one can have a discussion as to how ready they are, and therefore less priority was placed upon the SLS and Multi-Purpose Crew Vehicle.

So I think what Congress can do is look at that priority, take it into account and then respond through the authorization and appropriations act with its own priorities. If in fact Congress does believe what was passed in 2010 represents a strong bipartisan basis for moving forward, then that needs to be reflected in what the appropriations do that the Congress—the Administration has proposed. It is up to the Congress to dispose and put its priorities in discussion with the Administration.

Mr. SMITH. Thank you, Dr. Pace.

Mr. Cooke, Mr. Maser, do you have any other comments or observations on that?

Mr. COOKE. I would like to say once again, and it is in my testimony and my opening statement, we are at NASA taking the authorization act seriously and we are pursuing the concepts for Space Launch System and the crew vehicle. We have all the work in place to get us to a solution on that.

Mr. SMITH. Thank you. Mr. Maser, since I quoted you, feel free to respond.

Mr. MASER. Well, it is interesting because I spent a good portion of my career in commercial space, and actually this is my first gig in the government space world and I am still learning quite a bit. In fact, I talked to Dr. Pace and told him that four years ago I couldn't even spell space policy and now I appear in the middle of it. So from my private experience, it is hard for me to understand the situation, because I guarantee you, in the private world these

kind of situations resolve themselves relatively quickly one way or another. In the government world, the only thing I can do is agree with Dr. Pace and that is based on what I have been able to learn about this process is appropriations would be necessary. The authorization is law but does not provide the direction and the funding to go implement that law, and I think that would be the most expeditious.

Mr. SMITH. That is a good point. Thank you, Mr. Maser.

Dr. Pace, let me squeeze in one more question which is fairly specific and ask you to respond. In your testimony, you discuss how "policy instability or lack of clear direction for NASA over the last 20 years has resulted in at least $21 billion being wasted in various can celled human spaceflight programs," leaving us in a situation today of course where we are now having to pay Russia millions of dollars to launch our astronauts into space. Given the crisis and instability described in today's testimony, is it too late to consider continuing flying the shuttle orbiters while a concerted effort is undertaken to build a follow-on vehicle?

Dr. PACE. I have to say that mindful of the Columbia Accident Investigation Board recommendations, and I can't really in all good conscience support continuing to fly shuttles unless there was absolutely no alternative to supporting the International Space Station. So in that regard, I think the STS–135 is something I can reluctantly support as a necessary and important mission. But I do believe there is time to get back on track, but as Jim Maser is saying, time is running out for the industrial base to make those decisions. Decisions are needed really this year, and I think there is an alternative that continues building on the work of the Constellation program and that would not require us to go back and try to keep shuttles flying. I think the SCS–135 we have got to do but I really don't think we should continue flying shuttles unless we utterly, utterly have no other choice.

Mr. SMITH. Thank you, Dr. Pace. Thank you, Mr. Chairman.

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

Ms. EDWARDS. Thank you, Mr. Chairman, and thank you to the witnesses for this hearing.

You know, since I came into this Congress, I have been on this Subcommittee, served as Vice Chair in the last Congress with Ms. Giffords, and feel like we are in the Groundhog Day film, you know, going over the same things over and over again. I want to say a special thank you to the diverse and skilled and competent workforce. It is a private sector workforce. It is a public sector workforce. It is small and large businesses. And I share their uncertainty and confusion because as a Member of this Committee, I am uncertain and confused about what NASA is doing with regard to the Exploration program and confused by an authorization that we passed that in my view NASA seems not to be following, so I am confused about what authority NASA is operating under in terms of the continued implementation.

So I want to ask actually a few questions, Mr. Cooke, and if you aren't able to answer these now or they are in your written testimony which, you know, I study this testimony and unfortunately didn't have a chance to review because we didn't have it, and so

I do hope that doesn't happen in the future. But you issued a reference design for the Space Launch System with a caveat that you might make changes pending the results of industry studies. I just wonder if you have seen anything up to this point that would lead you to alter the reference design that you had issued.

Mr. COOKE. Right now we are not altering the reference design. We are updating our understanding of some of the approaches in design and some of the work that would make it more efficient. We are also studying alternative designs to do our homework to make sure that we challenge our own thoughts and come up with the best answers. So that work is ongoing but at this point we have not made changes.

Ms. EDWARDS. So I want to get some clarity then about the details. I want to go through a series of questions about the initial heavy-lift capability that you are looking at. Will the core stage vehicle use liquid oxygen or liquid hydrogen engines or liquid oxygen rocket propellant?

Mr. COOKE. The core stage on the reference vehicle is liquid oxygen hydrogen stage. It uses for the 130-metric-tone case five shuttle-derived engines, the same engines just adapted for this use.

Ms. EDWARDS. So you don't have any plans then to change that part of the reference design?

Mr. COOKE. Not in the reference design.

Ms. EDWARDS. And then what is the diameter of the core stage?

Mr. COOKE. The core stage is 27–1/2 feet in diameter. It is the same dimension as the current shuttle external——

Ms. EDWARDS. And can you tell us the thrust of the first-stage engine?

Mr. COOKE. The thrust of the first-stage engine as it is flown on the shuttle is, I believe, 470,000 pounds of thrust.

Ms. EDWARDS. And that remains what you are committed to in the reference design?

Mr. COOKE. That would be the same engine. We would probably make some modifications for manufacturer ability. Mr. Maser could comment better on that than I can.

Ms. EDWARDS. Well, let me just get through. So you mentioned earlier that you are still committed to a design to have an upper stage. Is that correct?

Mr. COOKE. Yes. Part of the reference design is an upper stage that would and currently employs the J–2X engine that we are developing in current contracts.

Ms. EDWARDS. And will it use solid rocket boosters?

Mr. COOKE. The reference design does use five-segment solid rocket boosters that are consistent with the design on Ares I.

Ms. EDWARDS. And there is nothing up to this point that you are looking at that would change that commitment?

Mr. COOKE. On the reference vehicle design, that is where we are. We are looking at slight modifications to it, but for the reference vehicle design, we are not making big changes to what I just described. We do have other studies in parallel, though, that look at liquid oxygen and kerosene approach to the launch vehicle and we have one that we call modular approach.

Ms. EDWARDS. I am going to submit some other questions but just as I run out here, I just wonder if the vehicle is going to be

available under the President's proposed five-year runout and then if you could tell me about the studies. You said that a final report would be issued in the spring. Well, we are hitting on spring, we hope. It doesn't feel like it outside but we are getting to spring, so can you give us an exact date or month that we should expect to receive that?

Mr. COOKE. We are aiming right now for late spring, early summer for the report.

Ms. EDWARDS. That is a long time. My birthday is in the late summer. I like that. But can you tell us, I mean, it is going to be April, is it May, is it June, July, August?

Mr. COOKE. Right now we are shooting to have the report in the late June time frame. It is a success-oriented approach but that is our goal.

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

Chairman PALAZZO. I now recognize the gentleman, Mr. Brooks from Alabama.

Mr. BROOKS. Thank you, Mr. Chairman. I have been going over the more extensive versions of your testimony, and quite frankly, I find the testimony conflicts somewhat challenging, and perhaps you all collectively could assist me in better understanding the true situation. In looking at Doug Cooke's testimony, for example, he refers to the President's budget request as a "vigorous path." He also states, "It is clear that NASA has a bright future."

Yet when I look at the testimony of Scott Pace, he states, "NASA effort to transition from Constellation program designs to the Space Launch System can be seen as incomplete and arguably adequate." He also states that "through its budget proposals, the current Administration has contributed to policy instability for NASA as a whole, not just in human spaceflight." Further, "In the fiscal year 2011 proposal of NASA, the Administration added funds back such that the NASA top line returned to where it would have been in continuing the spending levels of the Bush Administration. However, the composition of spending had changed significantly with exploration spending dropping." And then finally, we have "Planning for and successfully executing this transition has been made significantly more challenging by the policy, programmatic and budget instability of the past two years. As a result, the United States does not have at present a plausible architecture and strategy for conducting human missions beyond low Earth orbit for the next two decades."

And without belaboring it too much, looking at Jim Maser's testimony, he notes, "The United States space community is at a crossroads and facing an uncertain future that is unlike any we have seen in decades." And Mr. Maser's testimony contains additional comments to that substance and effect.

When I look at my own experience in communicating with people who are involved with NASA either as employees or part of the administration of NASA or some of the subcontractors and contractors and the employees in and about the Marshall Space Flight Center in Huntsville, Alabama, I can't help but note that many of these in the private sector contractors and subcontractors are being laid off in large numbers. More recently, we had a $300 million cut in NASA spending by a vote on the House Floor in which the cut

of $300 million was to instead go to the COPS program, which is a unique local function, a state government function, while NASA is a unique federal government function. Yet during the rather vigorous debate on whether to transfer those $300 million in NASA funds to the COPS program, it appears that the White House and the NASA leadership was AWOL on that vote in as much as based on the testimony previously in this hearing, neither the White House nor the NASA administration did anything to persuade any House Members of the effect that $300 million loss in funding would do to NASA or the contractor and subcontractor community. And just as an aside, 83 percent of Democrats voted to cut NASA $300 million in favor of the COPS program while 30 percent of Republicans similarly voted to make those cuts.

And then in my private communications with contractors and subcontractors, I see absolutely nothing that suggests optimism of any significant nature, and I am quite comfortable with any of you all addressing this situation. But what can you do to help persuade me that despite these conflicting testimonies and rather depressing information within the NASA contractor and subcontractor community that things truly are going to get better and get better quickly?

Mr. COOKE. Let me try. Obviously we are in tough economic times. Budgets are scrutinized. We have to make tough choices, and we do have an authorization act at this point that was passed by Congress and signed by the President at his direction. That is a path forward, and we are addressing that act. The budgets that are available will be negotiated through our normal budget processes between the Administration and Congress, and it is my job to implement what we have, and I can tell you that with all our ability, we are trying to make the most of what we are given and we are—and in challenging times we are working very hard to gain efficiencies in how we do our work and have extensive efforts within the SLS and MPCV activities to streamline what we do.

So we want to make progress. We want to get to exploration of space beyond low Earth orbit and within this environment we, I guarantee you, are working as hard as we can to make progress down that path.

Mr. BROOKS. Well, if I might just add 15 more seconds, Mr. Chairman, the Apollo program raced to the moon. The International Space Station, the space shuttle all existed because of strong, vigorous leadership from the White House, and if any of you gentlemen have any ideas as to how we can light a fire under this White House to provide that kind of similar strong, vigorous leadership, we certainly would as supporters of the NASA community appreciate that insight.

Chairman PALAZZO. The gentlelady from Florida, Ms. Adams.

