SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

NASA AT A CROSSROADS: REASSERTING AMERICAN LEADERSHIP IN SPACE EXPLORATION
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Questions Submitted from Senator Marc Rubio, Subcommittee on Science and Space

Question 1: Kennedy Space Center and the state of Florida is the world's space capital with the largest concentration of aerospace launch providers and suppliers. We've already seen Apollo, Shuttle, and ISS cargo launches from there and soon both Commercial Crew and SLS/Orion will be launching. Could you discuss what this means for the future of Florida's Space Coast, and what you foresee happening in the State in the next few years?

Answer 1: Under NASA's human spaceflight plans, Kennedy Space Center (KSC) will continue to be a vibrant hub of activity, serving as the launch site for future human deep space missions (using the Space Launch System [SLS] and Orion) and Commercial Crew missions to the International Space Station (ISS), and as one of the launch sites for Commercial Resupply Services (CRS) flights to ISS. We also expect commercial launch service providers under contract to NASA's Launch Services Program (LSP) to continue to use the Cape as a launch point for NASA's planetary robotic probes and the civil sector's geosynchronous communication and weather satellites.

In addition, NASA has been working with both the State of Florida and commercial entities to provide a number of assets for use by the commercial space industry (e.g., Orbiter Processing Facility 3 and associated Processing Control Center, Launch Complex 39A, and the Shuttle Landing Facility and associated land).

KSC is being transformed from a government- and program-focused, single-user launch complex to a more capability-centric and cost-effective multi-use spaceport, enabling both government and commercial space providers. NASA's 21st Century Space Launch Complex (21CSLC), extending from FY 2011 through FY 2017, has been modernizing and transforming the Florida launch and range complex at KSC, Cape Canaveral Air Force Station (CCAFS), and Wallops Flight Facility (WFF) in Virginia into a more robust launch capability that can support multiple users. Beneficiaries of this activity included current and future NASA programs, other U.S. Government agencies, and commercial industry.

For further information on planned developments at KSC through 2032, please see

the KSC Master Plan at: http://masterplan.ksc.nasa.gov/.

Question 2: During the birth of the Apollo program, the United States, under the leadership from President John F. Kennedy, was determined to beat the Soviets to the moon. Is the United States still in a position to remain competitive and challenge the likes of other global powers?

Answer 2: The Administration and Congress share the goal of sustaining U.S. leadership in space exploration, and NASA is working to extend human presence into the solar system and to the surface of Mars through an integrated human and robotic exploration strategy that yields a series of tangible milestones and capabilities that lead toward future human missions to Mars. This strategy embraces international and commercial partnerships and maintains America's role as the world's leader and foundational partner in space exploration. In building the SLS and Orion, as well as supporting ground systems, developing deep space habitation concepts, and proposing investments in technology development programs that are critical to any sustainable and affordable space exploration program, the U.S. is creating capabilities for mounting deep space missions that no other nation possesses.

In low Earth orbit (LEO), the International Space Station (ISS) is helping to cement continuing U.S. leadership in human spaceflight, with over 15 years of humans living off the planet, and Station is a clear demonstration of the benefits to humankind that can be achieved through peaceful global cooperation. Through the encouragement of a LEO economy, NASA is supporting the development of competitive American industrial capabilities and markets. The ISS partnership, with America as its leader, is very important; leadership in space brings with it economic growth, technological prowess, and national pride, and contributes to American global leadership more broadly.

Question 3: As the Senate looks to reauthorize NASA in the coming year, what reforms do you suggest?

Answer 3: The legislative proposals noted below, which were approved for the 113th Congress, are still of great interest to NASA:

- **Astronaut Occupational Healthcare –** would provide the Administrator the authority to allow NASA to perform medical monitoring and treatment of occupational diseases for current and former crew members.

- **Retention of Intellectual Property Rights by Users of the ISS National Lab –** clarifies the ownership of intellectual property resulting from commercial research projects on the ISS that are conducted under the auspices of the 501(c)(3) entity managing this research.

