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Statement of
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before the

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Committee on Commerce, Science, and Transportation
U. S. Senate

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify before you on NASA's exploration efforts. Consistent with the NASA Authorization Act of 2010, NASA's space exploration architecture is based on capabilities that will support multiple missions and destinations, enable private access to – and use of – space, and complement and advance other NASA, national, and international objectives and goals. This architecture is intended to be sustainable over the long term and affordable. This endeavor is responsive to changing environments, including on-ramps for new technologies, new approaches, and other space players. We also are tightly coupling the planning of our science and technology portfolios with this strategy.

Our architecture is designed for long-term human exploration of our solar system, including the goal of human missions to Mars. NASA's near-term strategy for exploration has four prongs: using the unique environment of International Space Station (ISS) to conduct the research and technology demonstrations necessary to keep our crews safe and productive on long-duration spaceflights; partnering with commercial entities to develop the capacity to transport cargo and crew affordably to low-Earth orbit (LEO); working in cooperation with other NASA Directorates to better understand exploration destinations and improve our ability to work there; and moving outward to deep space with Orion and the Space Launch System (SLS) to take us there. Orion and the SLS are foundational capabilities for the implementation of our integrated human and robotic exploration strategy. We will then travel beyond LEO to the proving ground of cis-lunar space, where we will expand and test our capabilities in a rendezvous with a redirected asteroid in lunar orbit. These steps will build the foundation for further deep-space exploration. With the technologies and techniques we develop, we will enable expeditions to multiple destinations, ultimately allowing us to pioneer Mars and other destinations as we lay the groundwork for permanent human settlements in the solar system. Conceived in coordination with our international partners, this strategy maintains America's role as the world's leader and foundational partner in space exploration.

The International Space Station: Learning the Fundamentals in LEO

The ISS is an unparalleled asset for the conduct of research and technology development in a unique, microgravity environment. The full focus of ISS is on operations and research to: 1) improve our ability to live and work in space, including enabling human exploration beyond LEO; 2) enable development of a demand-driven commercial transportation and research market in LEO; 3) enable science, engineering research, and technology development in the fields of Earth, space, life (biological and human research), and physical sciences; and 4) derive tangible benefits for citizens on Earth.

NASA's Human Research Program continues to develop biomedical science, technologies, countermeasures, diagnostics, and design tools to keep crews safe and productive on long-duration space missions. The progress in science and technology driven by this research could have broad impacts on Earth as it advances our ability to support long-duration human exploration.

On board the ISS, we are conducting technology demonstrations and development efforts to advance human and robotic exploration beyond LEO and the Station also serves as the foundation for an international exploration partnership. As an example of both the technology demonstration and exploration partnership aspects of the ISS, NASA is preparing for an extended duration, year-long human mission to explore human adaptation to space. The mission, which will involve NASA astronaut Scott Kelly and cosmonaut Mikhail Kornienko of the Russian Federal Space Agency, is slated to launch in March of 2015. The ISS partnership is strong, and the agencies involved continue to work together in the mutual pursuit of peaceful space exploration. Plans remain on track for upcoming launches to the Station and return of astronauts to Earth. Later this year, NASA intends to select from among American companies competing to provide crew transportation to the ISS beginning in 2017. In the meantime, NASA and its partners will continue to work with each other to maintain the Station, where humans have lived continuously for more than 13 years, and we are confident that the agencies will continue to work as closely as they have in the past.

Two U.S. companies – Space Exploration Technologies and Orbital Sciences Corporation – are supporting the ISS under Commercial Resupply Services (CRS) contracts. Purchasing cargo and crew transportation services from U.S. companies allows NASA to focus its efforts on developing the vehicles that will take our astronauts beyond LEO and to multiple deep-space destinations.

Orion and SLS: Traveling Beyond LEO

The dedicated NASA-Industry team, working across the Nation utilizing all of the NASA Centers and our primary industry partners, Lockheed Martin, Boeing, ATK, and Aerojet-Rocketdyne, is making excellent progress toward developing the next capabilities for human and robotic space exploration missions beyond LEO. The flight test milestones driving the schedule include the uncrewed Exploration Flight Test-1 (EFT-1) this December, the first uncrewed launch of Orion and SLS on Exploration Mission-1 (EM-1) in FY 2018, and the first crewed launch of Orion and SLS on Exploration Mission-2 (EM-2) in FY 2021-22. Both Orion and SLS are being designed to enable multiple missions and destinations rather than being optimized for one particular mission or architecture. Early missions will explore cis-lunar space and rendezvous with and return samples from a near-Earth asteroid, as well as demonstrate capabilities to support deep-space human research and exploration in a safe and sustainable manner. SLS will be evolvable to provide progressively greater lift capability, and, with Orion, will enable mankind to successfully navigate the proving ground of deep space, ultimately sending humans to a variety of destinations in the solar system, including Mars.

The Orion spacecraft will be capable of taking humans farther into deep space than ever before, to multiple destinations as needed, and sustaining them in this challenging environment for longer than ever before. The Orion spacecraft includes both crew and service modules, and a Launch Abort System that will provide for crew safety during ascent. Orion can fly a crew of up to four for 21 days; if used in concert with a potential future Habitation Module, Orion will be able to support larger crews on extended-duration missions. Orion has a focused and rigorous step-wise test campaign to validate these capabilities in the challenging deep-space environment.