Mrs. ADAMS. Thank you, Mr. Chairman.

Thank you for being here. I come from Florida's 24th district, home of Kennedy Space Center, and the hardworking men and women down there who have spent a lifetime, some of them, working on the shuttle and on the human spaceflights and all of the flights that we have had coming out of central Florida. They have concern that they bring it to me, and as I sit here and listen, I am just amazed because—a couple of questions I have, and hopefully

you can answer them. My colleague was asking what is your plan to keep human spaceflight, keep us moving forward, and you said it is tough budget times and you are working on it, but, you know, President Obama made a speech about space exploration last year. He committed additional $6 billion over the next five years to the budget. Then the budget runout proposes $8.5 billion less for NASA over the same five years. While cutting NASA's budget, the President proposes sizable budget increases in other federal R&D agencies and programs, especially climate change where Science Committee Chairman Ralph Hall's analysis shows there was $36 billion spent over the last five years. How does this dramatic increase in climate change research affect the overall budget picture for NASA? In other words when you are taking away form space exploration for the benefit of climate change, there are 16 agencies currently doing that. How does that affect your ability for human spaceflight?

Mr. COOKE. I actually would have to take that for the record but it includes more than the work I do. My job is to lead——

Mrs. ADAMS. Okay. How about this? Do you believe that affects your ability for human spaceflight to have those funds sent to another division within NASA?

Mr. COOKE. The amount of money we get obviously affects how much work we can do, and with the money that we have in our budget, we are—as I said, we are working to find efficiencies, to make the most of the budget we have.

Mrs. ADAMS. Thank you.

Mr. Maser, if we close down all our human spaceflight in this country, effectively not send anyone into space on American rockets for 5 or six years, how long would it take us to ramp up that kind of industrial base again and at what cost to the industry and to the government?

Mr. MASER. Well, that is a very hard question that obviously we are trying to avoid, but I believe——

Mrs. ADAMS. Your best guess.

Mr. MASER. To ramp back up after being shut down for 5 or 6 years?

Mrs. ADAMS. For 5 to 6 years.

Mr. MASER. You are talking at least six to ten.

Mrs. ADAMS. And about what cost do you think to the American people?

Mr. MASER. Well, what is the cost of loss of space leadership? I can't quantify it in dollars. I can try to get AIAA to compile that, but that is a tough question to estimate from a dollar standpoint. I think it stems back to the larger, what is the cost of abdicating space leadership for this country.

Mrs. ADAMS. Dr. Pace, I would like to speak to you a moment about America's leadership in space. Recently, Space News published an article accusing the Administration of being muddled on its China space policy. On the one hand, the Administration speaks to the concerns about a growing military in China, the technological advances, and on the other hand talks about increased cooperation in space. What do you suppose would happen to America's leadership in space if there were a Chinese flag planted on the

moon and America could not get past low Earth orbit, or even get astronauts into low Earth orbit on American rockets?

Dr. PACE. Well, I think it would contribute to a broader perception of American decline. I certainly have run into lots of people who feel that that memo has been sent and anybody who doesn't understand America has declined from its best days just doesn't understand the situation. I don't agree with those people and I have some wonderful arguments with them.

I don't mind the Chinese in space so much as I worry about us not being there with them. The rules in space, the norms of space are set by those people who show up, not by those people who aren't there. So I believe that we should be looking for ways to cooperate with China in science efforts. I think human spaceflight is too difficult and too hard for lots of reasons. We should be willing to reach out to them on smaller projects. But ultimately our fate is in our own hands, and we should be the ones in space welcoming the Chinese to work with us in times and places of our choosing, not responding to offers of them to work with them in times and places of their choosing.

Mrs. ADAMS. In the article dated on March 28th, it stated the Director of National Intelligence, James Clapper, testifying before Congress stated that China poses "potentially from a capability standpoint a threat to us as a mortal threat." While Clapper went on to note he was discussing capabilities and not intentions, is it clear that at the highest reaches of the U.S. government, China's capabilities both terrestrial and spatial are engendering great concern. I submit that our agencies are having some serious discussions, and maybe this Administration needs to listen to them.

Chairman PALAZZO. Does any other Member have a question?

Mr. COSTELLO. Mr. Chairman, I have a final question and then maybe a comment to follow up on the gentlelady's question concerning funding, and let me say, Dr. Pace, that I agree with your last statement concerning the United States and China.

Talking about funding, and this is a question for all three of you gentlemen, and that is that if in fact NASA were funded at the 2008 funding levels, what effect will it have on human space exploration and on the human spaceflight industry, the industry as a whole and the workforce? And I would ask you, Mr. Maser, first.

Mr. MASER. Well, certainly it is below the levels we had anticipated to develop the next-generation launch system. However, in 2008 at those funding levels, the shuttle was in operation with the presumption that shuttle is being retired, and you could reallocate those resources to the next-generation system. I think it would be very challenging, and I think we would have to capitalize on the ability to work more efficiently with our NASA partners and figure out how to operate within that budget, and so I think we would end up probably with lower overall industrial base. would it be devastating? Not as much as the situation we are in right now where we are doing nothing. And then we would have to look at timelines and we would have to look at priorities.

I believe—you know, there is a lot of talk about budgets but I think the reality of the situation, reality that we haven't faced, at least as a Nation and an industry, is that we are going to have to figure out how do with the budgets that are afforded to us by Con-

gress, and I believe a lot can be done and I believe there is a lot of ways to improve what we can do with those budgets. So personally from our perspective, if we headed on a path, we would figure out a way to achieve the same or similar scope as efficiently as possible. It might take a little bit longer, maybe with a little bit less people but it wouldn't be devastating.

Mr. COSTELLO. Dr. Pace?

Dr. PACE. I think the main point is the policy instability we have had and budgetary instability over the last several years has been the thing that has imposed additional costs on NASA. I think NASA is fortunate to receive the funding it does. While I personally might like to see more, I think that the funding levels at 2008, 2009 levels, a lot can get done. The problem that the agency has had is that the composition and prioritization within the agency have shifted dramatically. The top lines have gone down, come back up, shot back down again. So if you are a budget and planning and programmatic person such as Doug Cooke and his staff, it is an incredibly difficult environment to work in. So policy stability and direction at whatever level of funding the Congress is willing to support and then maintain time on target for a couple of years to make progress, that is probably the most important contribution that can be made and I think there is still hope for that.

Mr. COSTELLO. Mr. Cooke?

Mr. COOKE. Yes. Certainly I would agree with Mr. Maser that regardless of funding levels, we would work to do our best to make as much progress as possible. Dr. Pace points out an important fact that when you start working with the top level, then it matters how it is allocated within the agency. If I just look at the funding that we have, if the allocations were such that we had what we had in 2008, it is $200 million or $300 million less than we have right now this year, last year and next probably in that category. So it does matter how it is allocated. We would obviously do our best. The further it drops, the less we get done in a period of time.

Mr. COSTELLO. I thank you.

Mr. Chairman, let me just comment. When we are talking about the authorization and the intent of Congress, I agree with someone who suggested that the way to make certain that the authorization is followed by the agency is through the appropriations process, and I would suggest that that is where we ought to be talking as far as the intent of the authorization, making sure that the appropriators understand that and look at the 2010 authorization.

And finally, Mr. Cooke, let me commend you for your service. I understand that you have announced your retirement and that you are moving on, and you have had a distinguished career with the agency, and I think Chairman Hall said earlier that his remarks were not directed at you personally, and I have said the same thing, but you had a distinguished career and you have done, in my judgment, an excellent job for the agency and for the taxpayers, and I wish you well in the future.

Mr. COOKE. Thank you, sir.

Chairman PALAZZO. Thank you for that, Mr. Costello, and I am sure the entire Committee appreciates your service over the years. Thank you for your commitment and your dedication.

I want to thank all the witnesses for their valuable testimony here today, and the Members for their questions and their patience for the time overruns. It was a great exchange of information, and this membership has no lack of passion in finding solutions to NASA's problems.

The Members of the Subcommittee may have additional questions for the witnesses, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments from Members.

The witnesses are excused and this hearing is adjourned.

[Whereupon, at 11:42 a.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Douglas Cooke, Associate Administrator, Exploration Systems Mission Directorate, National Aeronautics and Space Administration

Questions for the Record from Chairman Steven Palazzo

Q1. What concrete steps is NASA taking, or planning to take, to minimize delays and disruptions in the transition from Constellation program to the Space Launch System?

A1. The President is committed to ensuring America's continued preeminence in space and launching a new era of human spaceflight that takes us beyond where we have ever explored before. Space exploration inspires the next generation of scientists and engineers and contributes to important discoveries about Earth and the solar system as well as innovation that grows our economy and creates jobs. NASA shares Congress' goal of restoring our Nation's human space launch and exploration capabilities as soon as possible and is committed to implementing the Space Launch System (SLS) that Congress authorized in the NASA Authorization Act of 2010. NASA is also committed to responsible stewardship of taxpayer dollars. Especially in these fiscal times, we must be prudent so that our space exploration program remains sustainable in the long run.

Over the last several months, NASA has evaluated options for developing an integrated and incremental development approach for the SLS, Multipurpose Crew Vehicle (MPCV) and their associated support elements that will be capable of achieving progress in an incremental and sustainable manner.

On May 24, 2011, NASA announced its decision to accept the Orion-based reference vehicle design, first outlined in NASA's January 2011 report to Congress, as the Agency's MPCV. NASA further determined that the contractual partnership with Lockheed Martin Corporation maps well to the scope of the MPCV requirements outlined in the NASA Authorization Act of 2010 and the current contract will be used for the development phase of the MPCV.

On September 14, 2011, NASA announced its selection of the design for a new space exploration system that will take humans far beyond Earth. This important decision will create high-quality jobs here at home and provide the cornerstone for America's future human space exploration efforts. This new heavy-lift rocket will be America's most powerful since the Saturn V rocket that carried Apollo astronauts to the moon and will be capable of launching humans to places no one has gone before, such as asteroids, Mars and other deep space destinations.

In combination with the crew capsule already under development, increased support for the commercialization of astronaut travel to low Earth orbit, an extension of activities on the International Space Station until at least 2020, and a fresh focus on new technologies- this rocket is key to implementing the plan laid out by President Obama and Congress in the bipartisan NASA Authorization Act of 2010, which the President signed last year.

This launch vehicle decision is the culmination of a months-long, comprehensive review of potential designs to ensure that the nation gets the best possible rocket for the investment-one that is not only powerful but is also evolvable so it can be adapted to different missions as opportunities arise and new technologies are developed.