- **Authority for Negotiated Disposal of Property for Use by Commercial Space Industry –** would provide a mechanism for federal agencies, including

the NASA and DOD, to transfer surplus federal property directly to commercial space companies when the property is no longer needed by the United States Government.

- **Authority to Protect Certain Technical Data from Public Disclosure –** would align Freedom of Information Act Requests with the requirements of Export Control Laws.

- **Detection and Avoidance of Counterfeit Electronic Parts –** this proposal mirrors language contained in the FY 2012 NDAA legislation, and affords NASA the same protections as DoD for the use of trusted suppliers.

- **Confidentiality of Voluntarily Provided Safety Information –** would protect the confidentiality of witness statements taken by mishap investigation boards. This is the same authority FAA and DOD currently have.

- **Confidentiality of Medical Quality Assurance Records –** would amend the National Aeronautics and Space Act of 1958 (P.L. 85-568) to establish that records created by NASA as part of its medical quality-assurance program are confidential and privileged and may not be disclosed to any person. This is the same authority Department of Veterans Affairs and DOD currently has.

- **Authority to Support Commercial Space through Acquisition and Joint Infrastructure Development –** would provide a mechanism for DoD and NASA to accept funding from the private sector to develop, enhance and maintain the Federal government's launch range sites. DoD was given this authority in the FY13 NDAA legislation.

- **Improvements to Baselines and Cost Controls Breach Reporting Process –** changes the timeline to better align the breach reporting process to the existing NASA processes on budget formulation.

- **Removal of Sunset to NASA's Enhanced Use Lease (EUL) authority** – Would enable NASA to continue to enter into EUL agreements for underutilized but non-excess NASA real property. NASA's current EUL authority (51 U.S.C. Section 20145(g)) is set to expire in December 2017.

Question 4: What programs within the agency pull its focus away from its intended main goal of placing humans on the surface of Mars?

Answer 4: The National Aeronautics and Space Act (as amended) sets out diverse yet complementary objectives of aeronautical and space activities. The shared underpinning of these objectives is two-fold: recognized national needs that can best be met via aeronautics and space research and development, and NASA's unsurpassed scientific, technical and systems engineering expertise. NASA works to maintain a balanced portfolio of programs that enable the U.S. to be the world leader in exploration, science, technology, and aeronautics research.

Question 5: Just last year, the President signed into law the U.S. Commercial Space Launch Competitiveness Act, which I proudly cosponsored in the Senate. This law clarifies the private right to space resources for commercial companies. One of these companies, Moon Express based in Cape Canaveral, has made an application to the FAA for authorization of its planned maiden mission of its robotic lander in 2017, which will make them the very first commercial space company to land on the lunar surface. How can NASA work with commercial space companies, leveraging private sector investment, to increase future mission success for NASA from both a scientific and operational standpoint?

Answer 5: NASA has partnered with U.S. commercial entities to transport cargo, and soon crew, affordably to LEO and has focused ISS operations and research to enable the development of a demand-driven commercial ecosystem. The commercial crew and cargo systems that support ISS will also enable NASA to focus its own development efforts on the Orion and SLS, which will send U.S. astronauts on missions of exploration beyond LEO. It is NASA's intention to transition LEO to private platforms and capabilities enabled by commercial markets and Government agencies with interest in LEO research and activities, while NASA's primary focus for exploration shifts toward deep space beyond LEO. Private enterprise and affordable commercial operations in LEO will enable a truly sustainable step in our expansion into space.

In 2014, NASA introduced an initiative called Lunar CATALYST ("Lunar Cargo Transportation and Landing by Soft Touchdown") and entered into competitively awarded partnerships with three U.S. firms (Astrobotic Technology, Masten Space Systems, and Moon Express) to provide in-kind support to develop commercial lunar robotic landing capabilities. The purpose of the initiative is to encourage the development of U.S. private-sector robotic lunar landers capable of successfully delivering payloads to the lunar surface using U.S. commercial launch capabilities. Commercial lunar transportation capabilities could support science and exploration objectives such as sample returns, geophysical network deployment, resource utilization, and technology advancements.

