EXAMINING NASA'S DEVELOPMENT ON THE SPACE LAUNCH SYSTEM AND ORION CREW CAPSULE

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

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EXAMINING NASA'S DEVELOPMENT ON THE SPACE LAUNCH SYSTEM AND ORION CREW CAPSULE

WEDNESDAY, SEPTEMBER 12, 2012

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

The Subcommittee met, pursuant to call, at 10:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Steven Palazzo [Chairman of the Subcommittee] presiding.

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CHAIRMAN

EDDIE BERNICE JOHNSON, TE.
RANKING MEMBER

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2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, DC 20515-6301
(202) 225-6371
www.science.house.gov

Subcommittee On Space and Aeronautics

Examining NASA's Development of the Space Launch System and Orion Crew Capsule

Wednesday, September 12, 2012
10:00 a.m.-12:00 p.m.
2318 Rayburn House Office Building

Witnesses

Mr. Dan Dumbacher,
Deputy Associate Administrator for Exploration Systems Development, NASA

Mr. Cleon Lacefield,
Vice President and Orion Program Manager, Lockheed Martin Corporation

Mr. Jim Chilton,
Exploration Vice President, The Boeing Company

Dr. Matt Mountain,
Director, Space Telescope Science Institute

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

Examining NASA's Development of the Space Launch System and Orion Crew Capsule

Wednesday, September 12, 2012
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The purpose of the hearing held by the Subcommittee on Space and Aeronautics is to examine on-going development of the Space Launch System (SLS), the Orion capsule and related systems, as well as discuss how these technologies can be used for future scientific missions.

Witnesses

Mr. Dan Dumbacher, Deputy Associate Administrator for Exploration Systems Development, NASA

Mr. Cleon Lacefield, Vice President and Orion Program Manager, Lockheed Martin Corporation

Mr. Jim Chilton, Exploration Vice President, The Boeing Company

Dr. Matt Mountain, Director, Space Telescope Science Institute

Over-Arching Questions

1. What achievements have been accomplished to date with SLS and Orion development, and what are next steps and near-term goals?
2. What design assumptions is NASA using for propulsion systems for both first and upper stages?
3. What are the biggest technical, programmatic, and risk reduction challenges now confronting the SLS and Orion programs, and what steps are being taken to address them?
4. How do we ensure the long-term success of the SLS and Orion programs?

Background

NASA's next generation heavy-lift launch vehicle – the Space Launch System (SLS) – together with the Orion crew capsule will provide our country a capability that has not existed since the Apollo lunar program (1972) – the ability to send humans beyond Earth orbit to lunar or other deep space destinations. It also makes possible our nation's ability to send larger, more sophisticated scientific payloads to distant planets and other deep-space destinations, and provide a backup capability for the US government to access the International Space Station in the event that commercial crew or Soyuz services are unavailable. NASA's current development schedule assumes an operational SLS and Orion to be ready by 2021. No specific destination has been announced for a first mission, although NASA and the White House have suggested visiting a near-Earth asteroid. The agency is currently undertaking a survey to identify likely targets.

The Space Launch System is modeled on the Ares V that was to be the heavy-lift launch vehicle of the *Constellation* program canceled by the Obama Administration in February 2010. As part of its redirection of the human space flight program, NASA began to aggressively advocate development of a commercial crew program to ferry astronauts to the ISS[1], and proposed delaying decisions on design and development of a heavy-lift launch system until 2015. With the impending retirement of the space shuttle and risks of losing national aerospace capabilities, perhaps indefinitely, Congress disagreed with accepting any delays in the development of a national heavy lift capability. The 2010 NASA Authorization Act (PL 111-267) directed the agency to initiate development of SLS "as soon as practicable", to extend and modify *Constellation* contracts where applicable, to develop an initial lift capability of 70 metric tons (to eventually reach at least 130 metric tons), to carry the Orion crew capsule, and to serve as a back-up capability for crew access to ISS in the event that commercial or Russian services could not do so.

The same law also directed NASA to continue development of the Orion crew capsule that also had its start as part of the *Constellation* program.

No matter that PL111-267 was signed into law October 11, 2010, NASA waited seven months before officially designating Orion as part of its new deep-space architecture, and took an additional four months (Sept. 14, 2011) before announcing the design of its Space Launch System. Frustration over the delays became so great that the Senate Commerce Committee subpoenaed NASA for records related to these two programs.

[1] The Full Committee has scheduled an oversight hearing Friday, Sept. 14, 2012, at 9:30 am, on the Commercial Crew Program.

Orion Multipurpose Crew Capsule

As previously noted, the Orion crew capsule was originally part of the *Constellation* program that was to be flown atop both the smaller Ares I rocket (for ISS and low Earth orbit missions), as well as the larger Ares V for deep space missions. While it looks similar to an Apollo capsule, Orion has a 16.5 foot diameter versus 12.8 for the Apollo, is heavier, and has greater interior volume. Key features include a launch abort system, life support system, thermal protection, avionics, and propulsion. It is currently being designed to carry as many as four crew. Lockheed Martin is the prime contractor, and the program is managed by the Johnson Space Center.

Orion is much farther along in development than SLS, because the Administration's decision to cancel Constellation was more disruptive to the launch vehicle development than to Orion's. In 2009 (under the *Constellation* program) a full scale engineering model was used to conduct a successful test of the launch abort system at the White Sands Missile Range, New Mexico. Full scale models have also been used to carry out splashdown testing at NASA's Langley Research Center and parachute drop tests at the Army's Yuma Proving Ground in Arizona. NASA and its contractors are also carrying out a number of activities related to developing and testing subsystems and manufacturing processes.

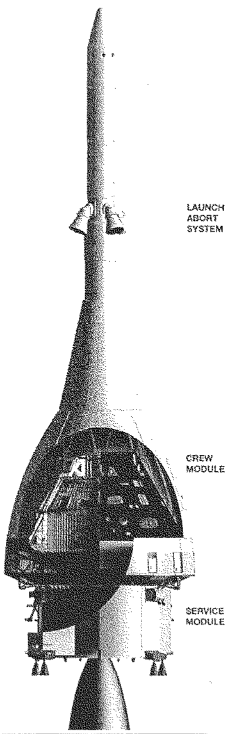

Image Credit: NASA

Another full-scale engineering model is scheduled to be launched in 2014 atop a Delta IV Heavy-Lift Launch Vehicle to test a number of vehicle systems. The uncrewed flight will take Orion on two highly elliptical orbits and re-enter the Earth's atmosphere at a speed equal to about 85% of lunar return velocity (20,000 mph). This will generate significantly higher temperatures during reentry than experienced by the space shuttle or other craft returning from the space station orbit and allow NASA to assess the heat shield's performance. The flight, dubbed EFT-1 (Exploration Flight Test-1), will also perform a number of other risk-reduction activities including a full scale test of the parachute system and a water landing in the Pacific.

A follow-on uncrewed flight test is scheduled for the end of 2017and will be launched atop an SLS first stage. EM-1 (Exploration Mission-1) will put Orion on a circumlunar trajectory before returning to Earth for reentry. Thereafter, NASA plans call for Orion (and SLS) to fly the first operational mission in 2021.

Orion's design also assumes a service module (SM) to provide power, propulsion, and consumable gases for life-support. For the EFT-1 flight, a truncated SM will be used to supply propulsion and battery power, but so far the agency has provided no concrete plans on how and when an operational SM will be developed and manufactured. Without a service module, flights of more than a few hours duration will not be possible.

Space Launch System

The initial version of the SLS will be comprised of a core stage using a liquid hydrogen, liquid oxygen propulsion system, with two five-segment solid rocket motor boosters. NASA has an inventory of 15 Space Shuttle main engines (SSME) to power the first several flights, but will eventually fund development of less expensive, 'expendable' SSME variants. The SLS will initially be able to launch 70 metric tons but will eventually be upgraded to at least 130 metric tons with development of more powerful boosters, and an upgraded upper stage using a J-2X engine. Like Orion, much of the SLS owes its heritage to the *Constellation* program, specifically the proposed Ares V heavy-lift launch vehicle. The SLS is similar in appearance to the previous Ares V, but less capable. Boeing is the prime contractor for the core stage. The SLS program is managed by the Marshall Space Flight Center.

NASA has identified SLS preliminary parameters to be:

- Providing an initial, crew-rated lift capability of approximately 70 metric tons;
- Conducting first uncrewed demonstration flight in 2017;
- Completing design, development, test and evaluation within a flat budget;
- Ensuring the design is evolvable to a lift capability of at least 130 metric tons; and
- Ensuring that production and operations costs are affordable and sustainable over the life of the program.

In order to minimize development and production costs, the SLS core and upper stages will share the same diameter as the Space Shuttle External Tank (27.5 feet) enabling the manufacture and machining of these components using the same production hardware. SLS will also use many of the same subsystems, materials, and tooling.

Earlier this year SLS successfully completed its Systems Requirements Review/System Definition Review. The next major formulation review will be the Preliminary Design Review (PDR) scheduled for the 4th quarter of FY2013, which will evaluate the completeness of the SLS's design in meeting all requirements with appropriate margins, with acceptable risk, and within cost and schedule constraints. PDR includes all major elements and determines the program's readiness to proceed to Critical Design Review scheduled for the 2nd quarter of FY2015.

For initial SLS flights, NASA will rely on an existing cryogenic upper stage already in use on the Boeing-designed Delta 4 rocket. Eventually NASA intends to use the much more powerful J-2X engine, designed and built by Pratt & Whitney Rocketdyne, to power the upper stage, enabling heavier spacecraft to escape Earth orbit. Earlier this summer the J-2X engine successfully performed a 22.5 minute test firing at the Stennis Space Center. The final development and testing phase of the J-2X engine is awaiting NASA's decision to begin development of the 130 metric ton variant "block 2" upper stage for the SLS. The Stennis Space Center manages the program for NASA.

The first two flights of SLS will use two solid-rocket motor boosters similar to those utilized by the Space Shuttle, although they will be longer – a five segment design. The manufacturer, ATK, has successfully performed three test burns of five segment motors. NASA is in the early stages of competing the development of advanced boosters, which may be either solid or liquid. In July 2012, the agency announced the selection of six study proposals (offered by four companies) for initial study of advanced booster risk-reduction work.

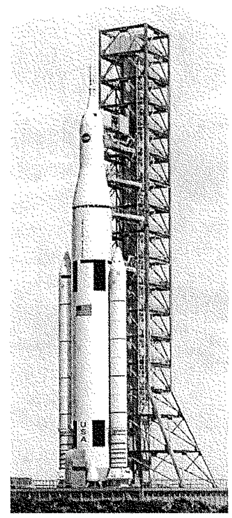

Image Credit: NASA

Budget

Exploration Systems Development: Orion and SLS Budgets (FY2013 PBR; $=millions)

	FY 11 Actual	FY12 Estimate	FY13 Auth	FY13 Request	FY13 vs. FY12
Orion Crew Vehicle Development	$1,086.0	$1,142.9	$1,400.0*	$968.5	-$174.4
Orion Program Integration & Support	$110.0	$57.1	---	$56.4	-$0.7
Space Launch System	$1,313.8	$1,456.1	$2,640.0*	$1,304.1	-$152.0
SLS Program Integration & Support	$222.3	$46.4	---	$35.9	-$10.5
Exploration Ground Systems	$250.0	$304.5	---	$404.5	$100.0
TOTAL	$2,982.1	$3,007.0	$4,040.0*	$2,769.4	-$237.6

**Authorization assumes – but does not call out – ground systems and other program support.*

NASA's FY13 budget request for Orion and Space Launch System is only 69% of amounts authorized in the 2010 NASA Authorization Act, and as shown in the table, is $237.6 million less than amounts appropriated during FY12.

Future Scientific Missions Enabled by SLS

NASA relies on a variety of small to medium-lift vehicles to launch robotic science missions into space. The size and weight of payloads is limited by lift capacity and the size of the payload faring of the launch vehicle. The Space Shuttle was NASA's most powerful launcher, capable of taking over 50,000 pounds to low Earth orbit (LEO), but with its retirement NASA now relies on a variety of expendable launchers such as the Delta 4 and Atlas 5 rockets that typically lift 20,000- 25,000 pounds to LEO. Only the United Launch Alliance Delta 4 Heavy, currently the largest launch vehicle in America's fleet, is capable of lifting approximately 50,000 pounds to LEO.

The Ares V heavy-lifter, as proposed in the *Constellation* program, was designed to carry about 140 metric tons to LEO in an 8 meter faring, far surpassing any existing launch system. NASA asked the National Academy of Sciences in 2007 to evaluate the potential for new science opportunities enabled by the Ares V which resembles today's planned SLS both in appearance and lift. The final report, *Launching Science: Science Opportunities Provided by NASA's Constellation System*, (http://www.nap.edu/catalog.php?record_id=12554), published in 2009, examined a number of possible mission concepts that might be possible in the 2020 – 2035 time frame.

Not surprisingly the report's findings and recommendations examined a number of 'flagship' mission concepts, including space-based telescopes and large planetary exploration spacecraft. Among their findings and recommendations -

- Most suitable missions were in the $5 billion estimated cost range (excluding launch costs);
- Astronomy, astrophysics, and planetary science missions tended to generate the most proposals;
- Earth science and heliophysics disciplines did not propose missions requiring heavy-lift launchers;
- International cooperation could provide access to international scientific expertise and technology useful for large, complex missions and could reduce costs through provision of instruments by international partners;
- With advanced robotic servicing technology, heavy-lift launch vehicles make possible the servicing and in-space assembly of large spacecraft; and
- NASA should preserve the capability for Orion crew capsules to carry small scientific payloads and should ensure that the Ares V development team (now SLS) considers the needs of scientific payloads in their system designs.

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

Good morning, everyone. Before we get started, there has been an incident in the Middle East last night where four Americans lost their lives in attacks on U.S. soil, U.S. embassies. If we could just take a moment of silence and pray for not only those that were murdered but also for their families.

Welcome to today's hearing entitled "Examining NASA's Development of the Space Launch System and Orion Crew Capsule." 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 our hearing, and I especially want to thank our witnesses for joining us today. I know many people put in a lot of effort preparing for these hearings, and we appreciate you taking time from your busy schedules to appear before the Subcommittee. I also want to assure you that we greatly value your expertise and wisdom, and that your testimony will benefit this Committee in the weeks and months ahead as we endeavor to ensure uninterrupted development of these important new programs.

The purpose of today's hearing is to discuss NASA's and industry's progress, next steps, and challenges developing our Nation's next-generation heavy-lift launcher and crew capsule. For the next several decades, the Space Launch System and Orion multipurpose crew vehicle will give our country the capability to launch exciting new human spaceflight exploration missions and robotic science missions.

No other country has the technical expertise or industrial base to produce anything similar to SLS or Orion, making it all the more compelling to ensure that these programs continue without interruption.

It is also important to realize other significant benefits that flow from the SLS and Orion programs. First, by building a heavy-lift vehicle, we will enable bold new science missions, and I look forward to Dr. Mountain's testimony about the scale of potential flagship missions that might be conceived for launching 10 or 15 years from now. I am optimistic that once our government's fiscal health has been restored, NASA will have the resources to once again consider robotic flagship missions that will maintain the momentum we currently enjoy with missions such as MSL.

Second, looking at the health and vitality of our aerospace industrial base, SLS and Orion will continue to challenge our best and brightest engineers to design and develop advanced propulsion, avionics and manufacturing capabilities that will maintain America's preeminence in space. While no other country currently has the capability to match what we can do with SLS and Orion, a number of emerging space powers may, in time, be tempted to challenge our leadership in space. That includes space-based technologies that are fundamental to our economy, our quality of life and our national security. By scaling back investments in aerospace R&D, we risk putting future generations of Americans at risk.

Finally, I worry that without SLS and Orion, NASA's and our country's ability to do the hard stuff—cutting-edge space exploration—would be seriously impaired. NASA's first 50 years plus of programs and missions have been awe-inspiring. I want to keep that spirit alive for decades to come.

[The prepared statement of Mr. Palazzo follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN STEVEN M. PALAZZO

Good morning. I'd like to welcome everyone to our hearing. I especially want to thank our witnesses for joining us today. I know many people put in a lot of effort preparing for these hearings, and we appreciate you taking time from your busy schedules to appear before the Subcommittee. I also want to assure you that we greatly value your expertise and wisdom, and that your testimony will benefit this committee in the weeks and months ahead as we endeavor to ensure development of these important new programs.

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Second, looking at the health and vitality of our aerospace industrial base, SLS and Orion will continue to challenge our best and brightest engineers to design and develop advanced propulsion, avionics, and manufacturing capabilities that will maintain America's preeminence in space. To be clear, there are a number of emerging space powers who may, in time, be tempted to challenge our leadership in space, and especially space-based technologies that are fundamental to our economy, our quality of life, and our national security. We simply can't afford to scale back investments in aerospace R&D or we may, in time, put future generations of Americans at risk.

Finally, I worry that without SLS and Orion, NASA's and our country's ability to do 'the hard stuff' —cutting edge space exploration—would be seriously impaired. NASA's first 50 years plus of programs and missions have been awe-inspiring. I want to keep that spirit alive for decades to come.

Thanks again to our witnesses for appearing before us this morning.

Chairman PALAZZO. I would now like to yield my remaining time to the chairman of the full Committee, Representative Ralph Hall, for any comments he would like to make.

Chairman HALL. Mr. Chairman, I of course thank you for holding this morning's hearing, and I thank the four gentlemen there for the time they gave in preparation, travel and for giving us this information that you give us.

The Space Launch System, as the Chairman said, and Orion crew vehicle are going to enable NASA's future human deep space exploration and it is vitally important that they be continued, I think, and I think most of us think that, and if Congress and the Administration work together to keep these programs on track and on schedule, but having said that, I continue to worry about NASA's commitment to the Space Launch System and Orion.

The agency delayed design selection of SLS for 11 months following enactment of the 2010 Authorization Act. Its budget request for these two programs falls significantly short of amounts authorized. I have yet to see evidence that design and development of

Orion service module, which would be required to support any multiday mission, has begun. No mission destination has been selected other than an asteroid to be named later, and while I acknowledge the Administration argues we have already been to the moon, I find it questionable that a trip beyond low-Earth orbit does not include the moon as an interim destination, maybe or maybe not, but to be considered to keep in view that we are considering it, the research and development systems that will be required for missions to other planets such as Mars. I have sense enough to know we are not going to Mars or on asteroid or anywhere else until people can go to the grocery store, and by that I know that the economy has got to get a lot better, but we have to be ready for it and that is continuing to be preparing and seeking it.