The rocket will use a liquid hydrogen and liquid oxygen fuel system, where RS–25D/E engines will provide the core propulsion and the J2X engine is planned for use in the upper stage. There will be a full and open competition to develop the boosters based on performance requirements. Its early flights will be capable of lifting 70–100 metric tons before evolving to a lift capacity of 130 metric tons.

The early developmental flights may take advantage of existing solid boosters and other existing hardware, which will help us control costs and make early tests smoother.

NASA has continued important work on existing Ares and Shuttle contracts that will benefit the SLS, including:

- Assembly of the Orion Ground Test Article was recently completed and it is being prepared for a series of ground-based environmental tests to validate the Orion design and computer models;
- The former Ares Project focused their development efforts on technologies and processes that could be utilized in the eventual SLS configuration, including vehicle avionics, J–2X engine testing, first stage motor testing (Development Motor-3), and installation of upper stage tooling applicable to large-diameter tanks; and

- Significant progress has been made in the modifications to Pad B at Launch Complex 39 at Kennedy Space Center in Florida. There are new fiber optic cables replacing copper wire, new digital control systems for the pad utilities, and a state of the art lightning protection system that helped us clear the Shuttle during STS–135 processing. These modifications have been done in continued preparation for clean pad, multi-user capability including SLS.

Q2. Your testimony states that NASA is considering infrastructure consolidation as part of the SLS program. What infrastructure consolidations are being considered and what are their anticipated cost savings?

A2. Moving forward on the SLS, one of NASA's greatest challenges will be to reduce the development and operating costs (both fixed and recurring) for human spaceflight missions to sustain a long-term U.S. human spaceflight program. We must plan and implement an exploration enterprise with costs that are credible and affordable for the long term under constrained budget environments.

NASA is currently assessing a number of potential opportunities for reducing the institutional costs associated with developing, producing, and operating SLS. For example:

- Stennis Space Center: NASA continues to partner with other federal government and commercial customers to maximize utilization of the rocket test facilities at Stennis. United Launch Alliance and the Air Force already utilize test stand capabilities there, including the B1 test stand for RS–68 testing and the E-complex for component and small-thrust testing. NASA is currently considering other potential opportunities for sharing capabilities. In addition, NASA is continuing to bring the A–3 test stand, which is under construction and which NASA does not require for near-term altitude testing, to a level that is safe to put in extended standby until a future use is identified.
- Kennedy Space Center: As part of the 21st Century Ground Systems Program initiative to recapitalize the launch capabilities at KSC, NASA continues to seek additional users and innovative uses for KSC infrastructure and capabilities, including SLS, in an effort to increase operational efficiency and reduce the launch costs for all customers. Discussions with potential government and commercial users were initiated in FY 2010 and continue today.
- Michoud Assembly Facility: We are looking for additional Government and non-Government users for that facility.
- As part of Shuttle transition and retirement, a wide range of facilities are being considered for retirement.
- At the Agency-level, capabilities forums are conducted to examine needs for facilities with the objective to consolidate and retire those not needed.

Several of NASA's current industry partners such as ATK and Pratt Whitney Rocketdyne are also looking at infrastructure reduction, streamlining and consolidation to help reduce their fixed costs. In addition to prudent consolidation of infrastructure, the SLS Program will continue to examine ways to increase efficiency and agility to deliver an affordable and achievable heavy-lift system as soon as possible. Examples being considered in formulating SLS plans include the following:

- Using common parts and common designs across the Government to reduce costs;
- Ensuring requirements are appropriately specific and also that requirements applied to NASA crew launch vehicles are similar to those provided to our eventual commercial crew partners, thereby ensuring that NASA vehicles are not required to meet more substantial requirements than commercial crew vehicles and vice versa;
- Conducting insight/oversight activities of our contract partners in a smarter way, thereby using our resources more appropriately to focus on the high-risk items; and
- Ensuring that there are no unique configurations or developments that do not end up directly supporting the final system.

Q3. What FY 2011 funds have been allocated to date on the SLS and MPCV projects?

A3. Please see the attached charts.

SLS and MPCV Financial Information (Obligations as of July 15, Cost as of end of June)

$M	2010 Total Funding (compare to 2011 Initial Operating Plan)	FY 10 Obligations through Jun, All PY (compare against FY 11 Jun amount)	FY 2011 Planned Funding	FY 11 Obligations through July 15, 2011, All PY	Anticipated Obligations for Remainder of FY 11, All PY	Anticipated Obligations for All of FY 11, All PY	Anticipated Unobligated Carried Out of FY 11	FY 11 Costs through June, All PY	FY 2011 Costs by Month, All Program Years										Anticipated Costs for Remainder of FY 2011	Anticipated Costs for All of FY 11
									Oct FY 2011	Nov FY 2011	Dec FY 2011	Jan FY 2011	Feb FY 2011	March FY 2011	April FY 2011	May FY 2011	Jun FY 2011			
Human Exploration Capabilities Total	**3,287.490**	**2,491.051**	**2,982.100**	**2,278.345**	**343**	**2,621**	**479**	**1,927.842**	**223.316**	**197.551**	**185.631**	**211.988**	**200.692**	**247.970**	**203.571**	**222.141**	**236.485**		**612**	**2,540**
Space Launch System & Ground Operations Total	1,721.107	1,243.213	1,786.100	1,259.277	262	1,521	378	1,123.005	138.073	109.743	121.452	128.770	122.063	137.094	117.895	117.983	131.432		366	1,489
Headquarters Program Support	5.816	0.507	34.200	29.407	7	36	2	19.872	0.613	1.065	1.305	1.658	2.227	3.031	4.206	3.779	3.487		7	27
Ground Operations	170.373	127.968	250.000	133.573	81	215	36	143.089	18.731	15.515	15.500	15.239	16.350	15.395	14.936	14.838	16.584		46	190
Ares I and SLS	1,387.333	1,004.384	1,311.416	958.401	93	1,052	284	824.273	109.568	80.281	88.131	96.796	88.308	101.372	80.682	84.525	94.611		270	1,095
Constellation Transition	No 2010 Funding	No PY 10 Funding	68.279	45.122	23	68	-	44.887	1.059	2.953	4.696	4.208	5.077	6.950	6.410	6.816	6.718		12	57
Altair and Lunar Surface Systems	19.756	11.489	13.948	11.119	5	16	-	10.458	1.434	1.253	1.050	1.211	0.902	1.415	1.410	1.392	0.392		5	15
Program Integration	137.829	98.864	108.257	81.655	52	134	56	80.426	6.669	8.675	10.771	9.658	9.199	8.930	10.250	6.633	9.640		25	106
Multi-Purpose Crew Vehicle Total	1,566.383	1,247.838	1,196.000	1,019.067	81	1,100	100	804.837	85.244	87.808	64.179	83.217	78.629	110.876	85.677	104.158	105.053		246	1,051
Headquarters Program Support	4.641	1.290	18.300	5.381	13	18	-	1.843	0.002	0.014	0.082	0.029	0.128	0.164	0.344	0.590	0.493		1	2
Orion and MPCV	1,436.459	1,179.727	1,083.134	952.284	38	990	99	726.631	78.537	80.222	56.060	71.676	70.584	101.490	77.499	95.714	94.848		221	948
Extravehicular Activity	57.684	28.817	21.471	14.977	5	20	1	21.421	2.814	2.294	1.930	2.540	2.301	2.562	2.135	2.548	2.298		8	29
Mission Operations	67.599	38.005	73.095	46.426	25	71	-	54.942	3.890	5.278	6.108	8.971	5.616	6.660	5.699	5.306	7.414		17	72

2011 SLS and MPCV Funds Distributed as of July 15, 2011

$M	NASA Headquarters	Ames Research Center	Glenn Research Center	Langley Research Center	Dryden Flight Research Center	Goddard Space Flight Center	Jet Propulsion Laboratory	Marshall Space Flight Center	Stennis Space Center	Johnson Space Center	Kennedy Space Center	Total Distributed, All Centers	Total Planned FY 2011 Funding	FY 2011 Funding Remaining to be Distributed
Exploration Systems Development Total	**11**	**32**	**42**	**43**	**9**	**5**	**6**	**963**	**38**	**1,137**	**209**	**2,495**	**2,982**	**486**
Space Launch System & Ground Operations Total	8	19	23	26	3	4	5	953	38	78	203	1,361	1,786	424
Headquarters Program Support	5	2	1	5	-	0	2	7	0	9	2	33	34	2
Ground Operations	-	1	0	-	-	-	-	0	-	14	197	212	250	38
Ares I and SLS	2	4	7	7	-	-	0	886	37	0	1	944	1,311	367
Constellation Transition	-	1	12	10	3	0	-	19	1	9	1	57	68	11
Altai and Lunar Surface Systems	-	0	1	1	0	1	1	2	-	7	0	13	14	1
Program Integration	1	8	1	4	0	3	2	39	0	43	3	103	108	5
Multi-Purpose Crew Vehicle Total	3	14	20	17	6	1	1	9	0	1,058	6	1,134	1,196	62
Headquarters Program Support	3	0	0	1	-	0	-	4	0	2	1	12	18	6
Orion and MPCV	-	10	19	16	6	0	0	5	-	969	5	1,030	1,083	53
Extravehicular Activity	-	-	1	-	-	-	-	-	-	18	-	19	21	2
Mission Operations	-	4	-	0	-	-	0	0	-	68	-	73	73	0

Q4. The Department of Defense and National Reconnaissance Office recently committed to buying eight Evolved Expendable Launch Vehicle (EELV) cores per year for each of the next five years. NASA did not commit to any purchases, and plans to rely on the NASA Launch Services 2 contract for future acquisitions. What is the rationale for this decision and what is the cost savings, if any, resulting from this decision?

A4. On March 10, 2011, NASA, the U.S. Air Force (USAF), and the National Reconnaissance Office (NRO) signed a Memorandum of Understanding (MOU) related to Evolved Expendable Launch Vehicles (EELVs). The MOU included USAF and NRO commitments to procure booster cores during FY 2013 through FY 2017, subject to Milestone Decision Authority. At the time of signing this agreement, the NASA requirements for procurement of EELV booster cores had already been fulfilled through FY 2015, with one EELV procurement in FY 2011 and two EELV procurements in FY 2012. The NASA manifest beyond 2015 was not firm enough to commit to the procurement of further EELV booster cores during the FY 2013 to FY 2019 timeframe. NASA informed the Department of Defense (DOD) of its projected EELV procurements so that DOD could factor them into its planning.

The majority of NASA's missions are not EELV-class payloads, and the Agency's requirements for launches on EELVs (i.e., Atlas V and Delta IV launch vehicles) have historically been one or two launches per year.