NASA is assisting SpaceX in developing the capability to land an uncrewed Dragon spacecraft on the Martian surface ("Red Dragon"). This partnership began in 2014 as part of the Collaborations for Commercial Space Capabilities initiative. In October 2015, SpaceX requested an expanded level of support from NASA to pursue a 2018 flight opportunity to Mars. NASA performed an internal feasibility study which determined that the support was feasible, would cost approximately $30 million, and would benefit NASA with flight data in the Mars environment on supersonic retro-propulsion, a candidate technology for human-scale Mars entry, descent, and landing (EDL). NASA approved proceeding in January 2016, resulting in a Space Act Agreement (SAA) amendment being executed in April 2016.

NASA learned in 2014 and 2015 through a Request for Information and studies solicited through a Broad Area Announcement of emerging commercial interest in the Asteroid Redirect Mission (ARM) to answer questions in and act as a catalyst for

future asteroid mining opportunities. Commercial industry was represented on the Formulation Assessment and Support Team in late 2015 and early 2016 which provided critical assessment for requirements formulation and partnership strategy. NASA released in early September 2016 a Broad Area Announcement soliciting partnerships for hosted payloads on the ARM robotic spacecraft and an investigation team to define investigations and exploit opportunities for the mission to benefit broad interests.

NASA has also been undertaking substantial private-sector and international engagement to define habitation concepts, systems, and implementation approaches to cost-effectively achieve NASA's goals for deep space and enable progress towards LEO commercial space station capabilities. The Agency's Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement (BAA) is an effort to stimulate deep-space capability development across the aerospace industry.

- NASA issued the original NextSTEP BAA to U.S. industry in late 2014. In March 2015, the Agency selected 12 awardees – seven in habitation, three in propulsion, and two in small satellites. NASA has since entered into fixed-price contracts with the selectees.

- In April 2016, NASA issued a NextSTEP-2 BAA, an omnibus announcement covering all aspects of basic and applied supporting research and technology for human space exploration and robotic precursor activities. The April release of the NextSTEP-2 BAA included Appendix A: Habitat Systems, which is focused on developing deep space habitation concepts, resulting in ground prototype units. This ground-based effort will support development of deep space long-duration habitation concepts and demonstrate systems that NASA will later need to test in the microgravity environment of space. The objective is to identify habitation concepts that can support extensive human spaceflight missions in the Proving Ground of cislunar space and beyond while encouraging application to commercial LEO capabilities. One goal of this public-private approach is to enable the United States to develop the deep space habitation capability at a lower cost than through a cost-plus procurement approach. In August 2016, NASA announced the selection of six proposals from U.S. companies under NextSTEP-2. NASA intends to perform integrated ground testing using habitation capabilities developed by the commercial partners in 2018.

Question 6: NASA's Viking Lander 1 successfully reached the Martian surface on July 20, 1976. Exactly seven years before that, man landed on the moon. It has been 40 years now since Viking 1 reached Mars. Has NASA appropriately used its funding since then to put man on Mars?

Answer 6: Since the Viking missions to Mars in the 1970s, NASA has learned a great deal – both about the Red Planet and about how to live and work in space for extended durations. Through a robust program of robotic exploration, the Agency has sent a dozen missions to Mars since Viking and collected data about many

aspects of the planet, including its varied surface features (including evidence of past and present water on Mars) and atmosphere – a critical foundation for future human exploration. The Space Shuttle Program enabled the conduct of science and technology research and development by astronauts in LEO, the launching of key science missions, and the construction of the ISS, the foundation of our Journey to Mars.

NASA's robotic missions since Viking have paved the way for greater understanding of Mars' surface and atmosphere that informs where and how humans will get to Mars. Understanding of resources needed for in situ resource utilization, radiation environments, terrain features, landing techniques, and autonomous operations have all aided the decisions being made today in architecture trade studies to reach Mars.

