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March 30, 2011

Statement of
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before the

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

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

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

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

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

Program to the SLS and MPCV programs and by transitioning and leveraging hardware and technology investments, wherever possible.

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

In moving forward on the SLS and MPCV, we will ensure that we have efficient contracting and management approaches so as to ensure affordability in the near term and over the long run. We will also build an evolvable and interoperable human spaceflight transportation system that will serve us for decades to come as we explore multiple compelling mission destinations. In a constrained budget environment, we know how important it is to look for ways to make our programs and projects more efficient, so finding and incorporating these efficiencies is a primary goal for us. Therefore, NASA has embraced the challenge to deliver human spaceflight systems for lower cost, and the opportunity to become more efficient, innovative and agile in our Programs. For example, we are revising the management of our requirements, contracts, and projects and incorporating approaches to ensure affordability in the near term and over the long run. This includes the use of focused insight/oversight, specifying, where appropriate, to industry what we need instead of how to build it, designing for cost-effective operations, increasing the use of common components and parts, and smartly consolidating infrastructure. Therefore, my testimony today will address progress made to date on the SLS and MPCV programs, as well as outlining the work ahead of us in order to ensure that we develop systems that reflect the NASA Authorization Act of 2010 using an affordable, sustainable and realistic approach.

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

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

- Developing a ground-based test bed for demonstrating life support systems needed to enable long-duration crewed missions based on lessons learned from operation of the life support systems currently in use on the ISS;

- Developing and testing components for an advanced spacesuit to improve the ability of astronauts to assemble and service in-space systems, and to explore the surfaces of the Moon, Mars and asteroids;
- Developing design concepts for future space exploration vehicles and deep-space habitats; and
- Conducting ISS and ground-based analog testing to validate operational concepts for long-duration missions.

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

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

The SLS and MPCV: Moving Forward

On January 10, 2011, NASA provided to Congress an interim report on our SLS and MPCV efforts, with a commitment to provide more extensive details in the FY 2012 President's budget request and in a follow-on report to Congress in the spring/summer timeframe of 2011. We recognize that Congress wanted more information than we were able to provide in the interim report. The report was due to Congress 90 days after the NASA Authorization Act of 2010 was signed into law, thereby formally authorizing NASA to move out on the SLS and MPCV programs. After passage of the Authorization Act, NASA immediately began studying potential SLS and MPCV configurations based on the requirements of the Act and began analyzing current Constellation contracts and their flexibility. However, the final FY2011 appropriation remains unknown, and the evaluation process entailed a longer timeframe to come to a comprehensive design and acquisition approach for these large and complex projects. Therefore, in an effort to be as responsive to Congress as possible, NASA developed an interim report which noted the progress we had made at that time, with a commitment to provide a follow-on report with more extensive details later this year.

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

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

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

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

The Authorization Act specified that the initial vehicle performance would range from 70 to 100 metric ton[1] (mT) to LEO, evolvable to 130 mT and that it use, to the extent practicable, existing contracts, investments, workforce, industrial base, and capabilities from the Space Shuttle and Orion and Ares I projects. Therefore, for the SLS, NASA has chosen a Reference Vehicle Design that is derived from Ares and Space Shuttle hardware. The current concept vehicles would utilize a liquid oxygen/liquid hydrogen core with five RS-25 Space Shuttle Main Engine-derived engines, five-segment solid rocket boosters, and a J-2X-based Upper Stage for the SLS as the 130 mT version of the heavy-lift vehicle – evolvable from the 70 to 100 mT version. This reference design would allow for use of existing Shuttle and Ares hardware assets in the near term, with the opportunity for upgrades and/or competition downstream for eventual upgrades in designs needed for affordable production.

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

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

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

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

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

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

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

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

The SLS: Where We Are Today

The NASA Authorization Act of 2010 directs NASA to develop an SLS that is capable of accessing cis-lunar space and the regions of space beyond LEO. The Act also states that the SLS must be capable of lifting the MPCV, and that the SLS must be able to initially lift 70-100 mT to LEO, while ultimately being evolvable to 130 mT or more. For the initial capability, the Authorization Act set a goal of achieving operational capability for the core elements no later than 2016.

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

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

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

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

NASA is still in the process of developing the full acquisition strategy for the SLS. Given that the current Reference Vehicle Design utilizes heritage systems from Shuttle and Ares, NASA is evaluating existing Ares and Shuttle contracts -- and potential money saving improvements and modifications to them -- to determine whether those contracts could be used for development work on the SLS and whether doing so would be the most affordable and efficient option for developing the SLS. In the meantime, in order to

maintain existing capabilities during this planning effort, NASA continues work on the elements of the Ares I Project that are most likely to feed forward into the SLS, as detailed later in this testimony.

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

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

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

The MPCV: Where We Are Today

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

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

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

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

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

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

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

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

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

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

The Constellation Program and its Relevance to SLS and MPCV

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

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

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

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

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

From the beginning, the Constellation Program used electronic records and a centralized database to capture and manage all data, risks and knowledge learned, including information from test flights, hardware and software tests and programmatic reviews. Therefore, there is a wealth of information that

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

the Program will be able to pass on to future human spaceflight developers, including those at NASA and those in the U.S. aerospace industry, when allowable by law. Since completing the technical portion of the Program-level Preliminary Design Review (PDR)[3] in March 2010[4] and after previously having completed the Project-level PDRs for Ares and Orion in 2008 and 2009 respectively, the Program has been working to finalize its technical library, thus ensuring that historical data from Constellation work is documented, preserved and made accessible to future human spaceflight designers.