Further, while the USAF and NRO launch payloads are specifically designed to be flown on EELVs, it is not a foregone conclusion that a NASA payload will be flown on an EELV. NASA procures its missions, consistent with the Commercial Space Act of 1998 (Public Law 105–303), through the NASA Launch Services II (NLS II) contract during a competition amongst the launch service contractors available on this Federal Acquisition Regulation (FAR) Part 12 contract. There are four contractors available to bid on NASA missions.

Finally, in addition to the USAF and NRO booster core commitment, the EELV MOU also established the jointly-chaired Government Expendable Launch Vehicle (ELV) Executive Board as a forum for interagency communication of acquisition, certification, and programmatic ELV launch issues. This forum will be used by NASA to formally notify the ELV Executive Board (including DOD and NRO) of its intent to procure EELV booster cores so these launch service requirements can be taken into account along with a DOD "block buy" commitment, and thereby benefit all parties.

Regarding cost savings, the NLS II contract enables NASA to continue to procure EELVs in a "commercial" manner and pay only the launch infrastructure cost associated with the NASA EELV launch flow (approximately $15 million per mission). In addition, the NLS II contract contains a "most favored customer" clause. This clause requires all NLS providers, including ULA, to charge NASA the same equivalent price for the basic launch service. The clause states:

"The Contractor hereby certifies the CLIN [Contract Line Item Number] prices for standard launch services (including standard mission integration) under this contract are no higher than the lowest price charged to any other commercial or U.S. Government customer for an equivalent launch service during the twelve (12) months both preceding and following contract award, or placement of a launch service task order. The Government shall be entitled to a one-time reduction in contract price for each standard launch service failing to meet this certification. The price credit will be equal to the difference between the standard launch service price under this contract and the lower price awarded for an equivalent launch service."

Thus, any NASA-procured EELV booster cores bought on the NLS II contract during the USAF block buy timeframe will receive the discounted pricing.

Background on NASA Launch Services

The Commercial Space Act of 1998 requires NASA and other Federal agencies to plan missions and procure space transportation services from U.S. commercial providers to the maximum extent practicable; Section 202 of Public Law 105–303 defines space transportation services as a "commercial item." The NASA Launch Service Program at Kennedy Space Center acquires these commercial launch services for NASA-owned and NASA-sponsored payloads through multiple Indefinite Delivery Indefinite Quantity Task Order contracts with negotiated not-to-exceed (NTE) prices. These NASA Launch Service (NLS) contracts provide launch services on a firm, fixed-price basis and incorporate best commercial practices to the maximum extent possible.

The NLS contracts have been the primary mechanism to procure commercial launch services since June 2000. The original NLS contract's ordering period expired in June 2010. The NLS II follow-on contract was awarded in September 2010, and is essentially a continuation of the NLS contract. There are currently four providers

on the NLS II contract: United Launch Alliance (ULA), Orbital Sciences Corporation (OSC), Space Exploration Technologies (SpaceX) and Lockheed Martin. To obtain an NLS contract, each provider had to meet the minimum qualification criteria, including being ISO9001 third-party certified and being a domestic source that is more than 50 percent owned by United States nationals.

NASA-owned and NASA-sponsored launch services are competitively procured on the NLS contracts in accordance with FAR Part 12 through the competitive Launch Service Task Order (LSTO), using specific mission requirements. Each NLS provider is given fair opportunity to be considered for each task order provided they have had one successful flight prior to submittal of an LSTO proposal. The NLS providers are required to propose on all task orders unless the NLS Contracting Officer waives the requirements for legitimate reasons (e.g., limited capacity to perform, excessive performance capability, first successful flight not achieved). Evaluation and award is based on Best Value to the Government, considering standard proposal evaluation factors: technical capability/risk; reasonableness of proposed price; and past performance. The NASA LSP negotiates launch prices for its missions through the LSTO process. The NLS contacts have a pre-negotiated set of NTE prices for the standard launch services, however, the contractors may propose (and, previously, have proposed) a lower price than the NTE prices.

Questions for the Record from Rep. Sandy Adams

Q1. Is NASA using the budget direction given by the NASA Authorization Act or direction given by OMB when doing its budget analysis of the SLS and MPCV?

A1. NASA remains committed to the faithful execution of the NASA Authorization Act of 2010 (P.L. 111–267), and the FY 2011 Full-Year Continuing Appropriations Act (P.L. 112–10). NASA has taken both laws into account when conducting ongoing schedule and cost analyses for the SLS and MPCV systems and their associated elements. Given that these Programs are multi-year endeavors, NASA must also take into account projections for funding in FY 2012 and out—projections that are included as part of any annual President's budget request.

Q2a. There are currently 16 agencies doing climate change research. NASA has seen an increase in funding for climate change research and a decrease in funding for space exploration. How has the shift in funding from exploration and toward climate change research impeded your ability to advance human space flight?

A2a. The President's FY 2012 budget request continues the Agency's focus on a reinvigorated path of innovation and technological discovery leading to an array of challenging destinations and missions that increases our knowledge, develop technologies to improve life, to expand our presence in space for knowledge and commerce, and that will engage the public.

NASA's budget reflects a balance of human space flight, science, aeronautics and technology development. The request prioritizes the International Space Station—and the safety and efficacy of its associated functions as well as a strong commitment to human spaceflight beyond low Earth orbit. It establishes critical priorities and invests in the technologies and excellent science, aeronautics research, and education programs that will help us in the future. The request supports an aggressive launch rate over the next two years with about 40 U.S. and international missions to the ISS, for science, and to support other agencies.

The proposed FY 2012 budget funds all major elements of the Authorization Act, supporting a diverse portfolio of programs, while making difficult choices to fund key priorities and reduce other areas in order to invest in the future. NASA's mission remains fundamentally the same as it always has been and supports our new vision statement —"To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind."

Q2b. What steps are being taken today to minimize the gap between the final shuttle flight and the operational capability of the SLS/MPCV?

A2b. The President is committed to ensuring America's continued preeminence in space and launching a new era of human spaceflight that takes us beyond where we have ever explored before. Space exploration inspires the next generation of scientists and engineers and contributes to important discoveries about Earth and the solar system as well as innovation that grows our economy and creates jobs. NASA shares Congress' goal of restoring our Nation's human space launch and exploration capabilities as soon as possible and is committed to implementing the Space Launch System (SLS) that Congress authorized in the 2010 NASA Authorization Act. NASA

is also committed to responsible stewardship of taxpayer dollars. Especially in these fiscal times, we must be prudent so that our space exploration program remains sustainable in the long run.

Over the last several months, NASA has evaluated options for developing an integrated and incremental development approach for the SLS, Multipurpose Crew Vehicle (MPCV) and their associated support elements that will be capable of achieving progress in an incremental and sustainable manner.

On May 24, 2011, NASA announced its decision to accept the Orion-based reference vehicle design, first outlined in NASA's January 2011 report to Congress, as the Agency's MPCV. NASA further determined that the contractual partnership with Lockheed Martin Corporation maps well to the scope of the MPCV requirements outlined in the NASA Authorization Act of 2010 and the current contract will be used for the development phase of the MPCV.

On September 14, 2011, NASA announced its selection of the design for a new space exploration system that will take humans far beyond Earth. This important decision will create high-quality jobs here at home and provide the cornerstone for America's future human space exploration efforts. This new heavy-lift rocket will be America's most powerful since the Saturn V rocket that carried Apollo astronauts to the moon and will be capable of launching humans to places no one has gone before, such as asteroids, Mars and other deep space destinations.

In combination with the crew capsule already under development, increased support for the commercialization of astronaut travel to low Earth orbit, an extension of activities on the International Space Station until at least 2020, and a fresh focus on new technologies- this rocket is key to implementing the plan laid out by President Obama and Congress in the bipartisan NASA Authorization Act of 2010, which the President signed last year.

This launch vehicle decision is the culmination of a months-long, comprehensive review of potential designs to ensure that the nation gets the best possible rocket for the investment-one that is not only powerful but is also evolvable so it can be adapted to different missions as opportunities arise and new technologies are developed.

The rocket will use a liquid hydrogen and liquid oxygen fuel system, where RS–25D/E engines will provide the core propulsion and the J2X engine is planned for use in the upper stage. There will be a full and open competition to develop the boosters based on performance requirements. Its early flights will be capable of lifting 70–100 metric tons before evolving to a lift capacity of 130 metric tons.

The early developmental flights may take advantage of existing solid boosters and other existing hardware, which will help us control costs and make early tests smoother.

NASA has continued important work on existing Ares and Shuttle contracts that will benefit the SLS, including:

- Assembly of the Orion Ground Test Article was recently completed and it is being prepared for a series of ground-based environmental tests to validate the Orion design and computer models;
- The former Ares Project focused their development efforts on technologies and processes that could be utilized in the eventual SLS configuration, including vehicle avionics, J–2X engine testing, first stage motor testing (Development Motor-3), and installation of upper stage tooling applicable to large-diameter tanks; and
- Significant progress has been made in the modifications to Pad B at Launch Complex 39 at Kennedy Space Center in Florida. There are new fiber optic cables replacing copper wire, new digital control systems for the pad utilities, and a state of the art lightning protection system that helped us clear the Shuttle during STS–135 processing. These modifications have been done in continued preparation for clean pad, multi-user capability including SLS.

These capabilities will be brought online as soon as feasible.

Q3. In your testimony to the subcommittee, you said in response to a question about how FY 2008 funding levels would affect NASA:

"regardless of funding levels we would work to do our best to make as much progress as possible. And Dr. Pace points at an important fact that when you start working with the top level then it matters how it's allocated within the agency. "

NASA's human spaceflight programs are undergoing a once in a generation upheaval not seen since the end of the Apollo program. Why hasn't NASA and the Administration acknowledged this unique situation and reprioritized funding from other directorates to permit a more reasonable transition and adhere to the guidance of the Authorization Act?

A3. The President's FY 2012 budget request continues the Agency's focus on a reinvigorated path of innovation and technological discovery leading to an array of challenging destinations and missions that increases our knowledge, develop technologies to improve life, to expand our presence in space for knowledge and commerce, and that will engage the public.

NASA has an incredible balance of human spaceflight, science, aeronautics and technology development. The request prioritizes the International Space Station—and the safety and efficacy of its associated functions as well as a strong commitment to human spaceflight beyond low Earth orbit. It establishes critical priorities and invests in the technologies and excellent science, aeronautics research, and education programs that will help us in the future. The request supports an aggressive launch rate over the next two years with about 40 U.S. and international missions to the ISS, for science, and to support other agencies.

The proposed FY 2012 budget funds all major elements of the Authorization Act, supporting a diverse portfolio of programs, while making difficult choices to fund key priorities and reduce other areas in order to invest in the future. NASA's mission remains fundamentally the same as it always has been and supports our new vision statement —"To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind."