Once the International Space Station is retired, we will have no manned presence in space except for missions launched on SLS and Orion. Without this new launch system, the technological capability, inspiration and innovation that springs from our human spaceflight programs is going to wither. None of us can afford to allow that to happen.

Mr. Chairman, I thank you and I yield back my time.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF CHAIRMAN RALPH M. HALL

Mr. Chairman, I want to thank you for holding this morning's hearing.

The Space Launch System and Orion crew vehicle will enable NASA's future human deep space exploration program. It is vitally important they be continued, and that Congress and the Administration work together to keep these programs on track and on schedule.

But having said that, I continue to worry about NASA's commitment to SLS and Orion. The agency delayed design selection of SLS for 11 months following enactment of the 2010 authorization act. Its budget requests for these two programs fall significantly short of amounts authorized. I have yet to see evidence that design and development of an Orion service module—which would be required to support any multi-day mission—has begun. No mission destination has been selected, other than an asteroid to be named later. And while I acknowledge the Administration argues we've already been to the Moon, I find it questionable that a trip beyond lower earth orbit does not include the Moon as an interim destination to research and develop systems that will be required for missions to other planets such as Mars.

Once the International Space Station is retired, we will have no manned presence in space except for missions launched on SLS and Orion. Without this new launch system, the technological capability, inspiration, and innovation that springs from our human spaceflight program will quickly wither. None of us can afford to allow that to happen.

Thank you, Mr. Chairman. I yield back.

Chairman PALAZZO. Thank you, Mr. Chairman, and thanks again to our witnesses for appearing before us today.

I now recognize Mr. Clarke for an opening statement.

Mr. CLARKE. Thank you, Mr. Chairman, and I appreciate the opportunity to be Ranking Member of this Subcommittee on this very important issue. We want to make sure that the plans, status and development of these two important projects are on time, and as we are well aware, our Authorization Act in 2010 directed NASA to develop both support human exploration beyond low-Earth orbit, provide backup capability to deliver crew and cargo to our International Space Station, and to preserve the critical capabilities of our aerospace workforce and industrial base. And we are all aware that the task of getting SLS's and Orion's architecture underway wasn't an easy one.

Back in March of last year, this Subcommittee pressed members of NASA for a final decision on the configuration of the next heavy-lift vehicle for returning Americans to human exploration beyond low-Earth orbit, which is our ultimate goal, at least on an interim basis, by 2021.

A year ago this month, we got the decision that the integrated SLS and Orion crew capsule architecture that NASA is currently developing, we got a decision on that. This system builds on the successful and proven space shuttle technologies as well as new developments begun under the former Constellation program before it was ended.

While NASA's decision took some time, I am encouraged that in just a year since announcing the final architecture, NASA and its industry contractors have made considerable progress, and that is something I would like to talk to you about today as well.

The Orion capsule has been delivered to the Kennedy Space Center in preparation for an uncrewed test flight in 2014. The SLS has completed its initial stage of review, which confirmed the vehicle concept, the overall architecture, and the design and integration approach. Now, in addition to the 2014 test flight of Orion, NASA's plans include an integrated SLS and Orion uncrewed test flight in 2017 and the first crewed test flight by 2021.

So it is my hope today that you as witnesses can help us understand how these test flights will help identify risks early on to human flight, any challenges that they face in meeting those milestones, and what is needed to ensure the earliest possible date for returning Americans to deep space exploration.

My next remarks have some great references to an outstanding American, Neil Armstrong, who came to this Committee a year ago next week. But as someone that is a Baby Boomer that was a kid during the 1960s, I remember as a kid President Johnson standing before, President Kennedy as well standing before the American people and being committed to the goal of sending Americans to the moon. President Kennedy said that in such an inspiring way. Those same principles of what he spoke about are embodied in the success of NASA Authorization Acts over the last several years, and what I believe is so important is that we work to achieve those goals set forth by Congress in those Acts by returning Americans to deep space exploration.

Thank you and I yield back the balance of my time.

[The prepared statement of Mr. Clarke follows:]

PREPARED STATEMENT OF ACTING RANKING MINORITY MEMBER HANSEN H. CLARKE

Chairman PALAZZO. Thank you, Mr. Clarke.

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

Before introducing the witnesses, the Chair wishes to express his thanks to Mr. Lacefield and Mr. Chilton for agreeing to appear before this Committee on relatively very short notice. While we normally require witnesses to provide testimony 48 hours in advance of a hearing, under the current circumstances, it would be inappropriate to hold them to the same standard, and we are pleased they are able to join us here this morning.

At this time I would like to introduce our panel of witnesses, and then we will proceed to hear from each of them in order. Our first witness is Mr. Dan

Dumbacher, the Deputy Associate Administrator for Explorations Systems Development at NASA. Mr. Dumbacher joined NASA in 1979 at the Marshall Space Flight Center. He has held a number of management positions during his career including most recently heading the Engineering Directorate at Marshall. Mr. Dumbacher has also served as Deputy Director of the Exploration Launch Projects Office, Deputy Director of the Ares Project Office, and Deputy Director of the Safety and Mission Assurance Office. He has received a number of awards and honors during his career with NASA, and Mr. Dumbacher graduated from Purdue University with a degree in mechanical engineering.

Our second witness is Mr. Cleon Lacefield, Vice President and Orion Program Manager at Lockheed Martin Corporation. He has more than 34 years of aerospace experience beginning in the Navy as an A–7 pilot, then moving over to NASA where he participated in a number of spaceflight programs including as Flight Director at Mission Control in Houston and as Director in the X–33 program. Mr. Lacefield earned a number of awards and honors during his tenure at NASA and as a graduate of California Polytechnic State University.

Our third witness is Mr. Jim Chilton, Vice President and Program Manager for Exploration Launch Systems at Boeing. Previously, Mr. Chilton served as Program Manager for the checkout, assembly and payload processing services contract at Boeing's Kennedy Space Center facility. Mr. Chilton joined Boeing at the Rocketdyne division as an engineer serving a number of roles in engine test and launch operations. Mr. Chilton holds a bachelor's degree in mechanical engineering from Washington State University and a master's degree in space technology from the Florida Institute of Technology.

Our final witness is Dr. Matt Mountain, Director of the Space Telescope Science Institute. Dr. Mountain has been director of the institute since September 2005. He leads the 400-person organization responsible for the science operations of the Hubble Space Telescope. He is the James Webb Space Telescope's telescope scientist, a member of the JWST Science Working Group, a professor at the Johns Hopkins University's Department of Physics and Astronomy, and a visiting professor at the University of Oxford. Dr. Mountain is a fellow of the American Astronomical Society and the Royal Astronomical Society and the American Association for the Advancement of Science.

Thanks again to our panel for being here this morning. As our witnesses should know, spoken testimony is limited to five minutes each. After all witnesses have spoken, Members of the Committee will have five minutes each to ask questions.

I now recognize our first witness, Mr. Dumbacher, to present his testimony.

STATEMENT OF MR. DAN DUMBACHER, DEPUTY ASSOCIATE ADMINISTRATOR FOR EXPLORATION SYSTEMS DEVELOPMENT, NASA

Mr. DUMBACHER. Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to update you on NASA's Explorations Systems Development Programs, which are depicted on the posters to my left: the Orion multipurpose crew vehicle, the Space Launch System and the related ground systems, and you can see there evidence of some of our progress.

Today marks the 50th anniversary of President Kennedy's speech at Rice University in which he discussed America's space efforts and particularly the coming missions to the moon. As the Nation celebrates the achievements of Neil Armstrong and the realization of President Kennedy's goal, I am pleased to inform you that we are making excellent progress towards developing the next-generation capabilities for human space exploration beyond low-Earth orbit.

Orion is a four-person spacecraft designed to support exploration missions to multiple destinations. We have pressed forward with the design and manufacture of the first flight test article and the first flight test crew module structure is at Kennedy Space Center for assembly and integration. In addition, the program has completed significant acoustic and vibration testing, water impact test and parachute tests. Fabrication of the heat shield has been initiated, and the testing of avionics and software systems continues.

Orion will be used in the uncrewed exploration flight test in 2014. This will be a two-orbit, high-energy reentry test mission that will obtain critical performance data needed to confirm the design of the spacecraft. Exploration flight test one will also serve as a pathfinder to validate innovative approaches, reduce cost, demonstrate recovery procedures and develop the launch vehicle adapter. This adapter will also be used on the uncrewed flight in 2017 and the first crewed flights beginning in 2021.

The Space Launch System is a heavy-lift launch vehicle that will transport Orion as well as cargo and other systems with a range of lift capabilities from 70 metric tons evolving up to 130 metric tons. The Space Launch System team completed the required acquisition strategy process and had all contractors working by December 31, 2011. The team has completed key reviews and over the next year is proceeding to preliminary design review for the booster and core stage elements as well as the integrated Block 1 vehicle.

The Space Launch System core stage team has successfully completed its systems definition review. Fifteen RS–25D liquid hydrogen engines have been delivered to the Stennis Space Center in preparation for installation and tests on the core stage. NASA has initiated efforts to prepare the B–2 test stand at Stennis for the core stage testing. Solid booster segments are being prepared for the qualification motor test with the first such test slated for next May.

In July, NASA selected six proposals under an open, competitive NASA research announcement to improve the booster's affordability, reliability and performance. These initial risk reduction tests will be followed by full and open competition for the full-scale design and development work leading to an advanced booster for the evolved Space Launch System.

The 130-metric-ton Block 2 Space Launch System configuration will require a new upper stage utilizing the J–2X engines currently in development testing. J–2X has completed a total of over 3,250 seconds in 29 tests on the engine power pack.

In the exploration ground systems effort, the Kennedy Space Center team has made significant progress on the necessary infrastructure design, development and refurbishment to support the Space Launch System and Orion. The Kennedy Space Center is proceeding also through its key reviews. The Center has completed the first phase of mobile launcher construction. Refurbishment and upgrades to the crawler-transporter are being performed at a pace to support the 2017 flight test.

In addition, work is beginning on the vehicle assembly building to support the Space Launch System. Pad 39B has been prepared for the mobile launcher with lightning towers in place and the needed refurbishment to pad infrastructure.

As we move forward, NASA is working to keep all of these efforts integrated and coordinated. We successfully completed an integrated systems requirements review in February of 2012 for all of the integrated systems, and are progressing toward our integrated systems definition review early next year. The agency is working with an affordable model using a smaller number of level 1 requirements similar to what we did during the Apollo program. We have also streamlined the decision and integration processes to assure timely decision-making while addressing the needed technical aspects.

The NASA industry team has made great progress over the past year. Orion and the Space Launch System fit well within a broader U.S. launch strategy of procuring commercial launches for crew and cargo to the International Space Station while concentrating NASA's development efforts on exploration missions beyond low-Earth orbit including flights to asteroids. Both Orion and Space Launch System are being designed to support multiple missions and destinations rather than being optimized for one particular mission or architecture. Ultimately, these capabilities will pave the way for the human missions to the Mars.

Mr. Chairman, again, thank you for the opportunity to appear before you today to provide you with our progress and status over the past year. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.

[The prepared statement of Mr. Dumbacher follows:]

HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
September 12, 2012

Statement of
Daniel L. Dumbacher
Deputy Associate Administrator for Exploration Systems Development
National Aeronautics and Space Administration

before the

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

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify before you regarding the status of NASA's Exploration Systems Development (ESD) Programs: the Orion Multi-Purpose Crew Vehicle (MPCV), the Space Launch System (SLS) heavy-lift launch vehicle, and the necessary launch and processing ground systems. I am pleased to inform you that the dedicated NASA-industry team, working across the Nation utilizing all of the NASA Centers, and our primary industry partners Lockheed Martin, Boeing, ATK, and Pratt Whitney Rocketdyne, is making excellent progress towards developing the next capabilities for human space exploration and scientific missions beyond low-Earth orbit (LEO).

We stand on the shoulders of all those who so tirelessly worked before us to achieve the Apollo Moon landings, to develop and operate the Space Shuttle, to assemble and utilize the International Space Station (ISS), to look deep into the universe with the Hubble Space Telescope, to signal a new era of commercial spaceflight with the ISS docking of the Dragon spacecraft, and, most recently, to successfully accomplish Curiosity's Mars landing. It is particularly fitting that we demonstrate our progress to you as this Nation celebrates the great accomplishments of Neil Armstrong and the entire Apollo team.

Introduction

In line with the NASA Authorization Act of 2010 (P.L. 111-267), the Agency has been moving forward with a space exploration program designed to carry human beings beyond LEO.

The first two major hardware elements of this exploration program are the Orion MPCV spacecraft and SLS heavy-lift launch vehicle. Orion is a four-person spacecraft designed to support exploration missions to multiple destinations beyond Earth orbit, as well as, contingency capability for the ISS. The SLS is a heavy-lift launch vehicle that will transport Orion as well as cargo and other systems, with a range of lift capabilities from 70 metric tons evolving up to 130 metric tons based on future mission requirements.

Orion and SLS fit well within a broader U.S. launch strategy of procuring commercial launches of crew and cargo to the ISS, while concentrating NASA's development efforts on exploration missions beyond Earth orbit. SLS and Orion are fundamental building blocks in a capability-based architecture designed for long-term human exploration of our solar system, particularly the goal of human landing on Mars. Both Orion and SLS are being designed to support multiple missions and destinations rather than being optimized for one particular mission or architecture. The capabilities we are developing will open a broad range of exciting destinations for human exploration in the solar system. NASA's approach to expanding the human presence into the solar system includes sending humans to an asteroid in the next decade and ultimately sending humans to Mars.

Before speaking in detail about the individual Programs, I would like to give you a status of where we are with regard to the integrated deep space exploration capability. NASA successfully completed an integrated Systems Requirements Review (SRR) in February 2012 for the full-up Orion, SLS, and ground systems capabilities. This milestone demonstrated that the requirements for the integrated programs meet the Agency's goals, and provide a sound basis for the individual development of Orion, SLS, and the ground systems. The Exploration Systems Development Division of NASA's Human Exploration and Operations Mission Directorate directs Program and system integration to ensure that the integrated Orion, SLS, and the ground systems capabilities meet the needs of the Agency's long-term human exploration objectives, function as planned, and remain within the tight cost and schedule constraints.

We have established the guidelines for the management and development approach; identified roles, responsibilities, and accountability; established processes for integration and configuration management, risk management, and program performance reporting; and implemented our procedures for decision making, and cost and schedule management. We have defined Program deliverables, and completed the first phases of the NASA program management process.

We are progressing toward our integrated System Definition Review (SDR) early next year, the associated flow-down processes are properly performed, and the Programs are properly integrated to meet the needs of the human exploration framework. The status of the integrated system will be reviewed and assessed at periodic checkpoints as we proceed through development and into operations. The flight test milestones driving the schedule include the uncrewed Exploration Flight Test-1 (EFT-1) in 2014, the first uncrewed launch of Orion and SLS in Exploration Mission-1 (EM-1) in 2017, and the first crewed launch of Orion and SLS in Exploration Mission-2 (EM-2) in 2021.

Orion was designated as NASA's Multi-Purpose Crew Vehicle in May 2011, and the Ground Systems program office was stood up in June 2011. The SLS vehicle plan was announced a year ago on September 14, 2011.

Orion Multi-Purpose Crew Vehicle (MPCV)

Orion's shape resembles its Apollo-era predecessors, but its technology and capabilities are far more advanced. Orion features dozens of technology innovations that have been incorporated into the spacecraft's subsystem and component design. To support our exploration missions the Orion teams at the Johnson Space Center (JSC) and at Lockheed Martin are developing state-of-the-art life support, propulsion, thermal protection, and avionics systems. Building upon the best of U.S. human spaceflight design and experience, the Orion spacecraft includes both crew and service modules, and a launch abort system that will significantly increase crew safety.

Since May 2011, the Orion Program has pressed forward with the design and manufacture of the first flight test article and design of Orion's critical test program. On July 2, the Program delivered the first flight test crew module structure to the Kennedy Space Center (KSC) for assembly and integration. In addition, the Program has completed significant acoustic and vibration testing in the Lockheed Martin Denver facilities, 19 of 25 water impact tests at Langley Research Center, and 6 of 26 parachute tests in various configurations at the Yuma Proving Grounds. Fabrication of the state-of-the art heat shield has been initiated in Denver, and NASA continues to test avionics and software systems. Glenn Research Center is leading the Orion Service Module efforts with Lockheed Martin.

The next step for Orion is to prepare for the EFT-1 in 2014. EFT-1 will be an uncrewed, two-orbit, high-energy-entry test mission that will obtain critical vehicle performance data needed to confirm detailed design of the Orion spacecraft to fly in 2017. EFT-1 will serve as a pathfinder to validate innovative approaches to space systems development to reduce cost, demonstrate spacecraft post-landing recovery procedures, and develop the launch vehicle adapter, which will also be used on the uncrewed flight in 2017 and the first crewed flights beginning in 2021. In the next year, we will continue EFT-1 manufacturing and begin phasing in, at a low level, the design work for the 2017 Orion flight article. Mission planning for the EFT-1 with the JSC Mission Operations Directorate is ongoing.

In the next year, we will continue to press toward the 2014 flight test, ramp up the service module design efforts for 2017, and begin phasing in, at a low level, the design work for the 2017 Orion flight article.

Orion provides our Nation with an approach for multiple-mission capability that builds upon the technology innovations and spacecraft development the NASA-industry team has previously accomplished. In designing for challenging deep space missions, the Orion team will perform rigorous human rating tests and critical certification milestones required for safe, successful human spaceflight. With a proven launch abort system and its inherent design to provide the highest level of safety for the crew during long-duration missions, the Orion MPCV is poised to take on increasingly challenging missions that will take human space exploration beyond Earth orbit and out into the solar system.

Space Launch System (SLS)

The SLS Program, managed at NASA's Marshall Space Flight Center (MSFC) with the Boeing, ATK, and Pratt Whitney Rocketdyne industry partners, is developing the heavy-lift vehicle that will launch the Orion spacecraft, and cargo, for NASA's exploration missions. The SLS vehicle family will start with a lift capability of 70 metric tons (mt) to LEO, with the ability of evolving up to 130 mt based on future mission requirements. The SLS is designed with one overarching purpose: to explore beyond Earth orbit with ambitious mass and propulsion requirements.