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

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

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

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

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

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

- On May 6th 2010, Orion conducted the PA-1 flight test at White Sands Missile Range in New Mexico. This test flight demonstrated a development version of the Orion LAS by simulating an abort during an emergency occurring before the launch vehicle has left the pad. The test demonstrated all three of the LAS' solid rocket motors (Abort Motor, Attitude Control Motor, and Jettison Motor) working in conjunction. It also demonstrated an early version of the parachute and forward bay cover deployment design. Data gathered from PA-1 proved the overall design concept and LAS architecture are feasible, and the data gathered will also improve computer design and analysis models and tools and reduce risks and uncertainty in the MPCV's production design – or that of commercial crew partners, should they choose to use this technology.
- The Orion GTA: NASA validated advanced-production processes, equipment and tools such as friction-stir welding) to manufacture this structural and thermal prototype of the Orion crew module. The GTA is now in final assembly at the Lockheed Martin facility in Denver, and will undergo a series of ground-based environmental tests to validate the Orion design and computer models. It will undergo structural load testing later this spring; vibration and acoustic testing during the summer; and drop testing at LaRC this fall. Given that the MPCV will be based on the Orion crew module, data collected from testing the GTA will be incorporated into MPCV development efforts so as to result in a safe, reliable and affordable human-rated crew capsule.
- On Oct 28, 2009, NASA successfully completed the Ares I-X test flight at KSC. Data from more than 700 on-board sensors showed that the vehicle was effectively controlled and stable in flight and that the vehicle had met all of its test objectives. Moving forward, this test flight is important in that it validated the accuracy of NASA's design tools, models and processes for inline crew launch vehicle configurations, allowing significant economies in integration and testing to be assumed for SLS development. For example, the test flight provided tremendous insight into the aerodynamic, acoustic, structural, vibration, and thermal forces that Ares I or other inline launch vehicles would be expected to experience. In particular, aero-acoustic forces were measured at key locations along the stack, which has highlighted differences between the predicted loads and the actual loads for the Ares I. Therefore, the adjustments to computer models made possible by this Ares I-X data may significantly reduce uncertainty and risk in future launch vehicle designs.
- In 2009 and 2010, two successful ground tests of the Ares I First Stage were conducted. In each test, a five-segment solid rocket motor was tested at a contractor facility in Utah, thereby demonstrating two temperature cases (normal and cold) for motor operation. During the full-duration ground test, also called a "cold motor" test, the motor's overall temperature was lowered to validate the motor's performance in cold weather and data was gathered to evaluate thrust, roll control, acoustics, motor vibrations, nozzle modifications and insulation upgrades. These tests validated performance of advanced designs and materials in upgrading solid rocket motor technology and eliminating obsolescence. Beyond validating the basic performance characteristics of the engine, the test resulted in enhanced modeling and a better understanding of key attributes that have historically been very difficult to predict analytically such as erosive burning, thrust oscillations and thrust tail off. As such, data from this test will help advance the safety, technology and knowledge of solid rocket motors in general – work that will likely be applicable to the SLS or other human spaceflight systems.

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

Going forward, SLS and MPCV will continue to focus on a risk-informed design approach, as Constellation has done, thus helping the Agency achieve its goal of increasing astronaut safety on the

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

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

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

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

The Commercial Orbital Transportation Services (COTS) Projects

Both of NASA's funded COTS partners -- SpaceX and Orbital Sciences Corporation -- continue to make progress in developing their cargo transportation systems, based in part on NASA's financial and technical assistance. NASA sees no reason to doubt either company's ability to achieve its desired objectives – that of demonstrating commercial cargo delivery to and from LEO. While each has experienced milestone delays, this is not unexpected, since both partners have aggressive, success-oriented schedules, and are facing challenges typical of a space flight development program. (See attachment 4.) These delays have not required any additional NASA funding of specific milestones, since the partners are paid only fixed amounts for achieving milestones. Additional development costs have been borne by the companies and/or other investors. NASA has added augmentation funding of $300M for additional milestones for additional risk reduction such as additional testing, as authorized by the NASA Authorization Act of 2010.

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

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

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

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

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

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

Conclusion

Americans and people worldwide have turned to NASA for inspiration throughout our history – our work gives people an opportunity to imagine what is barely possible, and we at NASA get to turn those dreams into real achievements for all humankind.

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

In conclusion, let me assure you that NASA is committed to meeting the goals and requirements of the NASA Authorization Act of 2010. As such, we are committed to developing an affordable, sustainable, and realistic next-generation human spaceflight system that will enable human exploration, scientific

discovery, broad commercial benefits, and inspirational missions that are in the best interests of the Nation. We look forward to working with you and other Members of Congress as we finalize our strategy for achieving human spaceflight to many destinations in our solar system.

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

Douglas R. Cooke

Associate Administrator for Exploration Systems Mission Directorate

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

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

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

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

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

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

In March of 1993, the agency undertook the redesign of Space Station Freedom. Mr. Cooke was assigned the responsibility of leading the engineering and technical aspects of the redesign. He was subsequently chosen to serve in the Space Station Program Office as Vehicle Manager, leading and managing the hardware development and systems engineering and integration for the International Space Station. From April to December of 1996, Mr. Cooke served as Deputy Manager of the Space Station Program.
Prior to his current appointment to NASA Headquarters, Mr. Cooke served as manager for the Advanced Development Office at the Johnson Space Center, Houston. Mr. Cooke provided leadership for the planning of human missions beyond Earth orbit; including the Moon, Mars, libration points, and

asteroids. This team developed integrated human and robotic mission objectives, defined investment strategies for exploration technologies, and managed NASA exploration mission architecture analyses.

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

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

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

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

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