Questions for the Record from Acting Ranking Member Jerry F. Costello

Q1. What is the primary mission that is leading to the requirements for the initial capability of the Space Launch System (SLS) and Multi-Purpose Crew Vehicle (MPCV)? What is the target date for that mission and what has NASA determined as the subsequent missions for the initial SLS and MPCV capability and when will those missions occur?"

A1. NASA plans to launch an initial uncrewed test flight of an integrated early version of the SLS and the MPCV as early as 2017. At present, as designated by the President, a key early destination for human flight beyond LEO is a crewed flight to an asteroid by 2025. Other destinations to follow could include cis-lunar space such as the Earth-Moon Lagrange points, the lunar surface, and eventually Mars and its moons.

Q2. Please describe in concrete terms what NASA is evaluating as it reviews Constellation contracts for potential translation to the SLS? What would be a definitive reason for not being able to transfer or modify Shuttle and Ares-I contracts for work on SLS?

A2. Analysis has been performed to make an assessment of contract scope to determine whether or not the SLS requirements are within the existing scope of the Ares contracts. If they are within the general scope of the existing contract(s), then it would be permissible to utilize the Ares contract(s) to accomplish SLS effort. If the analysis determines that the effort represents a material departure from the general scope of the original contract, then Federal Acquisition Regulations require competition or execution of a Justification for Other than Full and Open Competition prior to using the Ares contract for SLS effort. This analysis has been accomplished on a contract-by-contract basis.

NASA procurement teams have mapped SLS requirements. NASA has reviewed each element of Ares (First Stage, Upper Stage, Upper Stage J–2X engine, and avionics) and Shuttle Program contracts (Space Shuttle Main Engines, External Tank, solid rocket booster) to determine whether the new SLS requirements would be within scope of current contracts. At the same time, NASA has assessed SLS competition options, including the potential degree of competition.

Q3. What could be done with the projected level of resources in the FY 2012 budget request in terms of building an operational capability for the SLS and MPCV and when would that operational capability be achieved?

A3. The President's FY 2012 Budget requested $1.0 billion for the MPCV and $1.80 billion for SLS. NASA's direction to expedite development of the two programs is consistent with the NASA Authorization Act of 2010.

With funds requested in FY 2012, the MPCV Program will do a series of tests on the crew module ground test article that will determine how the integrated crew module and launch abort system respond to environmental and structural tests. In addition, the heat shield carrier structure will be finalized and integrated into the ground test article and taken to Langley Research Center for a series of water drop tests, which will mimic the landing conditions Orion will be subjected to. The program is also planning to conduct a series of parachute drop tests, wind tunnel tests,

and arch jet tests. All of these will inform the most important milestone for the program in 2012 which is to begin building the components and manufacturing of the first space worthy Orion crew vehicle. This includes the integration of avionics, software, hardware and outfitting the module.

With funds requested in FY 2012, the Space Launch System Program will make significant programmatic and technical progress in FY 2012 toward a heavy lift operational capability, to include a System Requirements Review early in the fiscal year, enabling a System Definition Review in mid-2012. Current acquisition planning activities will lead to procurements necessary for the Design, Development, Test and Evaluation of systems for initial SLS test flights.

Specific activities include refurbishment, fabrication and casting of Booster Qualification Motor (QM–1) for initial test flight application. Test and evaluation of the first J–2X development engine plus manufacturing and test of the second J–2X development engine and the J–2X powerpack assembly will occur in FY 2012, as well as design and development of core stage engines for initial test flights and evolved heavy lift capability. MPCV Adapter SRR and SDR are also planned for FY 2012, as well as initial design and development of payload adapter and fairing. And finally, design and development of baseline SLS Avionics and software, applicable to initial test flights as well as an evolved capability vehicle, and preparation for SLS avionics Preliminary Design Review will be achieved in FY 2012.

In order to meet our flight test schedule, all of these milestones provided for in the FY 2012 budget request will need to be accomplished. The intent of the President's budget request and of NASA planning (and the earliest we can prudently estimate given the scale of SLS development) is to conduct the first uncrewed flight test of an MPCV atop the SLS by the end of calendar year 2017 and the first crewed flight test in 2021.

Q4. Mr. Maser said in his prepared statement that if NASA is relieved of Constellation obligations, industry needs to know how the workforce will be transitioned and how the many investments will be utilized for future exploration efforts. Will industry have those answers when you provide your report to us in the late June timeframe? If not, what other activities and decisions are needed and when will those be completed?

A4. NASA has been preparing for Space Shuttle retirement since 2004, including conducting ongoing activities to facilitate transition of both key NASA civil service employees and contractor employees to other programs. The passage of the NASA Authorization Act of 2010 (P.L. 111–267) has provided valuable direction to the Agency and improved its ability to make workforce planning decisions. With this guidance, NASA has continued its efforts to map out the transition of its human spaceflight workforce from the Space Shuttle and Constellation programs. This effort is reflected in the Agency's update to its Workforce Transition Strategy report, provided to Congress in September, 2011. The first three editions of this report may be viewed at the website below, under "Workforce Highlights—View Archives." These reports provide details on NASA's initiatives to assist with workforce transition.

http://www.nasa.gov/transition/

On May 24, 2011, NASA announced its decision to accept the Orion-based reference vehicle design, first outlined in NASA's January 2011 report to Congress, as the Agency's MPCV. NASA further determined that the contractual partnership with Lockheed Martin Corporation maps well to the scope of the MPCV requirements outlined in the NASA Authorization Act of 2010 and the current contract will be used for the development phase of the MPCV. As such, the MPCV Program will continue the roles and responsibilities currently performed by the Orion civil service workforce amongst the NASA field centers.

On September 14, 2011, NASA announced its selection of the design for a new space exploration system that will take humans far beyond Earth. This important decision will create high-quality jobs here at home and provide the cornerstone for America's future human space exploration efforts. The rocket will use a liquid hydrogen and liquid oxygen fuel system, where RS–25D/E engines will provide the core propulsion and the J2X engine is planned for use in the upper stage. There will be a full and open competition to develop the boosters based on performance requirements. Its early flights will be capable of lifting 70–100 metric tons before evolving to a lift capacity of 130 metric tons.

NASA intends to maximize efficiency and minimize cost by leveraging investments in legacy space launch systems, as the investments are determined to be in the best interest to NASA, while using evolutionary advancements in launch vehicle design. Additionally, NASA will employ modern manufacturing and processing tech-

niques, improved insight/oversight practices, and streamlined infrastructure requirements. Through this approach, NASA will employ key components of the existing industrial base and will utilize the critical skills and knowledge base of the NASA civil service and contractor workforce.

NASA procurement teams have mapped SLS requirements. NASA has reviewed each element of Ares (First Stage, Upper Stage, Upper Stage J–2X engine, and avionics) and Shuttle Program contracts (Space Shuttle Main Engines, External Tank, SRB) to determine whether the new SLS requirements would be within scope of current contracts. At the same time, NASA has assessed SLS competition options, including the potential degree of competition. Final acquisition decisions for the SLS are expected to be made this fall. Until that time, NASA cannot predict what industry workforce impacts there would be.

With regard to civil servants, NASA's civil servants across the Agency should feel confident that there is exciting and meaningful work for them to do following the retirement of the Shuttle and the transition from Constellation, and the shift from assembly of the ISS toward ISS operations. Turning the Agency's focus toward a more capability-driven exploration architecture will offer far-ranging opportunities for the creative and skilled civil servant workforce across the Agency. There will be opportunities for them to apply their cross-cutting talents to new challenges, such as developing and demonstrating prototypes for human capabilities needed for beyond-LEO exploration. Here are just a few examples of enabling capabilities that must be developed before NASA can send crews beyond LEO—work that will be managed by the new Advanced Exploration Systems (AES) Program:

- Developing a ground-based test bed for demonstrating life support systems needed to enable long-duration crewed missions based on lessons learned from operation of the life support systems currently in use on the ISS;
- Developing and testing components for an advanced spacesuit to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the Moon, Mars and asteroids;
- Developing design concepts for future space exploration vehicles and deep-space habitats; and
- Conducting ISS and ground-based analog testing to validate operational concepts for long-duration missions.

Q4. How will lessons learned from the workforce, design and development work, and the management of Constellation be transferred to the SLS and MPCV programs? What are the most important take-away lessons from Constellation at this point?

A4. In planning the SLS and MPCV programs, NASA is taking to heart one of the key lessons of the Constellation Program—that a successful space launch system must be affordable, sustainable and realistic. The NASA Administrator has made clear that he will not propose a human spaceflight program that he is not fully confident he can deliver.

Much of what Constellation has accomplished is indeed transferable to the SLS and MPCV programs. For example, after rigorous analysis, the Orion design and contract was found to be the correct technical answer for the MPCV. The J2–X engine development originally initiated as part of the former Ares Project is absolutely applicable to our needs for the heavy lift vehicle, as are the avionics for the Upper Stage. Additionally, the five-segment booster that continues to undergo development and testing will support our early flights while a competition for advanced boosters is initiated and awarded. Much of what is transferable is not just hardware, validated requirements and infrastructure elements, but also less tangible items such as knowledge and experience gained by our team with the Constellation Systems being developed; from better understanding of the role of Government through refined insight/oversight models to advanced manufacturing techniques for the Upper Stage. As we work to close out the Constellation Program we are also taking care to capture and build upon Program accomplishments, especially those technologies that have a high likelihood of feeding forward into the SLS and MPCV programs.

From the beginning, the Constellation Program used electronic records and a centralized database to capture and manage all data, risks and knowledge learned, including information from test flights, hardware and software tests and programmatic reviews. Therefore, there is a wealth of information that the Program will be able to pass on to future human spaceflight developers, including those at NASA and those in the U.S. aerospace industry, when allowable by law.

The Constellation Program also can be credited with helping to reinvigorate NASA's technical base. Following the development of the Shuttle, NASA's human spaceflight launch community focused on operations rather than development in

that we were no longer a robust developmental Agency in terms of developing crew-launch systems, but rather an operationally-focused human spaceflight Agency. As such, the Constellation Program enabled us to re-learn how to build a crew launch system, beginning from the earliest stages of formulation and advancing through multiple key project review checkpoints and ultimately to the point where NASA, along with its industry partners, had built hardware and integrated systems that were used on two major test flights, the Ares I–X flight and the Pad Abort 1 (PA–1) flight for the Orion Launch Abort System (LAS). Each of these test flights produced substantial data that will be of great use to the MPCV and the SLS programs.