The initial 70-mt configuration will consist of an 8.4-meter-diameter core stage building from Space Shuttle and Ares experience, powered by four RS-25D liquid hydrogen/liquid oxygen engines which formerly powered the Space Shuttle Orbiter, and build on the U.S. state-of-the-art capabilities in liquid propulsion. The core stage is being designed for use on future configurations of the SLS with the diameter, materials, and manufacturing processes remaining the same as the vehicle performance evolves. In this configuration, two five-segment solid rocket boosters (SRBs) – a more powerful version of the four-segment boosters used on the Space Shuttle – will be attached to the core stage for the initial boost phase of flight. For the first two missions of SLS, an Interim Cryogenic Propulsion Stage (ICPS) will be used to propel the Orion spacecraft from LEO. NASA has chosen Boeing's Delta IV upper stage as the ICPS for the first two flights, and the contract is expected to be signed in the third quarter of FY 2013. We anticipate having a letter contract by the end of the year, followed by the final contract in the spring.

Since the Administration announcement in September 2011 of the SLS configuration, the SLS team led by MSFC has made tremendous progress. The SLS team successfully completed the required acquisition strategy process and had all contractors working on contract by December 31, 2011. This was a major accomplishment, and it led to significant progress in the design process. The SLS NASA-industry team has successfully completed the Systems Requirements Review, the System Definition Review, and has gained Agency-level approval to proceed to the Preliminary Design Review.

The NASA/Boeing Core Stage element has successfully completed its SRR and SDR. Manufacturing process development has proceeded to support the core stage and vehicle design efforts. NASA has initiated activities to prepare the B-2 test stand at Stennis Space Center (SSC) for Core Stage green run testing that will be performed prior to shipment to KSC for launch in 2017. The Core Stage element is on the critical path for the SLS, and all hands are on deck to achieve the aggressive schedule.

The initial segments for the first of two solid booster Qualification Motor tests have been poured at ATK and the 5-segment solid rocket motor is on track for a test firing next May. ATK has delivered booster avionics systems and Boeing has delivered vehicle avionics and software to MSFC for testing. The 15 RS-25D liquid hydrogen/liquid oxygen engines have been delivered to SSC from the KSC in preparation for installation and test on the Core Stage.

SLS is also an integral part of the 2014 EFT-1. SLS is responsible for designing and developing the structure adapter to attach the Orion spacecraft to the launch vehicle. This same structure will be used on the uncrewed flight in 2017 and first crewed mission in 2021. Machining on the first set of metal rings has been completed.

Future exploration missions will require increased launch vehicle performance. We have initiated the first phase for the development of the advanced boosters needed to perform these future missions. In July 2012, NASA selected six proposals as the basis for negotiations to perform engineering demonstrations and risk reduction under an open, competitive NASA Research Announcement (NRA) to improve the boosters' affordability, reliability, and performance. The advanced boosters can be either liquid or solid, and must meet the SLS performance and interface requirements. These initial risk-reduction tasks will be followed by another full-and-open competition for the full scale design and development work leading to an eventual advanced booster for the evolved SLS.

The 70-mt, 105-mt, and 130-mt lift capability SLS vehicle blocks all fulfill specific, important roles within the exploration architecture. The Block 1, 70-mt vehicle will prove out the new Core Stage and integrated stack for the initial exploration missions and can support scientific payloads with requirements beyond commercial lift capabilities. Mission analysis has shown that the Block 1A, 105-mt vehicle provides significant "mission capture" for the next set of human missions beyond LEO. A 130-mt Block 2 vehicle is also being designed consistent with Congressional direction and would be used for full capability asteroid missions and ultimately missions to Mars. This SLS configuration will require a new upper stage with one or two J-2X upper-stage engines—currently in development testing at SSC. J-2X has completed a total of over 3,250 seconds over 29 tests on the engine and powerpack.

In the coming calendar year, SLS will undergo a series of important reviews to ensure its progress toward final design. The Preliminary Design Review (PDR) will be conducted for the integrated SLS Block 1 vehicle, as will the PDRs for the booster and core stage elements.

Exploration Ground Systems

The Exploration Ground Systems effort has also been making significant progress since the September 2011 SLS announcement. The KSC and SLS teams are working very closely to define and develop the necessary interfaces for the launch vehicle. In a similar manner, albeit at a lower level, KSC has been working with the Orion program on the needed prelaunch processing to be performed.

The KSC team has made significant progress on the necessary infrastructure design, development, and refurbishment to support SLS and Orion. Based upon the SLS and Orion needs, KSC is proceeding through the Systems Requirements and Systems Definition Reviews. The reviews are proceeding well with minimal issues, and we are continuing the Agency review process. KSC is also providing valuable operations expertise to the SLS and Orion teams to address operational issues in the design in order to help reduce eventual production and operations costs.

In terms of the infrastructure and hardware, KSC has completed the first phase of the mobile launcher construction, utilizing significant work accomplished under Constellation. Refurbishment and upgrades to a crawler-transporter are being performed at a pace to support the 2017 flight of SLS and Orion. These upgrades are needed due to the increased mass of the SLS/Orion integrated stack compared to the Space Shuttle configuration.

Work is beginning on the Vehicle Assembly Building and the platforms in High Bay 3 to support SLS. Launch Complex 39-B has been prepared for the SLS/Orion mobile launcher with the Space Shuttle hardware removed, lightning towers in place, and the needed refurbishment to the pad infrastructure with replacement of copper wire with fiber optics and refurbishment of the water deluge supply tower.

Conclusion

The NASA-industry team has made great progress over the past year on Orion, SLS, and Exploration Ground Systems. In an endeavor of this magnitude there will always be challenges. Currently, the major challenges to the programs are not primarily technical. Rather, the challenges are in maintaining program stability while acquiring the Orion and SLS systems so that the next elements of the Exploration enterprise can be developed. Additionally, there will be the typical hardware development, manufacturing, and supply chain challenges. NASA and its industry team are working diligently to identify issues early and address them expeditiously.

In developing the Orion, SLS, and Exploration Ground Systems, NASA is building a National capability for the long-term human exploration of space. By providing more volume and mass for payloads, SLS could enable the simplification of the design and trajectories of future payloads, such as orbiting fuel depots, to support the construction, fueling, and repair of space systems. These capabilities will pave the way for a mission to an asteroid, and ultimately human missions to Mars.

Mr. Chairman, thank you for the opportunity to appear before you today to provide you with our progress and status over the past year as we look forward to the 2014 Orion flight test and the first SLS/Orion test flight in 2017. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.

Chairman PALAZZO. Thank you.

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

STATEMENT OF MR. CLEON LACEFIELD, VICE PRESIDENT AND ORION PROGRAM MANAGER, LOCKHEED MARTIN CORPORATION

Mr. LACEFIELD. Chairman Palazzo, Chairman Hall, Mr. Clarke, Congressman Clarke, and Members of the Space and Aeronautics Subcommittee, it is a pleasure for me to testify before you today concerning the Orion spacecraft and its contribution to the future of America's human space exploration program.

As you are well aware, Orion is the world's first interplanetary spacecraft supporting safe, long-duration human exploration and scientific discovery missions to deep space including the moon, asteroids, the moons of Mars, and ultimately Mars itself. Orion is complementary to and indeed has contributed to the development of technologies for many of NASA's programs.

The NASA–Lockheed Martin, Orion team is comprised of Lockheed Martin, Aerojet, ATK, Hamilton Sundstrand, Honeywell and many business suppliers in 41 states. It is an exceptional team that includes some of the most highly motivated engineers employed by in industry. On the government side, it is led by NASA's Johnson Space Center in Houston, and involves a number of other NASA centers across the country. The Orion team continues to make tremendous progress developing, manufacturing, assembling and testing this state-of-the-art space exploration vehicle.

We are currently advancing toward our next major milestone, Exploration Flight Test-1, or EFT–1, in 2014, leading to follow-on orbital flight testing of Exploration Mission-1, EM–1, and subsequent crewed flight far beyond low-Earth orbit in deep space, Exploration Mission 2, or EM–2. EM–1 and EM–2 will fly on the Space Launch System managed by NASA's Marshall Space Flight program in Huntsville, Alabama.

The following are examples of major program technical progress and our commitment to crew safety and system reliability. We have successfully tested a new launch abort system during Pad Abort Test-1 at White Sands Missile Test Range in New Mexico to demonstrate our capability to protect the crew under emergency conditions. In collaboration with NASA and our Colorado-based Ball Aerospace teammate, we developed an innovative navigation and docking system called STORRM, which was successfully tested during space shuttle mission STS–134.

We have completed parachute tests at the Yuma Proving Ground in Arizona, and we are continuing water landing tests at the Hydro Basin facility at NASA's Langley Research Center in Virginia, and we are building propulsion system components at Lockheed Martin's facility located at NASA's Stennis Space Center in Mississippi. We have successfully completed spaceflight acoustic and vibration testing on the Orion Ground Test Article spacecraft at Lockheed Martin's facility in Colorado, and we delivered the EFT–1 Orion crew module to the Operations and Checkout facility—America's spacecraft factory for the future—at NASA's Kennedy Space Center in Florida, with work moving forward on critical subsystem installation, assembly and test.

The NASA–Lockheed Martin team has also initiated major affordability measures and streamlined Orion program management oversight by incorporating proven commercial practices. That said, it remains critically important that Congress maintain fiscal 2013 funding at the current level to ensure timely and successful implementation of EFT–1 in 2014, as well as outyear budgets to support EM–1 and EM–2. In fact, Orion's considerable progress and the importance of our continued commitment to crew safety, reliability and risk mitigation testing was emphasized by the Aerospace Safety Advisory Panel, ASAP, in its most recent review of the Orion and SLS programs.

Mr. Chairman, with your leadership and continued bipartisan support of this Committee, Congress and the President, Orion, together with SLS, is prepared for unprecedented missions of exploration and discovery, taking humans further into the solar system than ever before experienced, while encouraging STEM education among our youth and providing high-tech careers and jobs.

Thank you again for this opportunity to testify, and I look forward to answering your questions. Thank you.

[The prepared statement of Mr. Lacefield follows:]

House Science, Space and Technology Committee

Subcommittee on Space and Aeronautics

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"

Statement by

CLEON LACEFIELD

Vice President and Orion Program Manager
Lockheed Martin Space Systems Company

"Orion Multi-Purpose Crew Vehicle"

September 12, 2012

CLEON LACEFIELD

Vice President and Orion Program Manager
Lockheed Martin Space Systems Company

"Orion Multi-Purpose Crew Vehicle"

Chairman Palazzo, Ranking Member Costello and Members of the Space and Aeronautics Subcommittee, it is a pleasure for me to testify before you today concerning the Orion spacecraft and its contribution to the future of America's human space exploration program.

From the days of Apollo, our nation's space program has been built on the foundation of strong, bi-partisan political support. Indeed, continued support from both parties sustained through multiple Congresses and Presidents will be essential to the future of America' space exploration program, and to ensuring value from our national investment in human spaceflight. I am, therefore, pleased to see Congress, NASA and the President establish the development of Orion and the Space Launch System or "SLS" as a top national investment priority for space.

As you are well aware, Orion is the world's first interplanetary spacecraft supporting safe, long-duration, human exploration and scientific discovery missions to deep-space, including the moon, asteroids, the moons of Mars, and ultimately Mars, itself. Orion is complementary to – and, indeed, has contributed to the development of – NASA's commercial space transportation initiative for operational support to the International Space Station in low-Earth orbit.

The NASA-Lockheed Martin Orion industry team is comprised of Lockheed Martin, Aerojet, ATK, Hamilton Sundstrand, Honeywell, and many small business suppliers in 41 states. It is an exceptional team that includes some of the youngest and most highly motivated engineers employed by Lockheed Martin. On the Government side it is led by NASA's Johnson Space Center in Houston, and involves a number of other NASA Centers across the country. The Orion team continues to make tremendous progress developing, manufacturing, assembling, and testing this state of the art space exploration vehicle.

We are currently advancing toward our next major milestone, Exploration Flight Test-1 or "EFT-1" in 2014, leading to follow-on orbital flight testing (Exploration Mission-1 or "EM-1") and subsequent crewed missions far beyond low-Earth orbit into deep space (Exploration Mission 2 or "EM-2").

The following are examples of major program technical progress and our commitment to crew safety and system reliability:

- We successfully tested a new Launch Abort System or "LAS" during the Pad Abort-1 test at White Sands Missile Test Range in New Mexico to demonstrate our ability to protect the crew under emergency conditions. The LAS required development of three new rocket motors with key work accomplished by ATK in Maryland and Utah and Aerojet in California.

- In collaboration with NASA and our Colorado-based Ball Aerospace teammate, we developed an innovative navigation and docking system called "STORRM" which was successfully tested during Space Shuttle mission STS-134.

- We have completed parachute tests at the Yuma Proving Ground in Arizona; we are continuing water landing tests at the Hydro Basin facility at NASA's Langley Research Center in Virginia; and we are conducting propulsion testing at a Lockheed Martin facility located at NASA's Stennis Space Center in Mississippi.

- We successfully completed space flight acoustic and vibration testing on the Orion Ground Test Article spacecraft at Lockheed Martin facilities in Colorado after demonstrating advanced, state-of-the-art friction-stir welding manufacturing techniques at NASA's Michoud Assembly Facility in Louisiana.

- We delivered the EFT-1 Orion crew module to the Operations & Checkout facility – America's "Spacecraft Factory of the Future" – at NASA's Kennedy Space Center in Florida, with work moving forward on critical subsystem installation and assembly.

The NASA-Lockheed Martin team also initiated major affordability measures and streamlined Orion program management oversight by incorporating proven commercial practices to ensure our ability to work within constrained NASA budgets while keeping the program moving forward.

That said, it remains critically important that Congress maintain FY2013 funding at the current level to ensure timely and successful implementation of EFT-1 in 2014, as well as outyear budgets to support a robust crew safety - risk mitigation demonstration test (Exploration Mission-1) leading to first crewed mission with Exploration Mission-2. In fact, Orion's "considerable progress" and the importance of our continued commitment to crew safety, reliability and risk mitigation testing was emphasized by the Aerospace Safety Advisory Panel (ASAP) in its most recent review of the Orion and SLS programs.

As I have already indicated, Exploration Flight Test -1 or "EFT-1" is the next major program milestone on the way to opening a new era of human space exploration and scientific discovery.

The EFT-1 Orion spacecraft will fly without crew aboard an existing Delta-IV Heavy launch vehicle from NASA's Kennedy Space Center in Florida in 2014. It will send Orion 3,600 miles into space – more than 15 times father away from Earth than the International Space Station. It will test the systems needed for a high-energy return for missions beyond low-Earth orbit. Orion will re-enter the atmosphere at nearly 20,000 miles per hour – speeds not seen since Apollo; and it will experience temperatures of almost 2,000 degrees Fahrenheit – higher than any human spacecraft since astronauts returned from the moon.

Bottom-line: EFT-1 is needed to reduce program technical risk and demonstrate important integrated performance capabilities necessary to ensure mission success and crew safety.

As NASA's Orion Program Manager Mark Geyer stated recently: "We can test parachutes by dropping them from a plane. We can test thrusters in stands on the ground. We can check the splashdown in a water tank. We can test all the pieces and parts, but a space flight is the only place we can see all these things work together and work under the real conditions they will face with a crew onboard."

EFT-1 will be followed by another uncrewed orbital flight test called Exploration Mission-1 or "EM-1" in 2017 which will fly on the new Space Launch System or "SLS" rocket managed by NASA's Marshall Space Flight Center in Alabama. EM-1 will put the entire, integrated exploration system through its paces, demonstrate human mission capability, and set the stage for first Orion-SLS crewed mission operations to deep space.

Mr. Chairman, with your leadership and continued bi-partisan support of this Committee, Congress and the President, Orion – together with SLS – is prepared for unprecedented missions of exploration and discovery, taking humans further into the solar system than ever before experienced, while encouraging STEM education among our youth and providing high-tech careers and jobs.

Thank you again for this opportunity to testify and I look forward to your questions.

Chairman PALAZZO. Thank you.

I now recognize our third witness, Mr. Chilton, for five minutes to present his testimony.

STATEMENT OF MR. JIM CHILTON, EXPLORATION VICE PRESIDENT, THE BOEING COMPANY

Mr. CHILTON. Good morning. Chairman Palazzo, Chairman Hall, Ranking Member Clarke, Congressman Brooks, on behalf of Boeing, thanks for the opportunity to be here. We want to thank you for your continued support of human spaceflight. You enabled a safe fly-out of the shuttle, completion of ISS and outlining this path for beyond-Earth-orbit exploration. Without your Committee, this wouldn't have happened, so thank you very much. It is a great honor to be here.

As previously stated, the Space Launch System is an enabler for human deep space exploration needed to propel elements free of Earth's gravity. It can serve as the backbone of our Nation's space program in any post-ISS era.

I would like to start by talking about challenges per your request. It is worth noting up front that many potential challenges on SLS have already been avoided. NASA quite wisely selected an architecture that allows reuse of designs and elements that have been very successful in other programs. This separation of product development and technology development increases our overall confidence in schedule, cost and mission success.

That said, accomplishing rapid development of the core stage of Block 1 of the SLS is foremost among the remaining challenges. The SLS engines and boosters are heritage space shuttle elements. The SLS Block 1 upper stage is directly adapted from our Delta IV heavy launch vehicle but the core stage, on the other hand, is a clean-sheet design, meaning the existing elements are waiting for the core stage to catch up with them.

To see the schedule challenge, we can compare the lead time required to produce a shuttle external tank to the time allotted for this core stage development. As the shuttle neared her end schedule estimates for calling up another ET ranged from 36 to 44 months. The time allotted from system requirements review completion that Mr. Dumbacher mentioned is about 51 to 54 months, and the core stage has got to design and certify that design in close to the same time, so it gives you a feel for the kind of challenge.

A flat budget profile for SLS, which is atypical for development programs, creates yet another unique challenge, and it necessitates that SLS development occur through an evolutionary process. Simultaneous development of all the elements needed to get to the final configuration of the SLS won't be possible under that flat budget profile so NASA will have to choose so that each succeeding element developed offers the most incremental beyond-Earth-orbit performance for the smallest cost. As we work the cryogenic stages, we are retaining the option for that element to be a large upper stage should NASA choose it so that the maximum economic efficiency can be gained from our core stage efforts.