This year's EFT-1 flight test will serve as a pathfinder to validate innovative approaches to space systems development. The test will demonstrate spacecraft post-landing recovery procedures and the launch vehicle adapter, which will also be used on EM-1 and EM-2. EFT-1 will allow us to test the heat shield at about 85 percent of lunar re-entry velocity, protecting the vehicle from temperatures near 4,000 degrees Fahrenheit. The EFT-1 flight test will significantly reduce or eliminate 10 of the top 16 risk drivers for the first crewed flight (EM-2). The flight test will also demonstrate 47 percent of the design, development, test, and evaluation (DDT&E) required for EM-2, and includes 50 percent of the software needed for the first crewed mission. Not only is EFT-1 testing hardware and software, but it also is testing key processes which will be needed for EM-2.

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 to 105 metric tons and eventually up to 130 metric tons, based on future mission requirements. The evolution of the SLS lift capability fulfills specific, important roles within the exploration architecture, with the 130-metric-ton vehicle supporting full capability asteroid missions and ultimately missions to Mars.

In 2014, NASA will make significant strides in SLS development. The testing of the Booster Qualification Motor-1 (QM-1) will occur this year with a test firing of the motor, and fabrication of the QM-2 motor will be completed. Manufacturing will begin on key components of the SLS vehicle to be used for the EM-1 mission, including Boosters, interim cryogenic propulsion stage (ICPS), and major components of the Core Stage (tanks, engine structure, intertank, and forward skirt), as well as the associated Structural Test Articles (STAs). Additionally, the Vertical Assembly Center at Michoud Assembly Facility will be completed this spring, as well as modifications to the A-1 Test Stand at the Stennis Space Center for testing of the RS-25 Core Stage engines. The SLS Program will conduct the detailed design review (Critical Design Review) for the Booster and Core Stage elements. Definitization of SLS contracts for Core Stages and the ICPS will be completed this year, as well.

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

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

In developing the Orion, SLS, and EGS, NASA is seeking to build a sustainable National capability for the long-term human exploration of space. By providing more volume and mass for payloads, SLS could enable the simplification of the design and trajectories of future spacecraft. The evolving capabilities of these systems will provide the Nation with flexibility over the long term to achieve a variety of goals. As we move out into the solar system to establish footholds in a variety of locations, having such flexibility will be important, as future missions can be built on what our astronauts and robotic probes learn during earlier expeditions.

NASA's Advanced Exploration Systems (AES) Division is pioneering approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond LEO. This work is important to enable exploration missions and ensure that they are safe, affordable, and sustainable. Activities focus on crewed systems for deep space, and robotic precursor missions that gather critical knowledge about potential destinations in advance of crewed missions. Major products include systems development for reliable life support, asteroid capture mechanism risk reduction, deep space habitats, crew mobility systems, advanced space suits, and autonomous space operations. As prototype systems are developed, they are tested using NASA ground-based facilities or flight experiments on the ISS. The AES Division works with the Space Technology Mission Directorate to infuse technologies into exploration missions, and with the Science Mission Directorate on robotic precursor activities. The Space Technology Mission Directorate supports exploration by investing in capabilities needed for deep-space exploration including advanced life support, entry, descent, and landing technologies, advanced space robotic systems, advanced thermal management technologies, advanced batteries and fuel cells, lightweight structures, cryogenic storage and transfer capabilities, and in-situ resource utilization.

Asteroid Redirect Mission: Expanding Our Capabilities for Deep Space Missions

NASA will employ SLS and Orion for an early human exploration mission to perform pioneering human operations further from the Earth than ever before, rendezvousing with and returning samples from an asteroid redirected to at stable orbit around the Moon by the robotic segment of the Asteroid Redirect Mission (ARM). The ARM is composed of three separate elements: the detection and characterization of candidate near-Earth asteroids; the robotic rendezvous, capture, and redirection of a target asteroid to a stable orbit around the Moon; and the crewed mission to explore and sample the captured asteroid using the SLS and the Orion crew capsule. Each mission element is heavily leveraging ongoing activities in NASA's Space Technology, Science, and Human Exploration and Operations Mission Directorates. The mission integrates a variety of technologies and capabilities important to future crewed missions to Mars and other deep space destinations. These include: the acceleration of high-power solar electric propulsion development, which will power the ARM mission and also has future science, commercial, and human exploration mission applications; and rendezvous with and maneuver of a non-cooperative target in deep space, which is enabling for missions to other deep-space destinations. The technologies needed for this mission, for example in power, propulsion, guidance and navigation, life support, and EVA, will be applicable to future human missions to Mars.