Additionally, the Constellation Program allowed us to incorporate new technologies and testing methods that will certainly become the norm as we move forward with SLS and MPCV. Historically speaking, during the Apollo era, NASA had comparatively little experience with in-flight aborts and limited computational capability. Today, however, flight tests are being combined with advanced simulation tools and advanced computers, thereby allowing NASA to conduct a more thorough analysis of hardware and software elements and operating processes. In fact, the increased accuracy of our computer modeling scenarios has allowed NASA to forgo more expensive ground tests in some cases, and we expect to see this trend continue with the SLS and MPCV programs, whenever possible without sacrificing safety.

Going forward, SLS and MPCV will continue to focus on a risk-informed design approach, as Constellation has done, thus helping the Agency achieve its goal of increasing astronaut safety on the next-generation human spaceflight system, relative to Shuttle missions. As such, NASA will continue to design systems with an overriding priority given to crew safety at every stage of the design and operational process. In doing so, we will design systems to be as inherently safe as we can make them; we will eliminate known risks and hazards; and then we will add backup such as an abort system to mitigate residual risks. In addition to leveraging heritage systems, when feasible, NASA will continue to utilize improved computer modeling to help identify, reduce and eliminate or mitigate hazards and risk. Additionally, we will continue to tightly interweave design and safety team members into the decision-making process, thereby allowing them to work with design engineers to provide expertise and feedback via various assessments and analysis techniques from the very beginning of the design process. At the same time, a prudent risk system will result in better cost/benefit assessments to improve overall affordability without sacrificing safety. Finally, NASA will continue to utilize its active risk-management process to identify technical challenges early in the process and aggressively work solutions.

NASA knows how important it is to identify ways to make our programs and projects more efficient, so finding and incorporating these efficiencies remains a primary goal. We have embraced the challenge to deliver human spaceflight systems for lower cost, and the opportunity to become more efficient, innovative and agile in our programs. For example, we are revising the management of our requirements, contracts, and projects and incorporating approaches to ensure affordability in the near term and over the long run. This includes the use of focused insight/oversight, specifying to industry—where appropriate—what we need instead of how to build it, designing for cost-effective operations, increasing the use of common components and parts, and wisely consolidating infrastructure.

Questions for the Record from Rep. Donna Edwards

Q1. What, in precise terms, does NASA mean by an incremental, evolvable SLS and MPCV? Please provide specific examples of how the systems will be evolved and when.

A1. While our initial development efforts would focus on the 70–100 metric ton lift capability, in parallel, we would plan to capitalize on synergies between Core Stage and Upper-Stage design and manufacturing, thereby allowing us the ability to develop some of the upper-range capabilities for an eventual 130metric ton capability vehicle at the same time. Doing so is actually a fairly natural, evolvable progression in terms of developing these capabilities.

This strategy allows for early test flights. These would include early flights that would begin with a lift capacity in the 70–100 metric ton range, sufficient to get out of Low Earth Orbit with meaningful mission content, with the first flight targeted for the end of 2017 and the second flight targeted for 2021. Therefore, the 70–100 metric ton flight configurations will offer early development of the Core Stage, continuation of the Orion-based design as the MPCV, an Upper Stage/kick motor ca-

pability that will enable a series of development missions/test flights beyond LEO, and use of existing solid rocket boosters.

Q2. What is the baseline plan for the SLS and what, if anything, would cause NASA to deviate from that plan?

A2. The Administration is committed to supporting this development and working with the Congress to identify and provide the resources necessary to ensure America's leadership in space exploration continues. While the fiscal challenges facing the country are great, a shared commitment to sustaining a space program worthy of a great nation will be the key to the success of this new human spaceflight program designed and destined to move the focus of NASA's space exploration efforts beyond low-Earth orbit. In the end, any successful space launch system must be affordable, sustainable and realistic, and NASA will not propose a program we are not fully confident we can deliver.

On September 14, 2011, NASA announced its selection of the design for a new space exploration system that will take humans far beyond Earth. This important decision will create high-quality jobs here at home and provide the cornerstone for America's future human space exploration efforts. This new heavy-lift rocket will be America's most powerful since the Saturn V rocket that carried Apollo astronauts to the moon and will be capable of launching humans to places no one has gone before, such as asteroids, Mars and other deep space destinations.

In combination with the crew capsule already under development, increased support for the commercialization of astronaut travel to low Earth orbit, an extension of activities on the International Space Station until at least 2020, and a fresh focus on new technologies- this rocket is key to implementing the plan laid out by President Obama and Congress in the bipartisan NASA Authorization Act of 2010, which the President signed last year.

This launch vehicle decision is the culmination of a months-long, comprehensive review of potential designs to ensure that the nation gets the best possible rocket for the investment-one that is not only powerful but is also evolvable so it can be adapted to different missions as opportunities arise and new technologies are developed.

The rocket will use a liquid hydrogen and liquid oxygen fuel system, where RS–25D/E engines will provide the core propulsion and the J2X engine is planned for use in the upper stage. There will be a full and open competition to develop the boosters based on performance requirements. Its early flights will be capable of lifting 70–100 metric tons before evolving to a lift capacity of 130 metric tons.

The early developmental flights may take advantage of existing solid boosters and other existing hardware, which will help us control costs and make early tests smoother.

Q3. What is the status of NASA's review of the industry studies that were funded in the Broad Agency Announcement? What criteria will NASA use to determine whether or not to incorporate concepts discussed in those studies into the SLS Reference Design and what analysis will be done to justify modifications to the existing SLS Reference Design?

A3. On July 29, 2010, NASA released Broad Agency Announcement (BAA) NNM10ZDA001K to solicit proposals for Heavy-Lift and Propulsion Technology Systems Analysis and Trade Studies (SATS) from industry. Specifically, the BAA sought technical solutions in support of heavy-lift system concepts and system architectures, and to identify propulsion technology gaps to support NASA's goals. NASA's intent was to gather unique and innovative options, technologies, and concepts to incorporate any new ideas into Government models and analyses, and to use the information for future planning and potential acquisition.

These activities helped determine the feasibility of meeting top-level mission requirements with notional launch vehicle architectures, while defining affordability strategies, streamlining systems engineering approaches, and in identifying best practices that will be applied to the final concept selected to go forward into formal design and development. In addition, the BAA competition brought out competitive cost pricing that was below historical averages and costing model calculations. Innovations resulting from the BAAs were then incorporated into the SLS, MPCV, and GO Requirements Analysis Cycles (RACs).

The RAC teams delivered their final results the week of February 14, with BAA presented their final results to NASA on April 28. NASA used these trade studies to inform the concept sets chosen to go forward in the Analysis of Alternatives (AoA) process. One key finding of the AoA was that cost and risk assessments did not identify distinct discriminators among the alternatives. At $2.5 billion per year, none of these alternatives achieved beyond-LEO capability with acceptable risk

prior to 2021 based on NASA cost and schedule estimates. Industry cost estimates through the BAA's were consistent with NASA estimates, and lower than NASA's historical cost models. However, there was one interesting finding—management and business approaches drive cost more than technical solutions do.

Another key finding of the AoA was early full-vehicle competition adversely affects the retention of Agency critical skills and seriously impacts the current industrial base due to time-lag in final vehicle configuration selection (fuel type, mission and ground operations).

Ultimately, the BAA competition strengthened the Government/Industry relationships and an increased level of contractor-to-contractor communication was observed.

Q4. How does NASA intend to ensure the safety of both the SLS and MPCV and the ability to control costs, in light of its proposed 70 percent reduction in oversight? What oversight activities are you proposing to eliminate? What alternative means will you use to secure the information normally captured during those oversight activities?

A4. NASA will retain the oversight necessary to ensure safety.

An example of improved insight and oversight can be found in the Orion project. A year-to-year reduction of nearly 70 percent of the dedicated oversight management workforce was realized. (Here it is important to note that oversight is not exclusively safety activities and the reduction was not to all oversight but rather to dedicated oversight by people in primarily a management role.) This included minimizing oversight, metering insight based on risk, establishing co-located government contractor teams, and focusing on near-term test flight missions. This approach deployed the Government workforce to emphasize the engineering insight that comes from focused, in-line, co-located contributions to design and testing, and to deemphasize dedicated oversight management.

The net result of the rebalancing of resources toward hardware procurement and spacecraft production has been the ability to accelerate first test article delivery under a dramatically smaller budget. Government performance of in-line tasks was increased which refocused Government resources toward tasks directly contributing to design and testing efforts, further enhanced Government insight, and fostered a more integrated government and industry team.

Through this process, the Government gains significant insight into the contractor's vehicle system and has early insight into any issues or concerns that could impact vehicle safety. The focused insight allows the government to make recommendations to the industry partner and the government oversight team to improve the vehicle design or correct a known issue/defect. As always, final Oversight decisions will be performed by NASA.

NASA's commitment to safety is paramount.

Q5. Last year, President Obama directed NASA to maintain the Orion development project for the purpose of serving as a crew rescue vehicle on the ISS. Is the requirement for modifying Orion as a crew rescue vehicle for the ISS still being pursued, and if not, how will crew rescue on the ISS be handled?

A5. NASA has efforts underway to develop an American-made commercial capability for crew transportation and rescue services to the station following this year's retirement of the Space Shuttle fleet. The Agency anticipates these systems will be available by the middle of the decade. These services will provide the primary transportation to and from the International Space Station (ISS) for U.S., Canadian, European and Japanese astronauts. To ensure a smooth transition as this new capability is developed, Russian Soyuz support will continue as a backup capability for about a year after commercial services begin. The use of Russian Soyuz services in support of the ISS is dependent on NASA's current exemption in the Iran, North Korea, and Syria Non-proliferation Act (INKSNA). This exemption will expire in July 2016.

NASA is also developing the Multi-Purpose Crew Vehicle (MPCV)—based on the Orion Crew Exploration Vehicle—for missions of exploration beyond Low Earth Orbit (LEO). Work on the MPCV will focus only on the deep-space design. While the MPCV could be called upon to service the ISS—a backup requirement established by the NASA Authorization Act of 2010—it should be well understood that utilizing the MPCV for routine ISS transportation would be a very inefficient and costly use of the MPCV deep-space capability. NASA is confident in the ability of our commercial and international partners to provide all currently foreseen support for the ISS. Therefore, there is no intention to conduct routine LEO missions with the MPCV.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Scott Pace, Director, Space Policy Institute, George Washington University

Questions submitted by Subcommittee Chairman Steven Palazzo

Q1. When discussing aerospace industrial base, and specifically our ability to compete with launch services, the conundrum appears to be that most missions flown from US launch facilities are government payloads. Commercial customers are taking their business to foreign launch facilities simply because they are less expensive. Are there steps Congress and government could take to make US launch companies more competitive? Do you have any suggestions about how to keep US commercial payloads on our shores?