As far as risk reduction goes, we are reducing risk through adaptation of existing subsystems and components even though the core stage will be new. We have to ensure SLS is a standalone exploration-class rocket that can be adapted to many missions that emerge over many years. This is going to require a guidance system independent of payloads or crew systems so it can serve multiple users in crew and cargo configuration. To ensure we can get there on time, we have chosen to produce many of the key elements in-house at Boeing. The best example of this is the overall vehicle flight computer. We have based it on a proven Boeing commercial satellite design and already have gotten to a critical design review and put test versions in the lab for NASA software.

To keep SLS and the overall programs stable over the long haul, it is important to ensure SLS is protected and nurtured long enough to succeed. Preventing temporary budget variations from impacting schedules is a key part of that. Stable funding, which should include planning for funding that escalates with inflation, will allow a steady and predictable progress. Construction of facility tasks should be fully funded even under continuing-resolution conditions early in the program so we can get the factory and test facilities up and active. We also will work hard with NASA to get defined contracts in place that allow thorough interrogation of costs and schedule for the long haul and the integrated baseline reviews.

Our progress has been really strong. We started in December, as Mr. Dumbacher mentioned. We have already passed through a system requirements review and system definitions review 2 months ahead of our contract milestones. Our first hardware deliveries are already behind us in the avionics area, and design tempo is increasing daily.

On the manufacturing side, we are past 50 percent on all the major tools. We will begin installation of the big tooling mission at Michoud late this year and finish late next so we will have an active factory by early 2014.

Our manufacturing developments are influenced and designed very positively. Early test welds indicate we are going to get to four weld thicknesses and about 14 unique schedules compared to 14 thicknesses and about 75 schedules on an external tank. That and less costly materials are going to make it much more affordable for the government.

Our plan for progress upcoming, we get to a preliminary design late this year or early next, critical design mid-2014, and we plan for first flight in 2017.

To close, NASA's unrelenting focus on mission success has always driven us and it still is in the way we are designing the SLS today on our pace.

Thank you for the chance to testify today.

[The prepared statement of Mr. Chilton follows:]

Written Statement for Testimony

Jim Chilton

Boeing Space Exploration Vice President

Program Manager, Space Launch System Stages

House Committee on Science, Space, and Technology

Hearing: Examining NASA's Development of the Space Launch System and Orion Crew Capsule

September 12, 2012

Good morning, Chairman Hall, Ranking Member Johnson and members of the committee. On behalf of the Boeing Company, I wish to extend our thanks for your continued support of human spaceflight. Your efforts enabled a safe fly-out of the Space Shuttle, supported the completion of the International Space Station, and outlined a path forward for the future of human space exploration. Without the support of your committee these achievements would not have been possible. It is my great honor to participate with the other witnesses on this panel to share Boeing's activities in support of NASA for the Space Launch System.

In the current environment there are 3 elements to NASA's path forward for human space flight for space exploration: development of capability for human exploration beyond low Earth orbit, utilization of the International Space Station, and commercial services for cargo and crew to the International Space Station. As stated in NASA documentation, the Space Launch System (SLS) is the enabler for human deep space exploration and is needed to propel Exploration elements free of Earth's gravitational forces. SLS will be capable of lifting the Orion MPCV, cargo and other exploration elements to Lagrange points, the moon, asteroids, and ultimately missions to Mars. It will expand scientific missions by enabling the launch of large robotic payloads and also serve as a backup launch system for supplying and supporting the International Space Station cargo and crew requirements not met by other available launch vehicles.

1. Challenges – Technical, Programmatic, and Risk Reduction

As we all know development programs often face challenges, and managing them is key to assuring program success. It is worth noting up front that many potential challenges on SLS have already been avoided by adapting proven approaches to the SLS mission. Foremost among these is avoiding the need for significant technology development. NASA wisely selected an architecture that allows reuse of elements and approaches from other successful programs. This separation of product development from technology development increases our confidence in schedule and cost predictions relative to starting from scratch.

With that said, we do see challenges. Accomplishing rapid development of the core stage is foremost among these. This is the only all new element of the Space Launch System, and is the backbone on which the other elements depend. The Core stage engines are heritage Space Shuttle Main Engines; the strap on boosters, in final phase of testing, are upgraded solid rocket boosters from the space shuttle program; and the SLS Block 1 interim upper stage is directly adapted from the Delta IV heavy launch vehicle. The core stage on the other hand, is a clean sheet design, albeit one that leans heavily on existing design practice and manufacturing technologies. To some extent, the existing elements are awaiting the core stage to catch up with them. To provide a sense of this schedule challenge, we can compare the time allotted for design and delivery of a core stage to the lead time required to produce a shuttle external tank to an existing design. As the shuttle program neared its end, schedule estimates for call up of an external tank ranged from 36 to 44 months. This was for production of an existing, certified design. The core stage timeline, which includes creation and certification of a new design, is 51 to 54 months from the system requirements review. It is clear from this comparison that achieving early design progress against stable requirements and funding will be necessary to enable core stage development success.

Integrating existing elements in new ways with the emerging design of the core stage is another challenge. The core stage will fly with a 4 engine cluster, vs. the 3 engine cluster used for the Space Shuttle. Each of the RS-25 engines must support different operating regimes. The Delta IV upper stage flying on top of core stage must accommodate different loads and guidance requirements. Integration of the five-segment SRBs will also be different that the four-segment SRBs used for the Space Shuttle. Although the risk of developing new elements is reduced by reuse of these heritage systems, the connections and interactions between the existing elements and the emerging core stage design must be carefully predicted and managed. New ground interfaces must be established as well. All this integration is ably led by the government engineers at the Marshal Space Flight Center, who provide analysis and integration to the industry team members responsible to deliver elements. These integration products are the foundation on which the core stage schedule and overall vehicle success depend. Without timely and accurate delivery of these integration products, none of the elements can be delivered to predictable schedules or predictable performance.

The flat budget profile, which is atypical for development programs, creates a unique challenge necessitating that SLS development occurs through an evolutionary process. Constrained budgets prohibit simultaneous development of the core stage, upper stage, payload fairings, new engines, and advanced boosters for final 130mT SLS configuration. The common Core Stage is the first priority for the SLS vehicle and the only new SLS element, but there is enough funding for limited development of a second new element. We are retaining the option for that element to be a larger upper stage, which offers a big improvement in BEO performance from the Block 1.

Another challenge is to maximize production and operations efficiency during the design and development phase. Many in industry assert that economic efficiency is only possible at high production rates. In a government system with fixed annual budgets, it is important not to design a system that requires other buyers who enable the high volume desirable for better economics. Our experience indicates that planning for high rates and then not achieving them can create an insurmountable economic challenge. This is especially true for launch vehicles, where new demand does not appear to be stimulated as capacity at lower prices becomes available. Therefore, enabling an efficient system for low production rate is our goal for SLS. We are adapting our design to maximize production efficiency in areas of tooling, headcount, procurement processes, and even the number of lifts and moves on the factory floor. This will enable the country to finally have access to an exploration class rocket within predicted annual budgets, which we see as a definition of affordability more appropriate than costs that are scaled around potential production rates.

We are working hard to reduce risk through adaptation of existing subsystem and component designs, careful work placement, and early demonstrations in areas where history indicates surprises can occur. An example of this approach is in our avionics approach and hardware- software integration. We are striving to ensure SLS is a standalone exploration class rocket that can be adapted to a wide variety of missions that emerge over many years. This requires the vehicle to have a guidance system independent of any specific payload or crew system so it can serve multiple users in crew and cargo configurations. To maximize our integration flexibility and ensure this happens on time, we have chosen to produce key elements of the avionics system in house. Noteworthy among these is the vehicle flight computer, which is based on a proven Boeing design used in commercial satellites. Not only does this allow lower costs, it has enabled rapid progress. We already have a test version in the government labs at the MSFC, on which NASA developed software is up and running. Critical design review of this flight computer commenced two weeks ago, and the first flight configuration circuit boards are being installed this week, We are incrementally adding the avionics systems and components in the lab environment to minimize the chances that surprises in the interactions between the systems disrupts progress in certifying the design. The approach described for avionics and software is representative of our risk reduction approach, and is in use across our subsystems. We rely heavily on reuse of designs from the space shuttle and other proven space systems across the board.

There are important goals to ensure SLS is protected and nurtured long enough to succeed.

First, prevent temporary budget variations from impacting schedules. Stable funding that keeps pace with inflation allows the program to maintain a steady and predictable rhythm. Construction of facilities tasks must be fully funded even under continuing resolution conditions until the factory is in place. It is also essential to have final and well defined contracts in place, with terms and conditions locked down to keep suppliers engaged and on track to original plans.

Second, recognize that current funding profiles mean NASA will have to evolve the launch vehicle to the final capability of 130mT to low-Earth orbit, which more importantly delivers approximately 50mT beyond low-Earth orbit. Given the current funding constraints only one new SLS element can be developed at a time. The decision for which element is next, is driven by LEO vs. BEO capability considerations and will directly impact the breadth of exploration missions which can be performed. If the true intent of the Exploration program is to explore beyond low-Earth orbit, the 50mT to BEO figure of merit should be used to guide the future evolution path. Supporting NASA as their evolution decisions emerge is important for stability.

Finally, assure constancy of purpose by keeping decisions made. This is applicable at all levels including keeping the architecture stable. For example, there is no need to revisit trades such as the one already completed that compared small vs. big rockets for deep space missions. The Augustine review panel concluded a big rocket is required for deep space exploration. Also in response to a question published in the April 30th 2012 Space News interview Norm Augustine was quoted "It was the view of both the reports that I worked on that we indeed need a heavy-lift launch system". It is also essential to get final and well defined contracts in place, to allow integrated baseline reviews early enough to control long term costs and schedules.

2. Current Progress

We have made significant progress on core stage development during the first nine months of the SLS Stages contract. In June we conducted the Stages Systems Requirement Review (SRR) and Systems Definition Review (SDR) two months ahead of the SRR contract requirement. We have also completed the first hardware deliveries, and have demonstrated a rapid increase in design release tempo.

On the manufacturing side, major tooling installations will begin at the Michoud Assembly Facility late this year, with a goal to have the factory complete and active in early 2014. The 2014 target date is dependent on government-led facility preparations.

Manufacturing process development is engaged with the Core Stage design team and is influencing the design to ensure affordable production. Manufacturing development test welds are underway using our new tooling and we will use four weld thicknesses and fifteen unique weld schedules for Core Stage rather than the fourteen weld thicknesses and seventy-four unique weld schedules for the Space Shuttle External Tank. To further reduce production costs, Core stage will use conventional rather than exotic materials for primary structure (AL2219 instead of AL2195). All major tool designs are on schedule to be completed by the end of the calendar year.

Avionics test units and prototypes are in the labs and are functional to retire hardware/software Integration risk early. Our single board software test bed flight computer was delivered to the avionics lab in April 2012. The redundant inertial navigation unit development test unit has also been delivered to the lab. These early prototype deliveries have enabled closed loop simulated vehicle fly out which were accomplished with the actual flight software. The flight computer critical design review was completed in August 2012.

Our next steps are exciting. Our design release tempo is increasing, and development testing will continue into 2013. We are currently targeting for a preliminary design review in late 2012 or early 2013. The design review will include key interface definitions which will drive the overall vehicle and ground systems design. Critical design review is scheduled for mid-2014 to support a first flight in 2017. We are also working to get final and well defined contracts in place, to allow integrated baseline reviews early enough to control long term costs and schedules.

3. Future Human Exploration and Scientific Missions Enabled by SLS

The SLS will provide an exploration capability beyond Apollo. SLS can be configured to transport crew, cargo, exploration elements, and science payloads to the far reaches of deep space.

As stated earlier, to accomplish any BEO mission requires a SLS type launch vehicle to escape Earth's gravity. The initial SLS capability rocket, using the smaller interim cryogenic propulsion upper stage, would enable capability demonstrations of the Orion MPCV. Early missions might include crew assessments of the deep space environment or telepresence lunar robotics. An evolved capability configuration, using a large upper stage with existing engines, would enable NASA to accomplish more ambitious HSF Exploration missions such as Earth-Moon Libration points, a return to the Moon, an Asteroid, or Mars precursor missions. All of these destination missions would benefit from the fully evolved SLS because they could be done at lower cost with fewer launches.

Robotic science missions will also be greatly enhanced by SLS. Robotic missions to the outer planets or a sample return mission from Mars would benefit from the greater lift capacity of SLS especially in its fully evolved capability. The additional payload volume of a full size fairing allows room for larger spacecraft. Next generation space telescopes will benefit from the SLS fairing because of the improved optics from larger mirrors. Outer planet missions with long journeys will benefit from the shorter trip times that SLS can offer.

In closing, our country's success in space has always been driven by NASA's unrelenting focus on mission objectives. The call for a robust capability and multiple destinations strikes an exciting challenge to create the space transportation architecture of the future. Today's plan for NASA – 1) space exploration beyond LEO, led by NASA with institutional funding; 2) supported by private enterprise providing space transportation to ISS in a public sector partnership with NASA – provides a balanced and cost effective approach to continue the great work being accomplished onboard ISS, and continue the great challenge of human space exploration to destinations beyond earth's orbit.

Chairman PALAZZO. Thank you.

I now recognize our final witness, Dr. Mountain, for five minutes to present his testimony.

STATEMENT OF DR. MATT MOUNTAIN, DIRECTOR, SPACE TELESCOPE SCIENCE INSTITUTE

Dr. MOUNTAIN. Mr. Chairman and Members of the Subcommittee, Chairman Hall, let me first thank you for your continuing support of space science, an endeavor where the United States leads the world.

In response to your questions about the role large space launch vehicles like NASA's Space Launch System could play in space science, let me provide some context. The partnership between NASA's science and human spaceflight programs has led to globally recognized icons of science such as the Hubble Space Telescope. A large launch system such as SLS provides another opportunity that could allow us to observe amazing phenomena that are well beyond the capabilities of the Hubble, the James Webb Space Telescope or our existing fleet of interplanetary spacecraft.

Imagine being able to answer the question that spurs endless wonder across the millennia: are we alone? That answer is now within reach. Imagine returning samples of Martian soil back to Earth in a single mission for analysis. Imagine landing a new generation of probes on far more distant bodies such as the icy moons of Jupiter, to drill through the ice of Europa and see if life may have existed or even continues to exist there.

Our imagination can become reality if NASA and the science community can find cost-effective ways to use the Space Launch System. Let me give some examples. The SLS has the potential to completely change the paradigm for building future space telescopes that simply would not be possible today. To search for the evidence of biological activity, life on hundreds of potentially habitable worlds that exist beyond our solar system would require a telescope that has a primary mirror that is 15 to 25 meters across. That is three to four times larger than the James Webb Space Telescope. The SLS would allow us to efficiently bring greatly simplified building blocks of such a telescope to low-Earth orbit where they could be assembled and moved to a more distant orbit. By both having the transport capacity and by providing the human or robotic infrastructure to assemble such a system in space, the SLS is the key tool needed to answer the question: are we alone?

Another example is the recent Planetary Decadal Survey's top priority: Mars sample return. To make this complex mission feasible with existing launch technologies, it had to be carried out over three separate launches, significantly stretching out this mission's duration and potential cost. The current SLS has the capability to combine all three into a single launch.

So what are the characteristics of an SLS that enable such an exciting scientific future for the U.S. space program? First, the 70- to 130-metric-ton lift capacity to low-Earth orbit means that more conventional materials and components can be used in spacecraft and observatory design. Ultra-lightweight components could be replaced with heavier, more rigid structures and perhaps more high-cost, specialized components could be replaced with more commercialized systems. This simplifies the design, consequently reduces mission risk, and hopefully cost.

Secondly, the SLS must be able to launch not just more mass but the payload fairing must be able to accommodate large volumes so we can simplify telescopes and large missions by reducing all or many of the on-orbit deployments that could otherwise be needed if one only had access to smaller launch vehicles.

Third, for some science missions, the ability of an SLS system to also bring up sophisticated robots or astronauts to assemble or service future complex science missions is a really exciting opportunity.

Fourth, the solar system missions, the increased energy of SLS launch vehicle also means planetary science payloads can be launched over a wider range of launch windows and in some cases being able to travel directly to solar system bodies, saving transit time.

Finally, but crucially, science can only realistically use Space Launch System if its availability for research missions is both reasonably frequent, probably at least once a year, and not excessively costly to the science mission providing that payload. There is a multi-decade precedent for this: the partnership between human spaceflight and science that has enabled 22 years of unparalleled discoveries with the Hubble Space Telescope. The costs of a space shuttle for the Hubble was not fully borne by NASA's Space Mission Directorate, rather provided as part of NASA's spaceflight infrastructure for use by the entire agency. Science should be considered an essential and exciting partner in the exploration endeavor but science cannot drive the development of a human spaceflight system.

In closing, the SLS can definitely enable several very ambitious and imaginative science missions that only NASA and this Nation can do. The results will be truly inspirational.

Mr. Chairman, thank you again for your support and that of the Subcommittee. I will be pleased to respond to any questions.

[The prepared statement of Dr. Mountain follows:]

Matt Mountain

Director, Space Telescope Science Institute

Testimony before the House Space and Aeronautics Subcommittee

Committee on Science, Space and Technology

September 12, 2012

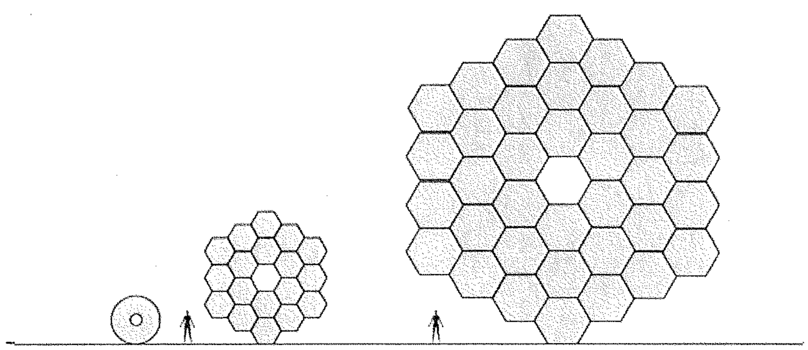
Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to testify about the scientific uses of NASA's Space Launch System or SLS. Since the dawn of the space age, visionaries such as James Webb, the second NASA Administrator (who put the Agency on the path to land men on the Moon), realized space technologies could engage the scientific community and create new scientific capabilities. That partnership between science and NASA led to globally recognized icons of science such as the Hubble Space Telescope, and most recently the Curiosity Mars lander. The SLS has the potential to enable us to cost-effectively build the next generation of ambitious space telescopes and planetary probes. This will allow us to observe amazing phenomena that are well beyond the capabilities of the Hubble or James Webb Space Telescopes or our existing fleet of interplanetary spacecraft.