The ARM mission is part of the overall plan for human exploration and pioneering. It allows for operations in the proving ground of cis-lunar space, builds off of the skills learned from ISS, prepares the way to support potential lunar activities of our commercial or international partners, and builds the skills and hardware needed for Mars-class missions. This mission represents a technological challenge – raising the bar for human exploration and discovery, while advancing detection of near-Earth asteroids and bringing us closer to human missions to Mars. NASA has already identified a number of candidate asteroids for this mission; the Agency is also continuing to refine estimated costs, and, at this time, we anticipate that the incremental cost of the mission will be less than half of what the initial Keck Study projected. The ARM would affordably support and leverage multiple efforts across the Agency as it paves the way for journeys to other destinations by helping NASA prove out its new heavy-lift launch vehicle and exploration spacecraft in a near-term mission.

Exploring Mars and Other Deep Space Destinations

NASA has been executing an integrated human and robotic exploration strategy leading to the human exploration of Mars. The capabilities required for a human mission to Mars have been understood for some time. The implementation steps and investments, partner approaches, and technical pathways to Mars are varied. NASA will ramp up its capabilities to reach – and operate at – a series of increasingly demanding targets, while advancing technological capabilities with each step forward. This will include early test and demonstration activities in cis-lunar space as called for in the NASA Authorization Act of 2010. The Agency is tightly coupling the planning of its science and technology portfolios with this strategy where appropriate.

As noted earlier, the Agency will conduct a series of test and demonstration flights, including EFT-1 with Orion flying uncrewed in 2014, EM-1 with Orion and SLS flying uncrewed in FY 2018, and the crewed EM-2 mission with Orion and SLS in FY 2021-22. In this vein, ARM will exercise these and other capabilities now in development. These missions will help develop the foundation for longer journeys to destinations which could include near-Earth Asteroids, the Moon, the moons of Mars, and then Mars itself. NASA's Orion and SLS will enable the Agency to send astronauts beyond LEO for the first time since 1972 and will provide the Nation a capability and architecture designed to also allow flexibility, partnering, and technological on-ramps. This strategy for human space exploration will ensure that the United States fosters a safe, robust, sustainable, and flexible space program by developing a set of core evolving capabilities instead of specialized, destination-specific hardware, to achieve human presence in successively farther destinations across the solar system.

NASA's exploration strategy is consistent with the Global Exploration Roadmap (GER), released in August 2013 by NASA with 11 of our international space agency partners in the International Space Exploration Coordination Group. The GER helps demonstrate how NASA's ARM and milestones leading up to it are important steps toward realizing our goal of future missions to Mars together with our international partners. It also demonstrates that NASA, together with its international partners, shares a common interest in advancing a unified strategy of deep-space exploration, with robotic and human missions to destinations that include near-Earth asteroids, the Moon and Mars. The roadmap begins with the ISS and includes a step-wise expansion of human presence into the solar system, with human missions to the surface of Mars as a driving goal. The roadmap expands on missions to send humans to the lunar vicinity, a proving ground that allows nations to advance exploration capabilities and learn to manage risks while using the presence of the crew to explore asteroids and the Moon. Our support of the GER helps our international partners seek funding support for strong roles in implementing the international strategy.

While there will always be challenges in involving multiple nations with diverse national interests in an interdependent human space effort, pioneering the solar system cannot effectively be undertaken by any one country. The partners' participation in the GER demonstrates their interest in an incremental, international approach to expanding human presence into the solar system. Utilizing the key capabilities of SLS and Orion, this roadmap builds on our collective successes to date, highlights many exploration preparatory activities underway around the world that will drive innovation and new technologies, and encourages collaboration and integration between human and robotic exploration to return great benefit to the global community.

NASA is also discussing with our ISS International Partners exploration uses of and transition beyond the Station. These discussions are being held under the auspices of the Multilateral Coordination

Board/Heads of Agencies to fully utilize the research and technology development capabilities of the ISS and to explore partnership opportunities based on the Station partnership.

Conclusion

NASA's exploration strategy will use an approach of pioneering multiple destinations in the solar system. Over time, we will move beyond conducting limited-duration forays to distant destinations and begin to lay the groundwork to establish outposts, build settlements, and utilize *in situ* resources as we expand the reach of humanity. The key to realizing this goal will be to channel all of the factors that have enabled our space achievements to date in a way that will ensure a sustainable foundation on which future generations can continue to build. So we will involve the private sector, taking advantage of entrepreneurial drive and business acumen to find novel solutions to the challenges we face. We will engage international partners, who will bring to the table their own unique scientific and technological expertise – expanding humanity's presence into space is too large a task for any one country to go it alone. Finally, we will strive to achieve the optimal balance of human and robotic exploration, taking advantage of what humans and machines each do best as we search for life in the universe and pursue a variety of objectives and goals. This long-term effort will expand the sphere of human life and activity, and draw upon the pioneering spirit and ingenuity in the face of the seemingly impossible that have helped make the U.S. the exceptional nation that it is.

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 EFT-1 and the award of Commercial Crew Transportation Capability later this year, and the first uncrewed SLS/Orion mission in FY 2018. We have a strong strategy that extends human presence into the solar system – beginning with Mars – in an affordable and sustainable manner. ISS, Commercial cargo and crew, Orion, SLS and the Asteroid Redirect Mission are all first steps in that strategy. I would be happy to respond to any questions you or the other Members of the Subcommittee may have.