A1. There are many reasons why commercial operators have gone off-shore to European and Russian launcher suppliers and cost is only one consideration, albeit an important one. Demonstrated reliability, schedule flexibility and schedule assurance are great importance to firms launching revenue-generating satellites. One of the limitations at the Kennedy Space Center is a congested launch manifest due to pad constraints (i.e., only one pad each for the Atlas 5 and Delta 4 EELVs) as well as staffing limits that constrain total launches to about eight per year.

Short of direct subsidies, the government can do little to affect near-term commercial competitions. One thing the government can do however is support launch range modernization and facility improvements that would create more schedule flexibility. The most effective long-term actions would be to support development of a new generation of efficient liquid propulsion systems, such as the J2-X, and ensure stable policies are in place so that industry can make efficient production decisions. As I mentioned in my testimony, the lack of stable architecture for exploration beyond Earth orbit and uncertain demand for engines such as the RS-68 have driven up the costs of U.S. launch vehicles.

Finally, it may be worth considering means by which U.S. launch suppliers could become more competitive for international payloads by creating international partnerships. For example, the "Liberty" concept of using ATK solid rocket motors and an Ariane liquid propulsion core upper stage could be used to launch European commercial payloads as well as U.S. government payloads from the United States. A robust and capable heavy lift vehicle could relieve some of the capacity issues at acceptable costs if it could reach a flight rate of 4-6 launches per year instead of just two per year for human space flight missions.

Q2. Your testimony does a very good job reminding us about the lessons from the Columbia Accident Investigation Board. Crew safety is an overriding concern. You suggest that the MPCV and SLS are not adhering to the safety standards of the previous Constellation system. Would you elaborate on your observation? As you see it, is there an inherent safety problem with the systems under consideration, or is the problem the lack of clear commitment from the administration?

A2. I apologize if I gave the impression that I thought the MPCV and SLS are not adhering to the safety standards of the Constellation program. I believe they are - and as was recently announced, the MPCV is essentially the Constellation program's Orion spacecraft.

The point I was attempting to make is that probabilistic risk assessments of varying designs, such as Ares 1, human-rated EELVs, and Shuttle-derived heavy-lift vehicles give different results for the safety, i.e., the probability of crew loss. These differences are due to many factors, such as the reliability of the vehicle's design (e.g. simpler, fewer parts are preferred), flight heritage (e.g., more real-world experience is preferred), and the effectiveness of the flight termination and crew escape systems. In comparing these factors, the Ares 1 was preferred over other alternatives on a crew safety basis by a significant margin. The variety of configurations being discussed for the SLS are all more complex than the Ares 1 and while using many demonstrated Shuttle components, some will be new and lacking in flight heritage (e.g., the expendable SSME or RS-25F; the J2-X being common to the SLS and Ares 1 upper stage). This doesn't mean the SLS or other designs could not attain the same safety levels as promised in the Areas 1 design, but it would take more design work and flight experience to do so.

The Congress should closely monitor the connection between NASA funding levels and safety. Under severe budget pressure, project managers must make very difficult choices in how much engineering testing is done to 'certify' the design of high-risk components. There are competing interests that come into play when projects

are funded at low levels, with little to no funding reserves to deal with the inevitable issues that arise in a complex development program.

Questions for the Record from Acting Ranking Member Jerry F. Costello

Q1. As the former Associate Administrator of NASA's Office of Program Analysis and Evaluation, what is your perspective on NASA's plan for an independent cost assessment? Is the plan sufficient for providing a robust and credible cost estimate to Congress? If not, what more is needed to ensure that Congress can have confidence in the cost and schedule estimate that will be provided as part of the final report on SLS to be transmitted to Congress this summer?

A1. Cost estimates are not just "point estimates" but have varying levels of uncertainty associated with them. For example, a cost estimate at a 50% confidence level is very different than a cost estimate for the same project at a 70% confidence level. Cost estimates are not just about money, but represent an integration of money, schedule, and risk. NASA has the capability to provide good independent cost assessments and good policies in place to enable such assessments. The challenge will be in ensuring the policies and processes are implemented in a rigorous, objective fashion.

Current NASA policy calls for a joint cost-schedule estimate at the 70% confidence level at KDP C, the transition from Formulation to Implementation. Congress should recognize and expect that prior to KDP C, there should be a range of cost estimates and associated confidence levels that are used to support program planning and design choices. Cost estimates become more exact as a project matures technically. The inclusion of schedule risk is a new and more realistic addition but since it is new, implementation and training challenges can be expected.

Congress should ensure that there is a process for comparing and reconciling cost estimates created by the project itself, NASA's internal independent cost estimators, and any outside cost estimate that made be required. The reconciliation process is a useful way of uncovering underlying assumptions about technical and programmatic risk and clarifying what risk the agency is actually prepared to accept. At the same time, NASA and the Congress should be particularly attentive to the cost implication of excessive risk aversion - that is, building in more reviews and oversight and paperwork to deal with even minor developmental risks. In this regard, it can sometime be more effective to budget for a robust series of hardware and flight tests. If the tests go well, budget can recovered for use on other problems in the project. If tests uncover unexpected problems, the project team benefits from learning about them earlier. This was indeed the path the Constellation Program planning headed toward following successful completion of the Ares I-X test flight in October 2009.

In summary, Congressional oversight should seek to understand what factors drive the confidence levels of the cost estimates, the process used for reconciling independent and project-based cost estimates, and whether there is a robust test program to identify problems early. To this end, a strong, expertly staffed independent cost and program evaluation function is one of the highest leverage management investments one can make at NASA Headquarters. If utilized properly, it can help the agency head off problems early and be a valuable resource for improving program and project outcomes.

Q2. NASA is expected to soon deliver an integrated plan for the SLS and MPCV vehicles.

- In your view, does this constitute a plan for the exploration program going forward? If not, what more do Congress, industry, and other stakeholders need to know in order to have a complete plan for the future of human exploration?
- What should Congress be looking for as it evaluates this forthcoming plan?

A2. The Augustine Committee made a clear recommendation on a path going forward, in particular:

Augustine pg 71: In the end, the Committee thought that the most cost-effective fallback option that would move NASA most rapidly toward exploration is to continue to develop the Orion, and move as quickly as possible to the development of a human-ratable heavy lift vehicle. The first stage of any of the heavy-lift launchers under consideration would be more than capable of launching an Orion to low-Earth orbit.

An integrated MPCV/SLS plan would be expected to meet this recommendation and should be welcomed. Unfortunately, there continues to be great uncertainty over what this capability is to be for. As covered in my testimony:

"The lack of a U.S. focus on human lunar return and an associated architecture is one of the most serious programmatic gaps that make transition planning difficult. Efforts to find a feasible and attractive mission to a Near Earth Object (NEO) have not been successful and likely await the completion of a more complete survey of such objects. Sending humans to Mars remains too technically difficult and expensive at our current level of development. The Moon was and continues to be the logical focus for efforts to move humans beyond low Earth Orbit as well as being vital to future commercial developments.The international space community has developed a lunar architecture as part of a large Global Exploration Strategy with strong U.S. technical participation. We should consider making greater use of international partners through existing international mechanisms to create a more rational approach for our own plans."

I would suggest that the Congress could consider updating the directions it provided NASA in its FY2008 Authorization Act to encourage a clearer, international strategy for returning to the Moon. This would clarify priorities for the MPCV/SLS programs, provide a firmer foundation for international engagement in exploration beyond the International Space Station, and encourage longer-range but still practical thinking about possible roles for the private sector in supporting exploration.

Q3. You identified updated workforce transition plans as one of the first measures Congress would use to judge the success of NASA's transition plans. What should we expect to see? How detailed were prior workforce plans for transitioning from Shuttle to Constellation? What were the lessons learned from these prior efforts?

A3. The Congress should expect to see an annual workforce transition plan at least as detailed as what was provided at the end of the last Administration, specifically the report on the Space Shuttle and Constellation Workforce of March 2008. That report responded to the directions in the Consolidated Appropriations Act of 2008 (PL 110-161) that called for a strategy that would include:

1) Specific initiatives that the National Aeronautics and Space Administration has undertaken, or plans to undertake, to maximize the utilization of existing civil servant and contractor workforces at each of the affected Centers; (2) Efforts to equitably distribute tasks and workload between the Centers to mitigate the brunt of job losses being borne by only certain Centers; (3) New workload, tasks, initiatives, and missions being secured for the affected Centers; and (4) Overall projections of future civil servant and contractor workforce levels at the affected Centers.

Based on multiple instruments, such as workforce surveys and time charges, it should be possible to reconcile civil service workforce assignments across all NASA centers and mission directorates. Skill gaps and surpluses, both present and projected, should be identifiable along with plans to rectify those imbalances over time. The "go to" workforce and skill levels should be aligned with the directions given to NASA by the Administration and Congress.

In order to make future projections, NASA would need to have strategic workforce management model that links workforce levels to varying assumptions about budgets, center project assignments, work contracted out, and necessary skills at each Center. In essence, NASA should be able to project how many people it will need over the coming decade based on what it is being asked to do, costs estimates for those projects, and expected budgets and schedules. The NASA Office of Independent Cost and Program Evaluation (formerly, Program Analysis and Evaluation) could do this work in cooperation with the Office of the Chief Financial Officer and the Office of Human Capital Management. However, to be most useful, such an analysis would benefit from guidance on what level of expertise (i.e., "intellectual capital") is to be retained by NASA for developing and operating flight hardware. Or to what extent NASA is expected to only perform R&D with actual development and operational skills coming from the private sector.

In terms of lessons from prior workforce transition efforts, they biggest benefit came from having a program to transition the Shuttle workforce to, i.e., Constellation. Although job losses and retirements were expected with the end of the Shuttle program and consequent "gap" prior to the first flight of Ares 1, core skills were to be retained. These skills were those considered necessary to developing and flying the next generation of human-rated spacecraft by NASA. The lack of a clear transition path today, the certainty of a much longer gap in government-developed flight system testing in the MPCV/SLS construct, and the uncertainty as to any future roles in developing and operating human-rated spacecraft make the current environment a difficult one for workforce planning. Thus **the most important step for**

workforce planning is to ensure NASA has a clear set of programs and mission direction to transition to. The details would then become clearer.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. James Maser, Chairman, Corporate Membership Committee, The American Institute of Aeronautics and Astronautics

Questions submitted by Subcommittee Chairman Steven Palazzo

Q1. When discussing aerospace industrial base, and specifically our ability to compete with launch services, the conundrum appears to be that most missions are taking their business to foreign launch facilities simply because they are less expensive. Are there steps Congress and government could take to make US launch companies more competitive? Do you have any suggestions about how to keep US commercial payloads on our shores?

A1. This is a complicated subject that crosses supply and demand economics as well as national agendas for access to space for security and exploration. As such, the reply attempts to address both of these topics.