Imagine being able to answer the question that stirs endless wonder across the millennia: "Are we alone?" The answer is now within reach. Imagine being able to observe weather on a habitable Earth-like planet orbiting a nearby star other than our Sun. Imagine being able to take a detailed picture of a black hole and see the cataclysmic fate of matter as it disappears into oblivion at the event horizon. Imagine returning samples of Martian soil back to Earth in a single mission for detailed analyses, or landing new generation of probes on far more distant bodies such as the icy moons of Jupiter or Saturn. One such ambitious mission could drill through the ice of Europa and see if life may have existed or continues to exist there.

Our imagination can become reality if NASA and the science community can find cost-effective ways to use the Space Launch System. For example, the cost and complexity of some of these missions will be greatly reduced as compared to what it would take to develop missions to fly on smaller less capable launch vehicles. On the other hand, some missions would simply be infeasible without SLS.

Today's ambitious space science missions have adapted to the limitations of current launch vehicles. For example, the James Webb Space Telescope is designed with many lightweight components so it could be launched with existing rockets – technologies had to be developed that reduced the mass of the JWST by over a factor of 100 compared to a comparable ground-based telescope. To fit within the confines of its launch vehicle's fairing JWST's mirrors and components had to be deployable. While these lightweight deployable components enable the JWST mission and have all been thoroughly tested, they also added complexity and cost to JWST's design.

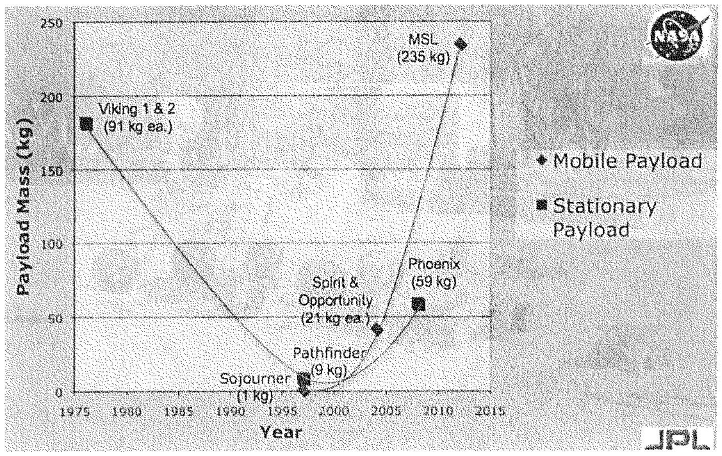
A 16-m telescope in space enables the
Era of Remote Sensing
of Oceans, Weather, Land and Vegetation coverage on
Hundreds of Habitable Worlds Beyond Our Solar System



The SLS has the potential to change the paradigm for ambitious space science missions. For example, the SLS provides the means for building a space telescope three to four times bigger than JWST allowing us to not only directly observe daily changes in weather on planets in other star systems but to search for evidence of biological activity – LIFE – on hundreds of potentially habitable worlds that exist beyond our solar system Such observations require a telescope that has a primary mirror that is 15 to 25-meters across. The SLS will be able to loft as much as 130 metric ton of payload to low Earth orbit. This means that more conventional materials could be used in the spacecraft and observatory design. Ultra-lightweight components could be replaced with heavier and more rigid structures. This simplifies the design and cost. The SLS would allow us to efficiently bring greatly simplified building blocks of such a telescope to low Earth orbit where it could be assembled and then moved to a more distant orbit where it would conduct these amazing observations. **SLS is a key tool needed to answer the question "Are We Alone?"** by **both** being the transport capability for bringing telescope complements into space and by providing the human and/or robotic infrastructure to assemble such a system in space.

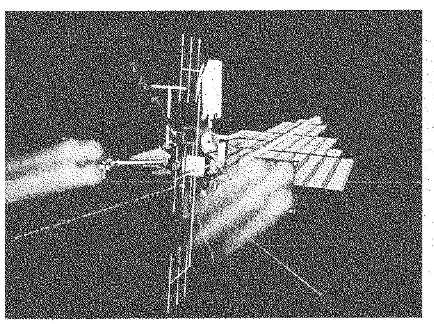
In the recent Planetary Decadal Survey, the top priority was a Mars sample return mission. But to make this complex mission feasible with existing launch technologies it had to be carried out over three separate launches, significantly stretching out this mission's duration and potential cost. The current SLS has the capability to combine all three into a single launch. It isn't just that all three missions can be combined into a single launch, but the individual components can again be simplified. Because of the greater launch mass capability of SLS, more traditional structural materials and approaches can be used, more conventional electronics can be taken into deep space since we can afford the significant additional mass of shielding these delicate electronic components from cosmic rays – all leading to reduced mission risk and potentially reduced cost.

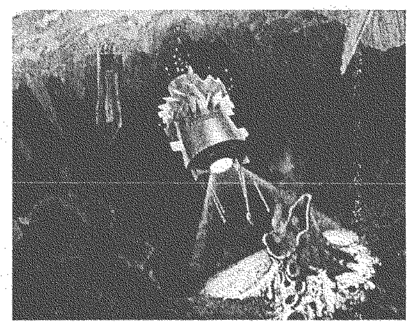
We now know there are many fascinating environments in our own solar system that beg for more detailed exploration. For example Europa, a moon of Jupiter, appears to have a large ocean below its thick outer layer of ice. The SLS once again enables these types of missions in two ways: the large mass launch capacity would allow the design of the sophisticated robotic laboratories required at these exotic locations, but equally important, the increased energy of an SLS may enable direct flights to the outer reaches of the solar system. If a Europa bound mission does not have



The increasing mass (and complexity) of NASA's Mars landers over time. To further increase the capabilities of future landers will either require multiple launches, or launch capability like the SLS.

to rely on gravity assist "sling shots" around other solar system bodies, the travel time to Europa could be reduced from seven years to only four years using SLS, significantly reducing mission risk and overall mission cost.





Two missions could that could be enabled by an affordable Space Launch System, [left] a long duration Jupiter Icy Moons Orbiter spacecraft (courtesy JPL), and [right] a probe to explore the oceans beneath Europa's ice mantle (courtesy APL).

On even grander scales, we can re-kindle the vision of the early space science pioneer Lyman Spitzer who first proposed the Hubble Space Telescope, and envision building a space observatory that has the resolution of a mirror that is a kilometer or just under a mile in diameter! Of course, we wouldn't build it as a single structure but by flying as many as 50 1-meter telescopes that fly in a precise formation that spans a 1-kilometer diameter. Such an array of telescopes would allow us to undertake remote sensing, at a resolution and cadence of today's Earth sensing systems, not of Earth but of other worlds around other stars. This kind of telescope array would normally require tens of launches with conventional launch vehicles and would never be undertaken unless we had the capabilities of the Space Launch System.

So what are the characteristics of an SLS that enable such an exciting scientific future for the US space program?

First, the 70 to 130 metric ton lift capacity to Low Earth Orbit (LEO) means that more conventional materials and components could be used in the spacecraft and observatory design – ultra-lightweight components could be replaced with heavier and more rigid structures, high-cost specialized electronics could be replaced with more commercial like systems. This simplifies the design and, as a consequence, reduces mission risk.

Second, the SLS must be able to launch not just more mass, but the payload fairing must be able to accommodate large volumes so we can simplify telescopes and large missions by reducing all or many of the on-orbit deployments that would be otherwise needed if one only had access to smaller launch vehicles. The next generation of UV-optical space telescopes will benefit from fairing diameters of at least 8-meters, and for some designs, up to 10-meters in diameter. Fairing height is important as well – some space science missions may need up to 25 meters of fairing height.

Third, the increased energy of the SLS launch vehicle also means planetary science payloads can be launched over a wider range of launch windows, in some cases being able to travel directly to solar system bodies, saving transit time, giving more flexibility in launch schedules or providing more regular access to otherwise hard to reach solar system objects.

Finally, to realize its enormous scientific potential, the cost of using the SLS has to be affordable to science.

Throughout history, whether it is Captain Cook's voyage to observe the transit of Venus, or Darwin's passage on the Beagle's voyage of discovery, exploration and science have been partners. Throughout NASA's history, science has thrived and been enabled by the US investments in space exploration, the most spectacular example being the partnership between the Human Space Program and Science that enabled 22 years of unparalleled discoveries with the Hubble Space Telescope. If we want NASA to be greater than the sum of its parts, science can only realistically use a Space Launch System if its availability for research missions is both reasonably frequent (probably at least one per year) and not excessively costly to the science mission providing the payload. There is precedent for the latter in that the cost of the Space Shuttle for missions like the Hubble was not fully borne by NASA's Science Mission Directorate but rather provided as part of NASA's space flight infrastructure for use by the entire Agency. Science, once again, should be viewed as an essential and exciting partner in the exploration endeavor, but science cannot drive the development of a human space flight system.

In closing, the SLS can definitely enable several very ambitious and imaginative scientific missions that only NASA and this nation can do. The results will be truly inspirational, and will irreversibly change our view of ourselves as a species and our place within this vast Universe.

Mr. Chairman, thank you for your support, and that of this Subcommittee. I would be pleased to respond to any questions you or the other Members of the Subcommittee may have.

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

The chair will at this point open the round of questions. The chair recognizes himself for five minutes.

Both the SLS and the Orion programs are operating under a flat funding profile through the first uncrewed flight in December 2017. How will NASA address any developmental challenges that cannot be managed within the constraints of the current budget, Mr. Dumbacher?

Mr. DUMBACHER. We are working hard within that flatline budget to phase the content. Our plan is set up to deliver on 2017 and 2021 as it has been submitted. The process that we have to go through, number one, is to make sure that the integrated system stays together in terms of SLS, Orion and ground systems all arriving at the needed delivery dates with the needed technical capabilities on time, and we work hard to do that.

How we do this is, one, we purposely chose a system that had minimal development risk. In the past with launch vehicle development propulsion systems are typically the high-risk items. By utilizing the RS–25's shuttle main engines from the shuttle program as well as boosters with shuttle heritage and Constellation development behind them, we have minimized a lot of that risk, and then we have to phase in the content, the program content, to support 2017 to be able to handle the natural development curve for things for elements such as the core stage, and we have been very deliberate, very detailed in our planning to put that plan together, to phase the content so that we arrive with the integrated system at 2017 to 2021.

Chairman PALAZZO. Mr. Lacefield or Mr. Chilton, if you would like to comment?

Mr. LACEFIELD. Yes. I would like to add that we are very well synchronized with the Space Launch System and Gemini have a lot of contact and we are staying closely integrated between Orion and SLS. What that allows us to do is, we have put together a plan working with NASA and industry that we feel is a high-confidence plan working towards 2017. We have worked multiple options with NASA looking at things that we could defer or things that we could pull forward, depending on the activities on the program or the needs of the program, and I think that allows us a great flexibility to accomplish what Dan is talking about.

Chairman PALAZZO. Although potential missions have been discussed, NASA is currently designing SLS and Orion to be flexible with regard to multiple missions and/or destinations. When does NASA expect to determine these missions and destinations? What is the impact of designing a vehicle with multiple capabilities, some of which would not be used depending on the destination, Mr. Dumbacher?

Mr. DUMBACHER. First of all, as you have seen in the agency's delivered exploration goals and destinations report from a week or so ago, we are looking at multiple destinations. We are in the process of doing the mission analysis at this time. We know that the ultimate destination is Mars. The intermediate destinations between where we are today and Mars and the exact timing of those are being sorted out through our mission analysis, and we are looking at options such as the asteroids, lunar space, lunar orbit, Lagrangian points, et cetera, on the way. That mission analysis is in work and also starting to understand what the implications can be to Orion and SLS. The process we are working very hard to do is get the fundamental capabilities, that is, the heavy-lift launch vehicle and the spacecraft, in place. We need those for any destination we go to, and then as we sort the mission planning, add the additional elements in that we need to execute the given missions at a given time, and of course, the timing of all that is based on the mission analysis and the available funding.

Chairman PALAZZO. Mr. Lacefield, do you anticipate each production Orion to be essentially the same basic design with components and systems to be inserted based on mission requirements?

Mr. LACEFIELD. We are certainly set up that way. We have a very capable vehicle that we can actually add mission kits to for whatever the destination is. We have done a lot of mission work with NASA, and Boeing has been with us as we have been supporting NASA in their mission development to make sure that the capability that we have or the mission kits that we have are easily obtainable and easy for us to reconfigure flight to flight if so needed.

Right now, the way that we are looking at the architecture is most everything that we need will be built into the first vehicle that we fly, EM–1, so that there is little update, if any update, for EM–2 such that we have the capability as soon as possible to get as much flight test time as we can on the vehicles before we put humans in the vehicles.

Chairman PALAZZO. Same basic question for Mr. Chilton on the Boeing's SLS design.

Mr. CHILTON. Yes. For all our cryogenic stages and especially core stage, we contemplate the same production configuration for economic advantage, and mods, we would anticipate, would only be driven by missions that are much further out than the early configs, and anything for obsolescence. All of that we see as next decade or beyond, so your question about schedule, to hold schedule and make sure we can get into a single configuration for economic advantage, we plan to fly the same stages every time.

Chairman PALAZZO. Mr. Lacefield, your hearing statement makes reference to work being done on Orion at Stennis. Could you please elaborate on the nature of the Orion work being done there?

Mr. LACEFIELD. Certainly. We are utilizing our Lockheed Martin space satellite factory there to manufacture all of the propulsion components needed for Orion so we are doing all of the tube styles, regulators and actually a lot of the insulation blankets are all done at Stennis and then shipped to Florida for assembly into the vehicle. It is a facility that in Lockheed Martin is known for its ability to put high-pressure systems together and weld them and have high reliability and we are using that factory for Orion.

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

Mr. CLARKE. Thank you, Mr. Chair, and I also have concerns about adequate funding for both of these important projects. I am also from the city of Detroit, metropolitan Detroit. We are also concerned about creating more jobs, but we will deal with the economic benefits of these projects later on.

Mr. Dumbacher, under a Continuing Resolution for fiscal year 2013, what level of funding and what spend rate will SLS and Orion get?

Mr. DUMBACHER. Under the current understanding of what the six month Continuing Resolution will contain, we are planning to 50 percent of the fiscal year 2012 appropriations levels, and that will be the spend rate that we are working to on SLS and Orion for the first six months. We do have to recognize, however, that the uncertainty in the potential budget appropriations for the remainder of the fiscal year also need to be included in our planning, and we are working to address that. But in the near term, we are planning for the next six months to plan at 50 percent of the fiscal year 2012 appropriations level.

Mr. CLARKE. Now, have you been given any guidance regarding the CR?

Mr. DUMBACHER. What I just talked about, the fiscal year 2012 50 percent level is the guidance I have been given.

Mr. CLARKE. All right. Even though we have made considerable progress in the development of both of these projects, we still have critical milestones ahead. As Congress and the Administration are weighing our funding priorities, how important is the need for funding and spending stability over this next year, and what is the impact of not getting it? I know many of you have actually alluded to this but, Mr. Dumbacher, I would like to know your opinion.

Mr. DUMBACHER. Funding stability of any endeavor of this magnitude—launch vehicles, spacecraft—is critical to the program planning and program success. The ability to plan into the future and to understand what the future holds within some reasonable level of understanding allows us to set up our program plans, to address that and then allows us to go execute. Changes to or instability in the funding forces replan work, rework, and all of that effort takes away from our ability to actually execute and get the hardware developed and build the program.

Mr. CLARKE. Thanks, Mr. Dumbacher.

Mr. Lacefield or Mr. Chilton, do you care to comment on the impact of not getting the funding that we need?

Mr. LACEFIELD. NASA has been very good at telling us what the levels are to assume and we have planned the program to those levels. But I would like to emphasize that with our workforce, and our workforce is our most important asset, and maintaining those critical skills across the program we believe is really important, the funding stability is extremely important to us because that is the way that we have to look at the program as we go through the different phases and we go from engineering phase to development phase to a test phase. It allows us to bring those people across those interfaces so they are available for the EM–1 and EM–2 missions. So having that stability allows us to keep that professional workforce, which is vital to these high-performance programs.

Mr. CLARKE. Thank you.

Mr. CHILTON. I would like to add that there is a bit of an unseen element in addition to cost, schedule and skills. We have had great luck attracting talent fresh out of college. A lot of young people have joined these programs. They see it as a very attractive place to go. I have experience on other programs where we started and didn't finish and had to stop. We don't get those young people back. They begin to see this industry as unattractive or unstable. They have a strong desire to start something and finish it, take something to flight. So I would argue our STEM attraction, it is important to keep stable and make progress.

Mr. CLARKE. Mr. Chilton, that is an interesting dimension to this funding issue. How important is it to actually get our young college graduates into the space programs?

Mr. CHILTON. In my——

Mr. CLARKE. Or do you have enough people right now in place at NASA with to be able to—and with your company and other contractors.

Mr. CHILTON. I will speak for Boeing. The Space Launch System currently is a great attractor of students out of college and a high proportion of our program is composed of them. If you just look at a talent pipeline over a couple of decades, you have to fill the entry level and you have to put them on our programs or you don't have the ability to touch stuff with senior people later. So I would argue keeping this stable and continuing to attract those young people is important for all of us.

Mr. CLARKE. And probably these programs too, I mean, it is a great incentive to encourage our college students to actually go into science and to get their advanced degrees to be able to do the work that is needed here to advance SLS and Orion. Thank you.

Yes, Mr. Lacefield?

Mr. LACEFIELD. Just as Mr. Chilton talked about Boeing, a third of our team, I would classify as under 30 and right out of school, and these kids are highly motivated and they have a technology level, especially when we talk about advanced computing, advanced avionics, that is really vital, I think, to not only NASA but also to the Department of Defense. So we see a lot of these technologies that these kids are involved with as playing forward to other vital programs in the United States.

Mr. CLARKE. Thank you, and I yield my time.

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

Mr. BROOKS. Thank you, Mr. Chairman.