The U.S. industrial base is a national asset that needs to be considered, addressed and optimized at the national level, rather than at individual agency levels (NASA and DoD). To make U.S. launch companies more competitive, the government must define an integrated, long term roadmap and strategy for access to space for national security and exploration that is relatively stable and predictable. The U.S. government must continue to invest in the industrial base in a stable and predictable manner, such that industry can align their strategy and investment consistently with more predictable returns and outcomes. Clearly the current discontinuity in our NASA exploration plans is creating a lot of inefficiencies that drive costs up. The U.S. government must continue to invest in and ensure that NASA pursues a robust space launch program, specifically a heavy lift launch capability immediately.

Clearly, on the international commercial launch market, the selection of a commercial launch provider, once proven, is based primarily on launch cost and secondarily on other factors such as availability and demonstrated reliability. However, currently other nations do not solely let market forces define the construct of their industrial base and take proactive steps to ensure the capabilities they believe are critical to their national agenda are maintained and healthy regardless of the commercial market. In order to provide lower commercial launch prices other nations carry the fixed costs necessary to achieve their national access to space objectives and allow their national launchers to sell commercial launches using marginal pricing based on the additional costs required to build the hardware and launch that specific satellite. The benefit to the government providing this type of launch subsidy is to increase the launch tempo of their systems affording improved reliability. Additionally, foreign national launchers have a continuous preplanned product improvement activity funded to eliminate the cost of obsolescence replacement costs from being passed on to users.

Furthermore, as new countries develop advanced launch capabilities, such as China and India and perhaps soon, South Korea, they are having an impact on the commercial market. First, as described above, they increase the supply of commercial launchers in a relatively fixed commercial demand environment, placing increased pressure on subsidies and pricing. Second, prior to having indigenous launch capability, they purchased launches for national satellites commercially. As they develop the launch capability, these launches are assigned to their vehicles and actually serve to pull commercial satellite launches from the market, thus reducing the demand for commercial launches relative to the supply. So as more nations develop launch capability, the more supply is available with subsidized pricing while demand remains relatively flat at best. Any country that expects their launchers to compete purely on market forces will find themselves in a less competitive position simply due to supply, demand, fixed and variable cost economics.

The Congress could take action to assure a steady government demand for launchers, fund a robust preplanned product improvement effort, and allow for marginal pricing of launchers to commercial customers. Further the Congress could request a study to understand the true total government demand for launches across civil and Department of Defense and assess whether adding launch capacity and dividing up the volume among multiple launch providers is more efficient in the long run than concentrating launches in one or two launch providers.

Q2. Given the impending end of the shuttle program how does the uncertainty of developing a follow-on system threaten our industrial base; can you characterize the capabilities that are at risk? Perhaps give examples from your own experience.

A2. The uncertainty of a shuttle follow-on system hits the industry at every level with devastating consequences to our human space flight program and ultimately our nation's position as the leader in space. In addition, there are potential ramifications and impacts to our national security access to space since much of the critical skills and industrial base supporting this sector have been maintained by NASA investment. Each company is forced to reduce workforce across the board to account for the reduced workload. Certain skill sets, such as launch site operations and mission analysis will experience immediate reductions in capability. Without immediate commencement of development work on SLS all other areas of expertise will be reduced until the industry undergoes a significant drop in capability going into next year. The important thing to remember is that these are not widget makers that are being put on the streets. They are rocket scientists, some of the most intelligent, highly-skilled, technically minded people in our country. These are professionals who have spent decades and decades building up their corporate knowledge. Once these people leave the industry, they generally do not come back. This capability will need to be rebuilt resulting in a significant increase in cost and delay in schedule once NASA's going forward plan for human space exploration is established.

Clearly, the best way to minimize the impact and damage that has already been done is to move on swiftly with full funding into development of the Space Launch System capability.

Questions submitted Acting Ranking Member Jerry F. Costello

Q1. Are the actions NASA is taking to ensure that the agency retains critical human spaceflight skills and capabilities during the transition from Constellation to SLS and MPCV enough, in your view, to sustain workforce capabilities? If not, what other actions are required?

A1. Without question, the actions taken by the NASA are not even close to sufficient to retain critical human spaceflight skills and capabilities. It has been more than 17 months since Constellation was canceled and they still have not announced the architecture for a heavy lift launch vehicle despite Congress mandating that they do just that. Had it not been for Congress mandating that Constellation efforts continue while NASA decides what to do instead, the situation would be much worse. However, now it appears NASA no longer has that constraint.

Additionally, while SLS has been funded by Congress, it is not clear how the money has actually been or is being spent on the SLS program There is speculation in industry that some of this funding is being diverted to other tasks and all work actually related to these programs are being either slowed or not started. The impacts of these continued delays, indecision and lack of a sense of urgency are being illustrated every day with the thousands of layoff notices being issued by space industry manufacturers across the country. We would recommend that Congress hold NASA to their legislated directive to make an immediate decision on SLS and that the funding provided for SLS and MPCV actually be provided directly to those programs so that a smooth skills transition could take place as the Space Shuttle program ends.

Q2. What issues and challenges does the aerospace industry face in light of movement away from Constellation? How many companies are affected and what types of businesses are hit the hardest? Are they mainly primes or sub-tier contractors? Are some of these small businesses? How dependent are these companies on NASA work? What is the impact on your workforce?

A2. The existing issues and challenges were not caused specifically by the movement away from Constellation. While cancellation of Constellation was certainly a significant development, the issues and challenges have resulted from NASA's total lack of movement on naming a replacement for Constellation, despite the fact that the program was canceled more than 17 months ago. The very precarious situation we currently find ourselves in as an industry and as a nation was totally avoidable. And the negative impacts can still be mitigated if NASA will make a decision, spend the full funding they've been appropriated, partner with industry to achieve efficiencies and get moving NOW, not one, three or five months from now.

The cancellation of Constellation has created a series of challenges for the entire aerospace industry which is compounded by the lack of a replacement direction and now exacerbated by the end of the Space Shuttle program. The original plan was to ensure any overlapping capabilities or suppliers from Shuttle to Constellation would have a smooth transition. Now there is no transition, and remaining efforts on elements of Constellation have been slowed significantly such that all involved companies are forced to spend significant effort in renegotiating and slowing down

planned effort hurting all tiers of the industry. This slow-down or outright cancellation of effort has forced all parties to resize their business to accommodate the reduced volume. Among the hardest hit are the companies who have the highest percentage of their business volume working products built to the exacting NASA standards. Small, specialized suppliers are being forced to exit this type of business and are unlikely to reenter without significant financial incentive. Examples of this are specialty electronics providers, super alloy production facilities, and specialty machining operations companies. As these specialized lower tier producers exit the market, designs will either have to adapt to lesser component capability or incur the increased costs of creating in-house capability at higher tier suppliers. It is safe to say that thousands of companies are feeling some impact and hundreds are feeling significant impact as a result of Constellation cancellation and lack of follow-on orders or direction.

Q3. Congress needs a better understanding of when companies reach the point-of-no-return when it comes to being at risk of losing their critical mass of key capabilities and skill sets. Is there a point where companies have to make a decision to leave the market? What, exactly, would trigger that decision?

A3. While there is no singular event that constitutes a "point of no return" since capability has been eroding steadily since the announcement of the cancellation of Constellation more than 17 months ago, it is fair to state that a major loss of capability is happening now, and will reach a dramatic crescendo by the end of FY2011 once the Space Shuttle work force is released with no other work in place to employ them. There has been a marked increase in skilled personnel attrition since the announcement however as a major reduction in force is implemented it is clear that many skilled personnel will leave the industry forever.

This erosion is not just a loss in current capability, it is a loss in future capability. Our workforce is aging and, with Constellation, we were in the process of hiring, training and motivating our next generation of high technology rocket scientists. Now, not only have we been reducing this demographic, we have also created a sense of disillusionment with the space industry. Commercial space will not make up for this, as ultimately that model is to take mostly existing technology and transform it into a profitable space trucking and taxi business. The real inspiration, motivation and innovation that has made this country a world leader, not just in space, but in many high technology areas of commerce, has come from the NASA hard challenges that push the limits of our knowledge and capability. As it stands right now, aside from some abstract statements, those challenges do not exist. This capability will need to be rebuilt at significant additional, and unnecessary, cost and time, once NASA decides what to do and how to do it. If too much time passes, and we get used to being mediocre, this nation may lose the willpower or desire to remain a leader.

Smaller companies who have traditionally relied on space flight business are also opting to leave the market due to greatly reduced volumes in the defense segment and made worse by the end of NASA development. Higher tier suppliers are forced to develop new suppliers who are reluctant to invest in these capabilities causing all launch costs to increase significantly. This has implications beyond NASA into the Department of Defense who will carrier a much heavier financial burden without NASA's ongoing investment in launch technology.

Q4. Are there international suppliers that would fill the gap if U.S. companies leave the market? Are there national security issues should the U.S. have to rely on foreign suppliers?

A4. There are many international suppliers who have been actively pursuing a position in the U.S. space market. They are all subsidized by their indigenous governments to service national security launch and are offering their products at marginal pricing within the U.S. As domestic suppliers have exited the industry due to lack of investment , lack of a stable and consistent strategic roadmap, lack of volume and opportunities for work, more foreign sourced components are finding their way onto U.S. launchers since it is cost prohibitive to recreate and sustain them going forward without any clear market demand.. The issues created by reliance on foreign suppliers are largely centered on two areas. First, these components cannot be optimized for U.S. use very effectively due to export control restrictions which prohibit co-development hardware with missile applicability. The second issue is that assured availability is at risk since each supplier's national policy could prohibit use of their components on defense related applications. Every other space faring nation has chosen to support its national infrastructure so that it has assured access to space. Only the U.S. has opened up its space markets while simulta-

neously prohibiting much of its domestic supply base from competing in foreign markets using marginal pricing.

Clearly, as mentioned earlier, The U.S. space industrial base is a national asset that needs to be considered, addressed and optimized at the national level, rather than at individual agency levels. To make U.S. launch companies more competitive, the government must define an integrated, long term roadmap and strategy for access to space for national security and exploration that is relatively stable and predictable. The U.S. government must continue to invest in the industrial base in a stable and predictable manner, such that industry can align their strategy and investment consistently with more predictable returns and outcomes. Simply allowing foreign supply in for critical, strategic capabilities that those nations have chosen to maintain and then market elsewhere because they offer lower prices is, in many cases a short term budget fix that creates long term issues. However, since it happens slowly over time, one critical supplier at a time and in the context of no national industrial base strategy, it goes unnoticed, until one day we are paying other countries to provide for our exploration and defense on their terms.

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