According to our Committee notes for this hearing, Orion is much further along in development than SLS because the Administration's decision to cancel Constellation was more disruptive to the launch vehicle development than to Orion's, and so I imagine that there is some plus then from the billions of taxpayer dollars that were sent on Constellation and that we at least have something to show for it, the progress that was made on the Orion capsule. On the other hand, though, we have much less to show for the billions of dollars that we spent on the Constellation launch platform. That having been said, Mr. Dumbacher, what assurances can you give America that this White House, this Administration won't unilaterally undermine or cancel the Space Launch System as it pretty much did with Constellation at a cost to taxpayers of again some billions of dollars?

Mr. DUMBACHER. Well, Congressman, I think the fiscal year budget request from the President demonstrates the stable funding and the intention to continue on and the desire to make SLS and Orion productive. I think that President's budget request is the plan that we have developed. It is what we are working to, and that—the support is there to go make that happen.

I will also add that we are taking more advantage than just Orion from the Constellation program, particularly in our solid rocket boosters that we are using on the first two flights. The five segment boosters do have shuttle heritage but they are coming out of the Ares development, and that development made great strides and we are taking advantage of that as part of the Space Launch System to move that forward, and that is an element of our success with the development motor that we completed firing on that a year ago and next May we will be doing our first qualification motor firing.

Mr. BROOKS. Well, the assurances that you have given me sound a lot like the assurances that were given to the Constellation program prior to its cancellation. Is there anything else that you can add that would make us in Congress or the American people feel more comfortable that we will not continue along this path spending billions of taxpayers' dollars on the development of the Space Launch System only to have once again the White House pull the rug out from underneath us?

Mr. DUMBACHER. I think, Mr. Congressman, as I have mentioned, the President's budget request demonstrates that commitment to continue on. The team that we have across the country at the various NASA centers, our industry partners, as well as the leadership of the agency has demonstrated its commitment and we are continuing to move forward with all due haste in order to meet our 2017 flight date, and that is our target.

Mr. BROOKS. Thank you.

Mr. Lacefield and Mr. Chilton, how have continuing resolutions as a funding mechanism for NASA impacted the private sector's ability to do what needs to be done to advance Orion and the Space Launch System? Has there been any adverse effect at all? Is it something that the private sector is comfortable with? As you know, we are about to face another continuing resolution for some number of months into this fiscal year. Can you help educate me on whether there is any impact on the private sector by continuing resolutions, and if so, please describe it?

Mr. LACEFIELD. Mr. Congressman, I will try to give our viewpoint on that. Continuing resolutions are an impact but this is one where over the last several years NASA has been very good at telling us what to plan to or what to anticipate to plan to. So we have really done a lot of planning to make sure that we can meet those numbers, and we have worked options so that if we have contingencies that arrive that we can work around those. They are hard constraints when you are working a development program because at this point in the development program of course there is a lot of hardware in the loop that you are trying to make sure that you can purchase and develop and test, but that is part of the planning, you know, that we have gone through.

I think what we have seen with the stress in the system has really allowed the team to go at this from a different point of view, from an affordability point of view. I know there has been a lot of discussion about the government programs versus the commercial programs. We have brought in a great deal——

Mr. BROOKS. Mr. Lacefield, if you don't mind, I am going to interject. My question was limited just to the impact of continuing resolutions.

Mr. LACEFIELD. Okay.

Mr. BROOKS. Are you saying there is no harm or there is harm?

Mr. LACEFIELD. It is very difficult but it is something that we plan around.

Mr. BROOKS. Mr. Chilton, please.

Mr. CHILTON. In general, we would always rather be executing our programs than replanning them. Any continuing resolution can push you into a replan situation. Mr. Dumbacher testified that NASA has protected us from that for the first six months of government fiscal 2013 by planning for 50 percent of 2012.

Mr. BROOKS. Thank you, gentlemen.

Chairman PALAZZO. I now recognized the Ranking Member of the full Committee, Ms. Johnson from Texas.

Mr. JOHNSON. Thank you very much, Mr. Chairman, and I would like to ask unanimous consent to place my opening statement into the record and simply apologize for having two conflicting very important committee hearings.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF RANKING MEMBER EDDIE BERNICE JOHNSON

Good morning, and welcome to our witnesses. I look forward to your testimony.

Mr. Chairman, I will be brief in my remarks. Today's hearing is important for a number of reasons. In a season that seems to be consumed by partisan rhetoric and campaign slogans, I am glad that Members will instead have a chance this morning to focus on the serious work being done by a dedicated NASA and industry team to bring the future of our nation's human space exploration program into being.

As you know, successive Congresses and Administrations have said that it is time to again move humanity beyond low Earth orbit and continue the voyages of exploration begun by Neil Armstrong and his fellow astronauts. And we will pay tribute tomorrow at the National Cathedral to Mr. Armstrong, a man who spoke eloquently about the importance of a national program of human exploration when he testified before our Committee.

Yet, as I have said before, I think the most fitting tribute we can give to Mr. Armstrong's memory is not a eulogy, but instead a real commitment to the spirit of exploration that he embodied. And that's one oflhe reasons today's hearing is so important.

It is easy for us to talk of returning to the Moon or going to an asteroid, or visiting Mars long after most of us will be gone from our positions in Congress and the White House. It is another thing for us to actually sustain the needed investments and provide the programmatic stability that will help turn those words into reality. Yet if we fail to do so, the consequences of our failure will be long lasting.

Based on the testimony we will hear today, it is clear that NASA and its contractor team have made significant progress under very challenging conditions. They are turning designs and concepts into hardware and software and are moving forward towards flight tests in spite of funding that has been significantly less than authorized.

However, they can't do it alone. We—Congress and the White House—can set them up for failure if we disrupt their funding and programmatic plans in the name of short-term cost savings or if we allow the funding that Congress provides for these programs to be reallocated or otherwise restricted within NASA during the upcoming Continuing Resolution. We will need to guard against both dangers in the coming months.

Finally, while I am pleased that the Space Launch System and the Orion crew capsule appear to be progressing well given the level of funding that has been available to them, we also need NASA to layout the plans for the use of these vehicles. SLS and Orion are simply the *means* to achieving the ends we are seeking in our human exploration program, and not ends in themselves. As NASA continues work on the development of these vehicles, it is not too soon for NASA to start clearly defining the steps it plans to take to achieve the broad exploration goals laid out by Congress in successive NASA Authorization Acts.

That, however, is the topic for a future hearing. Today we will hear about the status of the SLS and Orion vehicles that will make those exploration missions possible. My thanks again to our witnesses for their participation in this morning's hearing, and I yield back the balance of my time.

Ms. JOHNSON. My question is to Mr. Lacefield and Mr. Chilton. NASA has set a schedule of 2014 and 2017 for unmanned test flights with 2021 as the first manned test flights of the integrated Orion and SLS system. What of your funding levels will be required to achieve this schedule, and given the current funding constraints, what parts of the test plan are most at risk and what are the implications? What would be the implications of any funding reductions?

Mr. LACEFIELD. I think from the Orion point of view, we have planned the program through the scope to accomplish the 2014 mission and the 2017 mission at the marks that NASA has received so that we see those as high confidence level tests that we can get to. I think the thing that we worry about the most is trying to do the human spaceflight earlier than the 2021 and that is where we have probably spent the most time looking at options to bring that forward, but at the current time we are not able to bring that forward with the funding marks that we have today.

Mr. CHILTON. From a test perspective, it is very important that we get our government facilities ready to run tests. That includes test stands at the Stennis Space Center. The core stage of the SLS, the first flight stage will actually go to Stennis and undergo what we call a proto flight test. We will put her on the stand, learn about the tanking, run instrumentation and firing sequences that get us ready to fly. If we have budget disruptions that make it so those government facilities aren't ready, going back to Congressman Brooks' question, if under a CR, if our colleagues at the agency can't have those ready, that will certainly be a schedule challenge, so that funding is important.

And I would also agree with Mr. Lacefield. We think our production systems and our supply chains and our people will be ready to produce the Space Launch System and Orion more than one in 2017 and more in 2021 and we will just let funding dictate whether we get to do that or not.

Ms. JOHNSON. Thank you.

Mr. Dumbacher, do you care to comment?

Mr. DUMBACHER. I think our available funding is—the 2014, 2017 and 2021 dates are all within our available funding and the plan that we have, we are working to mitigate the risks associated with that but we believe we can execute the plan to those dates. The testing is very important. Twenty fourteen, the exploration flight test is critical for our Orion flight test, particularly because it addresses 12 of our 16 top risks for that spacecraft, as well as an opportunity to test out our recovery systems for recovering the crew module from the ocean once we land, and it is also critical from an SLS perspective in that we get the payload to launch vehicle adapter designed, developed and built and we will use that same adapter for the 2017 and 2021 flights. So our integrated test plan is very important. We have laid it out very carefully to make sure we address our high-risk items and to work that within the budget and we believe we have the answer and the plan that we need to execute.

Ms. JOHNSON. Thank you. My time is about to expire.

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

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

I am trying to figure out exactly how much money we are talking about here, and we keep getting answers dealing with the percentage of this and the percentage of that. What exactly is the budget amount that you are seeking to have appropriated for fiscal year 2013 for Orion/SLS?

Mr. DUMBACHER. The President's budget request as I recall, and we can take it for the record to go back and get the exact numbers, but we are in the ballpark of about $1 billion annually for Orion and $1.3 billion for SLS per the President's budget request. Now, we can go back and get the exact numbers but that is working off the top of my head, Congressman.

Mr. ROHRABACHER. All right. To be fair about it, I would think that someone would know exactly how much money they are requesting when they come to a hearing to talk about those projects. So roughly $2–1/2 billion is what we are talking about for Orion/SLS. And did we just hear that there is going to be no test with people on Orion until 2021?

Mr. DUMBACHER. Our first crewed flight is 2021, and that plan is based on the available funding level that we have today.

Mr. ROHRABACHER. And that $2.3 billion that we are doing today, do you expect that level of spending to continue or to go up according to your plan?

Mr. DUMBACHER. Our plan is laid out with—the President's budget request is laid out with constant year funding across the budget horizon, and that is what our plan has been built upon, and one item I would like to identify is that in addition to the SLS and Orion funding is also the funding that is necessary for the ground systems program at KSC in order to have the launch infrastructure ready to support both Orion and SLS.

Mr. ROHRABACHER. Is that included in the $2.3 billion figure you just——

Mr. DUMBACHER. Now, that is an additional $400 million plus.

Mr. ROHRABACHER. So now we are talking more like——

Mr. DUMBACHER. We are talking——

Mr. ROHRABACHER. —$2.7 billion, about?

Mr. DUMBACHER. In that—yes, and we will take it for the record to go back and get the precise numbers.

Mr. ROHRABACHER. That is a lot of money. We would hope that—you know, when we are dealing with these big projects, we are dealing with big money, and if something goes wrong, we end up losing big money, and we have seen a lot of examples of that in the past.

I am wondering if there is other ways to go about this. Let me ask, is it Mr. Lacefield? Did I pronounce the name? Now, the SLS is not scheduled to be ready but Orion will be ready before. Is that correct?

Mr. LACEFIELD. What we have done is, we have a test flight or a flight test of Orion early to——

Mr. ROHRABACHER. Right.

Mr. LACEFIELD. —prove that we can——

Mr. ROHRABACHER. And that is going to go up on a Delta IV?

Mr. LACEFIELD. Yes, sir.

Mr. ROHRABACHER. Yeah. What is the cost of a Delta IV flight?

Mr. LACEFIELD. It is in the ballpark of $300 million.

Mr. ROHRABACHER. Okay. And a test flight—and when we get the SLS done, what will be the cost of that flight, a flight on the SLS, beside all of the expenses of developing this $35 billion development cost? Who can answer that?

Mr. DUMBACHER. Well, I will take that one, Mr. Congressman. We are still working that number up. It will be a higher number than the Delta IV heavy cost that Mr. Lacefield mentioned.

Mr. ROHRABACHER. It is going to be higher and we have all the development costs. What can we do? Are there other missions that we can do with the Orion on top of a Delta IV? Mr. Lacefield?

Mr. LACEFIELD. When we look at the exploration missions and we start looking at the nearest mission that we are talking about doing is in the Cis-Lunar or the lunar environment. It takes the SLS for us to do that mission. So EM–1 and EM–2, which will fly to 300,000 miles out there, it takes an SLS to boost us there.

Mr. ROHRABACHER. So Delta IV's would not permit the Orion capsule from doing these lunar missions. Are there other missions that Orion might be able to do on Delta IV's?

Mr. CHILTON. May I address that? We seem to be talking about a big rocket versus a small rocket. Meaningful beyond-Earth-orbit exploration requires a heavy-lift rocket. It has been studied by the agency, many others, most recently and famously by the Augustine Commission. Both Augustine panels said a heavy-lift rocket is required to do beyond-Earth-orbit exploration. He confirmed that again, in fact, in an interview with Space News in April.

Mr. ROHRABACHER. Right, for manned flight. You can do a lot of things with the Delta IV but unmanned.

Mr. CHILTON. So the driver is the size for human-rated elements and the velocity to escape Earth's gravity.

Mr. ROHRABACHER. Well, we are going to be watching, and we wish you luck. We want you to succeed, and we have just been through a number of these in the past where we end up having budget problems on this end and then we end up losing billions of dollars. So, I hope that you are successful, and we are on your side. Thank you very much.

Chairman PALAZZO. We are going to be going into a second round of questioning, and I will lead it off for five minutes.

Dr. Mountain, what is more important to the people designing trajectories for science missions, an emphasis on the amount of mass that can be carried to low-Earth orbit or an emphasis on the amount of mass that can be delivered to escape velocity for beyond-

Earth orbit? Is the SLS being designed to optimize beyond-Earth-orbit missions?

Dr. MOUNTAIN. It depends entirely on the science you want to do. There are several methods. If you are trying to get to interplanetary science, you care about going out of the Earth's gravity well and getting into interplanetary space, and that is where you need the acceleration and the energy to take these missions out. When you are looking at building very large telescopes, the kind of telescopes that can perhaps detect life, what you care about there is volume and mass to get something out of the Earth's atmosphere and into orbit where you could either assemble it or have a big enough telescope that you could then send out to a Lagrange point too. And so it really depends on the science. Where we are right now are limited in both those areas by our current launch technologies. We don't really have the energy or the acceleration to go directly to places like Europa and we don't have the volume or the lift capacity to launch bigger telescopes than the James Webb Space Telescope.

Chairman PALAZZO. Your statement noted that even if the SLS was primarily a vehicle for human exploration, as long as it was available for the science missions and wasn't excessively costly for the science mission providing the payload that it could serve to unify and integrate NASA to be greater than the sum of its parts. The synergy between the shuttle and the Hubble Space Telescope are a good example. With the retirement of the shuttle, in your view, has NASA lost some of the synergy between human spaceflight and the science community?

Dr. MOUNTAIN. Certainly, when you come to look at missions like the Hubble Space Telescope, there is no way back to the Hubble, for example, or no way back to contemplate missions like a future Hubble or a future large telescope. We have gone down another path where we are going to send out specialized missions that can't be serviced or upgraded or repaired, and one has to examine the model, whether that is a smart model for future, even more ambitious missions. I think the power of being able to actually reconnect the human spaceflight program and science is demonstrated by the tremendous success of the Hubble or our ability to test things initially on Space Station that would then allow us to try new technologies into deeper space. I think there is a huge opportunity to actually connect some of the technologies in the human spaceflight with the ambitions of the science program, and development of new technologies always goes hand and hand with exploration and science.

Chairman PALAZZO. Thank you.

Mr. Lacefield, what is the significance of the friction stir welding technique that you referenced in your statement with respect to the manufacturing of the Orion crew module, and what role was played by the team at Michoud Assembly Facility in the application of that technique?

Mr. LACEFIELD. Well, the welding teams that both Boeing and Lockheed Martin have are located at the Michoud facility. It is state-of-the-art. It allows us to not have joints on the vehicle. It is a huge mass savings for Orion and I think it is a huge mass savings for Boeing also on SLS. It is something that does play forward into other programs, into other industries, and it is a significant accomplishment, I think, for the program.

We were able to build the first article without any problems that we had to go back and grind out in the welds—they just came out pristine. So it is one of the best welding processes that we have seen for spacecraft.

Mr. CHILTON. I would add, it is significant from a safety perspective. You have very few defects with a friction stir weld because there is no heat, and that makes it economically more efficient, you get more schedule certain, but also the type of flaw you could get is going to be an order of magnitude bigger than the standard industrial detection capability so we are not going to have much chance of ever having a problem we don't find, so I believe it is a safer method as well.

Chairman PALAZZO. Mr. Dumbacher, in response to a previous question, you said that NASA was planning to the President's request. Could you elaborate? Was your response in the context of SLS and Orion or is NASA using the budget request as guidance for all programs, projects and activities?

Mr. DUMBACHER. Well, I can only speak to the exploration systems development area, which is SLS, Orion and the ground systems, and we are planning to the President's budget request as it has been submitted. I would like to emphasize that one of the advantages we have going for us is that the development risk associated with the configurations we have chosen, we purposely chose the configuration as well as set the dates for the flights were set up consistent with that President's budget request, and that is what you have before you.

Chairman PALAZZO. And does that include commercial crew planning?

Mr. DUMBACHER. No, the commercial crew is outside of my jurisdiction. That is a separate office within the Human Exploration and Operations Mission Directorate, and that is outside of the SLS and Orion budgets.

Chairman PALAZZO. I now recognize Mr. Clarke.

Mr. CLARKE. Thank you, Mr. Chair.

I have several questions of different aspects of these projects, but just to go back to the progress that all of you have indicated that we have made on the architecture of both Orion and SLS in the last year, in spite of that progress, what are the key challenges in maintaining that progress and what is needed to address those challenges? Any of you, in your opinion?

Mr. DUMBACHER. I think the major challenges, we have talked about one earlier, which is the budget stability and being able to plan the program out from an integrated fashion in order to arrive at the 2017 and 2021 flight dates. As is usual with this kind of work, we have technical challenges ahead of us but they have been minimized by the choices we have made in terms of the configuration for the launch vehicle and we are also starting to see—and Mr. Lacefield and Mr. Chilton can elaborate—we are also starting to see the typical first unit kind of problems that you have as you work through hardware with the suppliers and making sure that they are able to supply the right hardware on the right dates in order to support the flight dates. Now, we have planned margin into the schedules and other things in order to be able to adjust for much of that but that is the typical program planning, program execution challenges that we see from an integrated level. I will leave the rest, the further details to Mr. Lacefield and Mr. Chilton.

Mr. LACEFIELD. I totally agree with what Mr. Dumbacher said. I think that the one thing I would like to bring up is that I think our supply chain in the United States is very fragile. When we look at the triple-E parts needed, you know, for avionics, all the electronic components for electronics, in the environments that we see, which is a radiation environment in deep space, those components are very hard to find in the United States right now, and just our program with Honeywell, Lockheed Martin and Hamilton Sundstrand buying those components, we are seeing lead times that we have never seen before. So I would say that the supply chain is the area that we really have to focus on. We really have to focus on the long lead times of these components, and the robustness of that supply chain isn't what it was, you know, ten years ago.

Mr. CLARKE. Just to follow up on that, Mr. Lacefield, because that is very disturbing, so number one, you have got long lead times because the components are hard to find, and then secondly, you see a fragility overall in our supply chain. Can you address that?

Mr. LACEFIELD. So we have outsourced our composites because we have a great deal of lightweight composites on the vehicle. Approximately, I think, 40 percent of the vehicle is composites. We have outsourced those composites across the country so that we would be able to meet the schedules of the 2014 flight. We have outsourced across all of the electrical components to get the parts that we need by the time we need to do the vehicle checkout on the pad next March, the electrical checkout, and we are waiting on those parts to enable us to do the vehicle checkout on the pad in Florida. That is what we are waiting on. We have outsourced all of the mechanical components across the country also. With our program, we are using up a great deal of the capacity that is required in spacecraft so that the lead times that we are seeing, you know, we are in line with other DOD programs and it is just something we haven't seen here recently, and I think it is something that we should all be aware of, what is happening with the supply chain in the United States on American suppliers.

Mr. CLARKE. I know this is likely off topic from the focus of our hearing, but if you have any thoughts on what we could do to actually shorten those lead times and strengthen our supply chain, because it is very disturbing. It has enormous impact on other industries as well. If anyone has any other comment on that, on the supply chain, what we can do to strengthen it and shorten the lead times on those components?

Mr. LACEFIELD. Well, I think when we talked about the funding stability and the stability in high-tech programs as they exist today supporting DOD and NASA, I think we need to see some stability there for those suppliers to make it, and because they aren't seeing that stability, they are all retrenching, you know, with their capability and capacities.

Mr. CLARKE. I got you. That is important.

I yield back my time. Thank you.

Chairman PALAZZO. I now recognize Ms. Johnson.

Ms. JOHNSON. Thank you very much.

Just sitting here listening with a thousand thoughts going through my mind, I am fully aware that we are facing lots of constraints and I fully acknowledge that we have some real concerns about how we are going to able to fund. I hope we can stay online. But I am also aware that until we out-innovate, and we only can innovate through research, our economy is really not going to get much better, and so I am hoping that you will keep the pressure on us—sometimes we get a little lightheaded here—to stay on track because when you just reflect, we are aware that where we are today basically came from this type of research and where we are going to be tomorrow, it will come from this research. It will either be done here in partnership or it will be done somewhere else. If it is not done by the United States or not a major part, we will be watching it as spectators.

And so I would just simply say to keep the pressure up, keep young people intrigued so that we can continue to educate the manpower we need. We simply cannot afford to do without this research. Thank you.

Chairman PALAZZO. Thank you.

I thank the witnesses for their valuable testimony and the Members for their questions. 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 and statements from the Members.

The witnesses are excused and this hearing is adjourned.

[Whereupon, at 11:24 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. Dan Dumbacher

Questions for the Record
Submitted by Rep. Steven M. Palazzo, Chairman
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. SLS is designing to the 70 metric ton lift capability vehicle, and accepting risks that additional modifications to key components – such as the core stage – will be needed to support later versions of SLS. As a result, while costs for developing the current vehicle are flat, they could significantly escalate under the SLS designs. How is NASA planning to control costs for future designs of SLS? Does the program anticipate a budget wedge opening up once the 70 ton variant is largely complete?

2. The Orion crew vehicle is facing a flat funding profile through 2017 and as a result has prioritized EFT-1related activities while deferring development and testing of critical components needed for the first crewed flight, such as crew life support systems. What is the impact of deferring this work until later in the project's development?

3. The SLS will use heritage hardware from the Shuttle program that will need to be modified to operate as part of SLS, examples being the solid rocket boosters and the space shuttle main engines. When will the exact modifications to these components be known and how much depends on the design of the core stage? How confident is NASA that these modifications can be made in order to support the first uncrewed flight in 2017?

4. I am concerned about how quickly NASA is proposing to do an asteroid mission. Based on agency comments, one could surmise that an asteroid visit may be the first operational mission of SLS/Orion. Depending on the asteroid chosen, I've heard that a mission may take anywhere from five to six weeks to several months. How does this approach align with a strategy of moving deeper into the solar system in a step-wise fashion? Is the plan to do a 2021 EM-2 mission, and then queue up an asteroid as the next destination?

5. I understand the Delta 4 cryogenic upper stage will be used on the initial set of flights. What is the schedule for developing a new upper stage powered by the J-2X engine? And as a follow-up, to what degree will a new upper stage require modifications and testing of the core stage?

6. The operational costs associated with maintaining the Space Shuttle were unsustainable and NASA's intent under the Constellation program was to develop vehicles that required significantly less in terms of operational costs. Has this approach transferred to SLS and Orion programs and if so, what is the current estimate for operational costs of these vehicles?

7. Your written statement says that NASA will "ramp up service module design efforts for 2017." Is the plan to use a service module in 2017 for the EM-1 test flight? How would you characterize the technical risk of designing and developing a fully functional service module?

Questions for the Record
Submitted by Rep. Jerry Costello, Ranking Member
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. Given the need to complete development and flight testing of the core stage SLS and the Orion under limited funding, what is the rationale for NASA's decision to seek an advanced booster competition and development, which will require significant resources over time—rather than focusing limited funding on first completing development of the initial SLS and Orion, as well as the upper stage engine, which is already far along and required for the full SLS capability? What does a commitment to advanced booster development mean for the timeline and availability of a completed upper stage engine?

2. What is the detailed plan for evolving the initial SLS variant to the full 130 metric ton capability? When will NASA make decisions regarding the upper stage propulsion and advanced boosters required for the full capability? What criteria will be used in making those decisions?
    a. How will NASA ensure that work needed to get to the evolved capability will get done without slowing down work on the initial capability?

3. What steps is NASA taking in the design of SLS and Orion to promote safety? What do you consider the most significant safety challenges?

Questions for the Record
Submitted by Rep. Dana Rohrabacher
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. What portion of the recurring cost is the DoD willing to pick up to launch military payloads aboard the Heavy-lift Launch Vehicle?

2. Can NASA improve the SLS affordability by having commonality with EELV... having common systems supporting both NASA and national security missions?

3. The SLS and Orion will be capable of transporting astronauts to multiple destinations beyond LEO. While the plan calls for the initial destination for human flight beyond LEO to target an asteroid by 2025, there are other viable destinations including cis-lunar space such as the Earth-Moon Lagrange points, the lunar surface, and eventually Mars and its moons.
   a. Where does NASA think the near-term destination should be?
   b. What destinations can you reach with the 70 mT? 105 mT?
   c. How would that change with Block 2 or the 130mT?

4. What is the expected recurring or launch cost for SLS/Orion?
   a. Can you break the cost estimates down in terms of fixed vs. variable costs?

5. Given that the President's FY 2013 budget request had notional figures for the out years, what funding levels are required in the out years for SLS to meet its target date of 2017 for the EM-1 mission?

Questions for the Record
Submitted by Rep. Eddie Bernice Johnson
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. Under NASA's current plan, the first crewed flight of Orion and SLS won't occur until 2021. What critical measures would need to be taken to achieve a crewed SLS/Orion flight capability in *this* decade? Are the constraints technical or budgetary? Under the current budget plan, you are losing purchasing power due to inflation. If you received inflation-adjusted flat funding, could you pull the first crewed flight forward in time? If so, by how much?

Questions for the Record
Submitted by Rep. Hansen Clarke
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. Given the current funding situation facing the SLS and Orion programs, what is the rationale for funding development of a multipurpose launch pad for the exploration program at this point instead of just focusing on a pad to support SLS operations? What vehicle, other than SLS, would use it, and if you don't yet know, how will you determine the launch pad requirements?

2. Inspiration is an intangible but critical element in maintaining the momentum and support for space projects. What decisions and actions will be most effective in stimulating and sustaining excitement in the SLS/Orion program?

Responses by Mr. Cleon Lacefield

Mr. Cleon Lacefield
Vice President and Orion Program Manager
Lockheed Martin Space Systems Company

Response to Questions for the Record: "Examining NASA's Development of the Space Launch System and Orion Crew Capsule" (September 12, 2012 Hearing – House Science, Space, and Technology Committee – Subcommittee on Space and Aeronautics)

Chairman Palazzo

- **Question #1:** The Orion crew vehicle is facing a flat funding profile through 2017 and as a result has prioritized EFT-1 related activities while deferring development and testing of critical components needed for the first crewed flight, such as crew life support systems. What is the impact of deferring this work until later in the project's development?

- **Mr. Lacefield Response #1:** EFT-1, together with follow-on flights EM-1 and EM-2, are top program priorities for Orion. Key system elements (including: thermal protection system; propulsion; avionics; power; software; and some aspects of the crew life support system, such as the Active Thermal Control System and the Crew Module Uprighting System are included in EFT-1 and will support successful follow-on flights with EM-1 (Exploration Mission-1) and EM-2 (Exploration Mission-2). The program has adopted a flexible approach of incremental development relative to some lower risk elements (such as: communications & tracking; crew stowage and lockers; and some life support system components in order to ensure the ability to execute the program within NASA's constrained budget resources.

Ranking Member Costello

- **Question #1:** What steps are you taking in the design of Orion to promote safety? What do you consider the most significant safety challenges?

- **Mr. Lacefield Response #1:** The Orion spacecraft system is designed to have significantly improved safety performance that will protect the crew throughout the flight/mission from launch to landing. In fact, the NASA requirement was to develop a system that was ten times safer than the Space Shuttle system on launch. A major safety element of Orion that allows this improvement is the Launch Abort System which was successfully tested in May 2010 at the Army's White Sands Test and Missile Range in NM, as well as development of the world's largest composite heatshield structure ever built for high-speed re-entry from deep-space. The realities of long-duration, deep-space missions – especially, for example, the impact of radiation exposure on humans and spacecraft functionality – are the most significant safety challenges facing Orion and America's future human space exploration program.

- **Question #2:** The FY13 budget proposal reduces funding for Orion development by approximately $200 million. How would the reduction affect the planned test program for

Orion, including the amount of outfitting of the capsule that will be possible for the planned 2017 flight? What other impacts would the reduction have on Orion and related activities?

- **Mr. Lacefield Response #2:** It is important that the current Continuing Resolution maintains FY2013 funding at $1.2 billion to ensure timely and successful implementation of EFT-1 in 2014 and protect critical development activities for the EM-1 and EM-2 flights. It is also important that out-year budgets are funded to support a robust crew safety - risk mitigation demonstration test (EM-1), the first integrated flight with Orion and the SLS, and a crew capable system leading to first crewed mission with EM-2. In fact, Orion's "considerable progress" and the importance of our continued commitment to crew safety, reliability and risk mitigation testing was emphasized by the Aerospace Safety Advisory Panel (ASAP) in its most recent review of the Orion and SLS programs. Reduced funding could impact the program's ability to demonstrate a fully crew capable system as part of EM-1 in 2017. The EM-1 flight must include the equipment that needs to be demonstrated in-flight prior to the first crewed mission, EM-2.

Rep. Johnson

- **Question #1:** Under NASA's current plan, the first crewed flight of Orion and SLS won't occur until 2021. What critical measures would need to be taken to achieve a crewed SLS/Orion flight capability in this decade? Are the constraints technical or budgetary? Under the current budget plan, you are losing purchasing power due to inflation. If NASA received inflation-adjusted flat funding, could the first crewed flight be pulled forward in time? By how much?

- **Mr. Lacefield Response #1:** Current program plans include demonstrating a crew capable system as part of EM-1 in 2017. This is critical to enabling the first crewed flight whether it is in 2012 or sooner. While programs always face certain technical challenges, accelerating the time schedule for first SLS/Orion crewed missions (currently set for 2021) is primarily a question of funding constraints. In that regard, while action to offset inflation as part of NASA's out-year budgets would be a positive development overall for NASA, it would likely not provide sufficient funding needed to enable an accelerated schedule to achieve first human missions to deep-space in this decade.

Rep. Clarke

- **Question #1:** During your response to hearing questions, you noted the fragility of the supply chain in the US, the unprecedented lead times you are seeing as a result, and the overall effect of this situation on the aerospace industry. What can Congress do and what actions will need to be taken to help address this situation?

- **Mr. Lacefield Response #1:** Orion and NASA are only a reflection of a much larger dynamic that is impacting our nation's aerospace industrial base. That base has been adversely affected by reductions in funding for the Department of Defense, which will be seriously compounded by projected defense budget reductions and the devastating impact that will result if Sequestration is put into effect in January. Orion and human space exploration require a long-term, consistent and sustained level of budget support and policy stability through multiple Congresses and Presidents. In addition, Congress and the President must take action to avoid the catastrophic impact of Sequestration on our nation's security and aerospace industrial base. The lack of stability in high-tech government programs does not incentivize small US businesses to maintain certain critical manufacturing capabilities. When suppliers leave the aerospace sector, it is often a long and expensive process to qualify new suppliers to the demanding standards of this industry.

- **Question #2:** Inspiration is an intangible but critical element in maintaining the momentum and support for space projects. In your opinion, what decisions and actions will be most effective in stimulating and sustaining excitement in the SLS/Orion program?

- **Mr. Lacefield Response #2:** There are many STEM (Science, Technology, Engineering and Math) education outreach activities that the Orion industry team, as well as NASA, carries out to promote enthusiasm for space exploration among our nation's youth. In addition, the Orion program participates in multiple public outreach events (such as the Shuttle celebrations that have or are taking place around the country in NY, CA, FL and Washington D.C.) that help raise the profile of what's next for America's human space exploration program. Most importantly, NASA, Congress and the Administration must provide leadership in the definition of missions that inspire students to pursue difficult STEM fields. Congress and the Administration must also provide funding and policy continuity and sustainability over the long term for Orion and exploration, while NASA and the Orion industry team must successfully execute the program taking humans further into space for longer periods of time than ever before possible. In this way, support for space projects will be assured for the future.

- **Question #3:** Given the need to complete development and flight test of the core stage of the SLS and Orion under limited funding, what is your view on NASA's decision to seek an advanced booster competition and development, which will require significant resources over time – rather than focusing limited funding on first completing development of the initial SLS and Orion, as well as the upper stage engine, which is already far along and required for the full SLS capability? What, in your view, are the key trade-offs that must be considered in making these decisions?

- **Mr. Lacefield Response #3:** . First, I do feel strongly that a sustainable SLS is critical not only to Orion, but to the types of missions that I envision we would want to do as we stretch beyond low-Earth orbit. That said, given my lead responsibility for Orion and not SLS, I recommend that NASA respond to this specific question regarding the management of the SLS program

- **Question #4:** Are NASA's plans and funding projections for SLS/Orion sufficient to ensure workforce stability over the long-term? If not, what is needed to maintain the critical workforce capabilities required to help ensure success in meeting SLS/Orion milestones and carrying out test flights?

- **Mr. Lacefield Response #4:** Workforce stability for Orion is impacted by sustained, predictable funding that allows NASA and the Orion industry team to plan for the effective execution of the program. In that regard, we are moving forward making progress toward our goal of successful flight tests in 2014 (EFT-1) and 2017 (EM-2) with first crewed missions to deep-space in 2021. Even with that kind of support and progress, however, the Orion workforce is only a small part of a much larger national aerospace industrial base which has been and may continue to be adversely impacted by cuts in funding for the Department of Defense and the potential reductions that would accompany Sequestration absent a budget agreement between Congress and the President. NASA and industry must always work through short-term changes in workforce and skill base as programs move through design and development to manufacturing, assembly, integration and flight. Maintaining stable budgets and plans allows us to manage those normal changes most effectively.

Responses by Mr. Jim Chilton
SLS Hearing Questions – September 12, 2012

Rep. Costello

1) What steps are you taking in the design of SLS to promote safety? What do you consider the most significant safety challenges?

The SLS program leverages demonstrated hardware with known reliability for the significant propulsion elements. Extensive re-use of existing human rated elements from the Space Shuttle Program is a design practice to ensure SLS safety. In fact the only new element of the initial SLS configuration is the core stage; the remaining elements either exist or are in production today.

Sixteen Space Shuttle Main Engines (SSME's) are currently in storage at the Stennis Space Center and will undergo a final check out test prior to installation in the first four flight vehicles. The initial SLS configuration also will use the new 5-segment Solid Rocket Boosters (SRB's) which have been upgraded from the 4-segment SRB's flown in the Shuttle program. The 5-segment SRB development was initiated during the Ares Program and is currently in the testing phase. The upper stage for the initial 70mT SLS configuration will be a Delta IV heavy upper stage, which is currently in production.

The SLS program also elected to perform core stage hot fire testing in the B-2 test stand at NASA Stennis Space Center. This testing will validate core stage designs, operating conditions and flight operations procedures before the core stage is transferred to the Kennedy Space Center for final flight processing. This testing is commensurate with prior testing conducted on all U.S launch vehicles prior to the first flight.

Finally safety is directly related to design simplicity; the more simple the design the greater the inherent vehicle safety. While the SLS uses propulsion systems from the Space Shuttle Program, the SLS design for core stage relies on proven technology that is well characterized. The resulting less complicated design is very straightforward to analyze and assess prior to the initial stage hot fire test.

2) Is NASA's plan for evolving the initial SLS variant to the full 130 metric ton capability directed in the 2010 NASA Authorization Act clear? What, in your view, are the key tradeoffs that must be considered in making decisions on the upperstage propulsion and advanced boosters? Is the 130 metric tons the appropriate metric for ensuring a heavy-lift vehicle to support deep space crewed missions?

The intent of NASA to evolve the SLS from the initial 70mT configuration to a final 130mT capability is clear, but questions remain regarding the evolution development path. This path is highly dependent upon SLS rocket development funding. NASA continues to manage funding allocations between Orion, SLS ground and test systems and the SLS vehicle development to align budget with skills and critical path. The agency has recently realigned funding between SLS, Orion and ground systems consistent with the integrated Exploration plan.

While ground infrastructure is an important element needed to support the SLS program, the level of current investment is higher earlier than has been experienced in other ~~recent~~ launch facility construction efforts. This is especially significant at this stage of the rocket development where constrained funding must be applied with lead time considerations in mind.

Current funding projections constrain SLS development to the core stage, and partial development of a second rocket element. NASA is currently evaluating between a large upper stage and advanced boosters as the next new development in the SLS evolution path. From our view, NASA should trade development cost and schedules against the resulting increase in SLS performance to assess the value of the next SLS development. From a performance perspective, a large upper stage provides significant increases in payload delivered beyond low-Earth orbit over advanced boosters. Our analysis indicates a large upper stage is less costly and ~~much~~ faster to develop than advanced boosters. This significant increase in deliverable payload to a destination of exploration interest could allow NASA to undertake a greater set of missions sooner rather than later. We believe modest upgrades to SRB's can be accomplished within current annual funding limits for SRB's, providing an increase in low earth orbit performance should that be deemed desirable.

The130mT SLS performance metric currently used for SLS references the payload delivered to low-Earth orbit (LEO). This metric is useful to describe the relative size of the rocket needed for deep space exploration, but the use of 50mT to Beyond Earth Orbit (BEO) provides greater specificity for the same size rocket to ensure it is more useful for BEO exploration. The 130mT to LEO references the mass of the exploration payload plus the upper stage mass delivered to LEO, and can therefore be interpreted to design a rocket optimized for low earth orbit performance rather than exploring beyond earth orbit. The 50mT to BEO metric ensures the rocket is designed large enough to propel larger payloads or similar payloads to further destinations, thus allowing NASA to accomplish more exploration missions with a single configuration. As missions emerge, NASA will develop functional maps that assign tasks to new elements using their systems engineering process.

Rep. Palazzo

1) The SLS will use heritage hardware from the Shuttle program that will need to be modified to operate as part of SLS, examples being the solid rocket boosters and the space shuttle main engines. When will the exact modifications to these components be known and how much

depends on the design of the core stage? How confident is Boeing that these modifications can be made in order to support the first un-crewed flight in 2017?

Boeing is not aware that the core stage is driving any modifications to heritage elements such as the solid rocket boosters or space shuttle main engines. We are confident these propulsion elements are either well understood or have been characterized well enough as to not require downstream design changes of the core SLS stage.

Regarding avionics, we are aware that the SSME computer controller has recently been upgraded to a derivative of the J-2X controller. The J-2X controller was previously integrated with the Ares upper stage avionics, which have been carried over to the SLS program. The new SSME controller will be validated in hot-fire testing, and we are currently running simulated SLS flights in NASA MSFC's avionics lab to verify full compatibility with the overall avionics suite. Boeing's selection of an existing flight computer has greatly accelerated the avionics validation testing, and provides sufficient time to ensure full compatibility before the initial stage hot-fire test in 2016.

2) I understand the Delta 4 cryogenic upper stage will be used on the initial set of flights. What is the schedule for developing a new upper stage powered by the J-2X engine? And as a follow-up, to what degree will a new upper stage require modifications and testing of the core stage?

Boeing is not currently funded for upper stage work other than the interim Cryogenic Propulsion Stage (iCPS), which is the SLS designation for the Delta IV Heavy upper stage when used on SLS. At NASA's request, we have provided cost, schedule and technical information on the development of a large 8.4m upper stage. This stage could be produced on the same tooling and with the same team as the core stage, offering concurrent development savings and common production efficiencies.

NASA's approach is to develop a single common core stage to accommodate future SLS evolution configurations. We are currently developing the core stage using preliminary design data from a larger upper stage configuration to ensure the core stage is designed to be ready for that configuration. This approach allows NASA the option of embarking on concurrent development of the core stage and the preliminary design of the upper stage to capture this one-time cost savings opportunity. Concurrent development of the core and upper stage also ensures these elements are manufactured using common tooling, process and procedures. Given the flat funding profile, NASA is trading this amongst other options as missions emerge that will drive the next SLS evolution step.

Rep. Johnson

1) Under NASA's current plan, the first crewed flight of Orion and SLS won't occur until 2021. What critical measures would need to be taken to achieve a crewed SLS/Orion flight capability in this decade? Are the constraints technical or budgetary? Under current budget plan, you are

losing purchasing power due to inflation. If NASA received inflation-adjusted flat funding, could the first crewed flight be pulled forward in time? By how much?

The initial flight scheduled for 2017 is constrained by the schedule needed to develop, integrate, test and test the SLS core stage. Increased funding would not accelerate the 2017 flight, but would provide additional schedule confidence.

The 2021 flight on the other hand is constrained by the currently proposed budgets. If additional funds were applied to the SLS core stage, the 2021 flight could be accelerated. Some budget process approaches are also making earlier missions more difficult. Planning to a funding level without inflation aggravates this issue; withholding contract specific termination liability from obligation also creates a challenge. In addition to inflation another challenge to SLS program improving schedule is maintaining the flat budget level from which the SLS program plan was created. Through the annual appropriations cycle the Administration and Congress have agreed on funding direction for SLS. The President's Budget Requests have been lower than the agreed upon level. Budget planning constrained by current and future PBRs, rather than the most recent agreements represented by the latest appropriations, makes achieving an earlier schedule more difficult.

Rep. Clarke

1) Inspiration is an intangible but critical element in maintaining the momentum and support for space projects. In your opinion, what decisions and actions will be most effective in stimulating and sustaining excitement in the SLS/Orion program?

Inspiration will continue to be a key element to maintain the momentum and support for the human Exploration program. A critical element of inspiration is developing and nurturing science, technology, engineering and math (STEM) students, and our space exploration efforts have always been at the forefront of this inspiration. Of course, students who work through challenging STEM curriculums become ambassadors for future students. Repeated program starts and stops which cause them employment uncertainty do much to erase this inspirational factor as well as their credibility as ambassadors. After the Space Shuttle retirement, many Americans believe NASA's human spaceflight program is going "out of business" and are unaware of the SLS/Orion programs. In our outreach efforts we consistently find people are excited to learn of NASA's current SLS/Orion development efforts and relieved to know the human space program will continue. NASA's plans for the 2014 Orion flight test and interactions with industry to promote significant development progress is aimed to increase greater awareness of the Exploration program.

Another aspect affecting the inspiration and enthusiasm issue is an overall disappointment with the lack of mission specifics regarding the future path for human exploration. From our perspective, outreach to excite public interest and enthusiasm would benefit greatly from more specifics regarding missions than is currently available. Future mission sets with specifics would provide greater depth and understanding of what we are trying to accomplish and why these missions are important. Mission specifics will promote greater interest of the American population, but also serve to rejuvenate the inspiration to throughout the educational system lost with the retirement of Space Shuttle. Greater clarification and communication of the intermediate missions NASA will undertake to enable larger mission objectives will restore near–term opportunities needed to inspire students of all ages to pursue STEM related curriculums and once again strive to become an astronaut or to help build and launch the vehicles that will unlock the mysteries of the universe.

2) Are NASA's plans and funding projections for SLS/Orion sufficient to ensure workforce stability over the long-term? If not, what is needed to maintain the critical workforce capabilities required to help ensure success in meeting SLS/Orion milestones and carrying out test flights?

For the near term, current budget appropriation levels appear to be sufficient to maintain stability in the workforce, and provide stability for program execution. Flat budget appropriations for SLS development program have driven NASA away from directly developing the desired 130mT SLS vehicle to an incremental evolutionary approach. This incremental approach extends vehicle development and makes it vulnerable to factors such as inflation. The biggest threat to meeting out-year milestones is the continual inflationary erosion of a flat line budget which reduces NASA's effective purchasing power. By the 2020 the SLS budget effectively is estimated to be reduced by twenty-five percent through inflationary erosion alone. The resulting reduction in purchasing power is likely to extend SLS development and also delay the initiation of other deep space exploration element developments critical to enabling meaningful missions.

Although the appropriations level is sufficient if escalated, the approach selected to manage the liability of a potential termination makes this portion of the appropriated budget unavailable to the program. To protect against contract-by-contract termination, hundreds of millions of dollars that could be obligated to make forward progress are being held in reserve to satisfy the selected termination liability threshold levels. An alternate approach where termination liability is aggregated and reserved at the agency level could alleviate this issue.

Another stability challenge is inherent in the current budget planning process. Through the annual appropriations cycle, the Administration and Congress have agreed on funding direction for SLS. The President's Budget Requests have been lower than the agreed upon level. Budget planning constrained by current and future PBRs, rather than the most recent agreements represented by the latest appropriations, makes workforce stability more difficult to achieve.

Responses by Dr. Matt Mountain

Submitted by Rep. Steven M. Palazzo, Chairman, Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12,2012

1. In your testimony you suggest that an SLS may make it possible to do a Mars sample return mission in one launch instead of three. Can you outline how a single launch mission might be designed and carried out?

The National Academy of Sciences recent Decadal Survey for Planetary Science called for a sample return campaign to Mars which was envisioned as three separate missions. In discussion with colleagues at NASA's Jet Propulsion Laboratory, the Space Launch System (SLS) would have the potential to launch all three elements of a Mars Sample Return on one launch vehicle with generous mass margins. Mars Sample Return requires four functional steps: landing on Mars' surface, acquiring a scientifically selected sample, launching the collected sample from Mars' surface, and then returning that sample safely to Earth. With a heavy lift capability, one can consider using an architecture that will have an integrated system composed of several major parts: the first will deliver the system to Mars, a lander to acquire samples, another to launch it from Mars' surface to orbit, and the first element will capture the sample launched and return it to Earth. SLS enables combining these parts fully developed, tested, launched and operated as an integrated system. This approach has the potential advantage of lower total cost due to integration reducing otherwise common functions, a reduction in systems engineering complexity due to the high payload capability of the SLS, and launch vehicle cost savings.

However, as discussed in my testimony, science can only realistically use a SLS if its availability for research missions is both reasonably frequent (probably at least every other year) and not excessively costly to the science mission providing the payload. There is precedence for the latter in that the cost of the Space Shuttle for missions like the Hubble was not fully borne by NASA's Science Mission Directorate but rather provided as part of NASA's space flight infrastructure for use by the entire Agency.

Submitted by Rep. Jerry Costello, Ranking Member, Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12, 2012

1. Congress has, through successive Authorization Acts, directed NASA to maintain a robust space science program including a mix of mission sizes. That said, some might argue that given the current fiscal crisis, we can't afford to build the size and scope of science missions that would require an SLS/Orion launch. What is your response?

Maintaining a robust science program requires robust science objectives with facilities that can ultimately lead to scientific breakthroughs capable of moving discovery and science forward. After forty years of the most successful science program in history, space science is at the point where certain questions can only be answered with missions of a certain scale. For example, to answer the question, "Is there life on Earth-like planets around other stars?" requires a space telescope capable of taking spectra of objects fainter than the objects in the Hubble Deep Field: that is, we need a telescope larger than the Hubble Space Telescope, and in fact it turns out larger than the James Webb Space Telescope. This is one example, and in other areas of space science substantive progress cannot be made relying solely on small to moderate missions using today's conventional launch systems.

To make such facilities possible (and affordable) takes new technologies, and the SLS is one such enabling technology. As the National Research Council report "Launching Science: Science Opportunities Provided by NASA's Constellation System," pointed out on p. 13, "NASA should conduct a comprehensive systems-engineering-based analysis to assess the possibility that the relaxation of weight and volume constraints enabled by Ares V for some space science missions might make feasible a significantly different approach to science mission design, development, assembly, integration, and testing, resulting in ***a relative decrease in the cost of space science missions***" (my emphasis added.)

Similarly, the new SLS will be able to loft as much as 130 metric tons of payload to low-Earth orbit. This means, for example, that more conventional materials could be used in the spacecraft and observatory design. Ultra-lightweight components could be replaced with less costly conventional materials and structures. Complex deployment schemes as required by most of our missions could be replaced by less risky fixed components. The SLS can potentially simplify the design and cost of certain science missions. The high thrust of the SLS can also significantly reduce the transit time by years for missions to the outer planets, reducing cost and risk. The SLS enables a new paradigm in space science.

Submitted by Rep. Hansen Clarke
Space and Aeronautics Subcommittee

"Examining NASA's Development of the Space Launch System and Orion Crew Capsule"
September 12,2012

1. Inspiration is an intangible but critical element in maintaining the momentum and support for space projects. In your opinion, what decisions and actions will be most effective in stimulating and sustaining excitement in the SLS/Orion program?

The SLS program follows in a great line of NASA vehicles that are etched in the minds of the public. When people hear "NASA," among the first things to come to mind, depending on their generation, is a Saturn V rocket, the Moon landing, the space shuttle, pictures from Hubble or rovers on Mars. Yet, the public is not very familiar with the technical characteristics of the vehicles, it is the achievements that they enabled that make them everlasting (e.g., the moon landing, launch and service of Hubble, and the International Space Station). SLS does hold the potential to continue this proud tradition.

For SLS to inspire the next generation, several elements must be clearly articulated:

1.) **Its nature as the backbone of many NASA scientific missions,** including current (in development) and future large telescopes. Establishing this connection allows the public to be engaged through the importance of the scientific missions to address mankind's most fundamental questions about the Universe.

It is my view that science, once again, should be viewed as an essential and exciting partner in the exploration endeavor. Science cannot drive the development of a human space flight system, but it both gives it genuine purpose in the minds of the US public, and in the long run provides the most impact.

2.) Its role in the **overall national strategic vision for space exploration,** especially including future human missions to other planets or moons. The lack of a clearly defined vision causes public confusion on the priority, which translates to a loss of purpose for SLS/Orion.

The use of sequels to describe "SLS + [future mission]" as the next "Space Shuttle + Hubble" will resonate with the public. These connections will also help bring forth new opportunities to highlight the strength of NASA's interdisciplinary work force. Engineers working on SLS and scientists developing future telescopes should work in joint education and public outreach campaigns to highlight how STEM fields come together. Such engagement can directly inspire a new generation of students, the ones who will want to be a part of this vision.

3.) **Its return on investments** from launch vehicles, as exhibited by the role of the Space Shuttle in the Hubble Space Telescope project. The Space Shuttle served many purposes, only one of which was to launch and service Hubble. This synergy enabled the groundbreaking science mission of the Hubble Space Telescope, which is now in its 23rd year. Just as groundbreaking is the education and public outreach programs developed at the Space Telescope Science Institute (STScI) using Hubble results. For over 20 years Hubble education programs have connected students, educators, and the public to Hubble's amazing discoveries.

   STScI has developed these national educational programs, whose success is evidenced by their use in all 50 states and 42 of the largest school districts in the nation, and by the audience for its public websites, which regularly attract over 2.5 million people each month. Additionally, the program annually creates 30-40 standards-based curriculum support materials that support the teaching of science and math.

4.) **The impact of spinoff technologies** that result from the investments, and clear descriptions of how the projects are critical to maintaining the nation's technological edge.

In developing the Space Shuttle, NASA made sure there was a partnership between Science and Human Space Flight to ensure that the Space Shuttle had sufficient capabilities. These capabilities made possible the ongoing support of missions like the Hubble Space Telescope, enabling its Nobel Prize-winning science. The Space Shuttle ensured Hubble's place as a global icon of American science for the last 22 years. To maximize America's investment in the SLS, NASA should make sure that these systems' capabilities are sufficient to enable a new generation of science missions that will once again have the potential to make unimaginable discoveries and inspire America for the next 22 years.

2. What aspect of the SLS/Orion system is the most important for carrying out science missions? Is it the ability to carry humans? The heavy-lift capability? Or is it the potential future destinations (near Earth asteroid, cis- lunar space, Mars) that SLS/Orion might visit?
    a. What, if any, requirements would need to be met to enable the deployment of high-priority science missions from the SLS/Orion?
    b. To what extent is NASA working with the Science Mission Directorate to consider the science opportunities that would be enabled by SLS/Orion?

Which aspect of the SLS system is important for carrying out science missions depends critically on the science one wants to conduct. If your goal is an interplanetary science mission, one is concerned about the Earth's gravity and getting into interplanetary space, so acceleration and the energy to send the mission to its destination in space are important. If one is looking to build a very large telescope – one that could be used to detect life for instance – one is concerned about volume and mass. Once you got the telescope out of the Earth's atmosphere and into orbit, one could assemble it or have a big enough telescope that could then be sent out to Lagrange point 2.

However, the most critical aspect of an SLS system, if it is to be realistically used for science, is that its availability for research missions is both reasonably frequent (probably at least one every other year) and not excessively costly to the science mission providing the payload. There is precedence for the latter in that the cost of the Space Shuttle for missions like Hubble was not fully borne by NASA's Science Mission Directorate but rather provided as part of NASA's space flight infrastructure for use by the entire Agency. Science can only benefit from a national investment in SLS if, once again, science is viewed as an essential and exciting partner in the exploration endeavor –science cannot drive the development of a human space flight system. Currently, we are limited by our launch technology, so to summarize and respond to (a) on possible requirements for science:

a. First, the 70 to 130 metric ton lift capacity to Low Earth Orbit (LEO) means that more conventional approaches (e.g., less light-weighted material) and components could be used in the spacecraft and observatory design. This simplifies the design and, as a consequence, reduces mission risk.

   Second, the SLS must be able to launch not just more mass, but the payload fairing must be able to accommodate large volumes so we can simplify telescopes and large missions by reducing all or many of the on-orbit deployments that would be otherwise needed if one only had access to smaller launch vehicles. The next generation of UV-optical space telescopes will benefit from fairing diameters of at least 8 meters, and for some designs, up to 10 meters in diameter. Fairing height is important as well – some space science missions may need up to 25 meters of fairing height. We don't have the volume or the lift capacity to launch bigger telescopes, including the James Webb Space Telescope.

Third, existing launch vehicles don't have the energy or acceleration to go directly to places like Europa. The increased energy of the SLS launch vehicle also means planetary science payloads can be launched over a wider range of launch windows, in some cases being able to travel directly to solar system bodies. This will save transit time, give more flexibility in launch schedules, or provide more regular access to otherwise hard-to-reach solar system objects.

b. I am aware that the SLS Team is working with the Science Mission Directorate to consider the science opportunities that would be enabled by SLS, but do not know of any details.