Now, NASA's strategy is to make human exploration of thesolar system affordable and sustainable. Our Journey to Mars is guided by Administration policy as well as the strategic direction included in the NASA Authorization Act of 2010; the Agency is well positioned to continue on this long-term mission. Today on the ISS, we are already conducting research and evolving the critical technologies necessary to support humans on the Journey to Mars. From this Earth-Reliant phase in LEO aboard the ISS, we will then move into the Proving-Ground phase deeper into cislunar space around the Moon with the Orion crew vehicle, SLS (as well as the ground systems that support them), and other commercial and international capabilities. We will demonstrate key capabilities such as high power solar electric propulsion, deep space docking and crew EVA interacting with a natural space object through the Asteroid Redirect Mission, as well as deep-space habitation capability. Once we have developed the required technologies and practiced the techniques necessary in these environments, we will move on into the Earth-Independent phase, in which we will send our crews on missions of exploration and on to Mars in the 2030s.

Question 7: As you know, earlier last week the Juno Spacecraft entered into Jupiter's orbit. It is my understanding that NASA plans to terminate Juno in CY18 to avoid contamination of Jupiter's environment. Do you feel NASA's plans for this $1.1B mission after its completion in February 2018 is an efficient use of federal funds, or could Juno's mission be extended until it experiences hardware failure?

Answer 7: Juno's primary goal is to reveal the story of Jupiter's formation and evolution. Using long-proven technologies on a spinning spacecraft placed in an elliptical polar orbit, Juno will observe Jupiter's gravity, magnetic fields, atmospheric dynamics and composition during its planned primary mission.

While facilitating the science goals, Juno's close orbit also enables it to avoid the most intense region of Jupiter's harmful radiation, which is concentrated in a belt around the planet's equator. In this region, ions and electrons zip around at nearly light speed and can damage a spacecraft's electronics. Even with this special orbit and the titanium vault that houses the electronics, the amount of radiation that's expected to bombard Juno over 20 months of science operations is the equivalent of more than 100 million dental x-rays. This extreme dose of radiation is destructive to

electronics and is the main limiting factor for the length of the mission.

The baseline plan for the end of mission is to purposely steer Juno into Jupiter prior to a loss of control due to radiation damage to the computers, so as to not risk any chance of contaminating Europa or the other potentially habitable moons. However, NASA is already evaluating alternative plans that would potentially allow for an extended mission. This includes the idea of making minor orbital adjustments so that Juno would eventually enter Jupiter on its own, even if control of the spacecraft is lost due to the radiation damage to the spacecraft components. This would allow for additional science data above and beyond what is expected from the primary mission, if an extended mission is approved.

Question 8: How often have our space exploration programs been able to conduct operations beyond the forecasted end date?

Answer 8: Science missions that have successfully completed their primary objectives are eligible to enter into extended operations to continue conducting science. Such missions are reviewed by a panel of established and respected senior scientists from the community, to assess the scientific value and cost effectiveness of the proposed extension. SMD is currently flying 46 extended science missions, and since 1990 has extended over 40 more.

Question 9: NASA recently conducted a successful expansion of the Bigelow Expandable Activity Module (BEAM) aboard the International Space Station (ISS). Can you elaborate on how technology such as this can help alleviate some of the payload obstacles created by sustaining human life during deep space exploration and possible extraterrestrial surface landings?

Answer 9: NASA is investigating concepts for habitats that can keep astronauts healthy during space exploration. Expandable habitats are one such concept under consideration – they require less payload volume on the rocket than traditional rigid structures, and expand after being deployed in space to provide additional room for astronauts to live and work inside. The Bigelow Expandable Activity Module (BEAM) is the first test of such a module attached to the ISS. It will allow investigators to gauge how well it performs overall, and how it protects against solar radiation, space debris and the temperature extremes of space.

In late May, BEAM was filled with air and expanded. Astronauts enter BEAM on an occasional basis to conduct tests to validate the module's overall performance and the capability of expandable habitats. After the testing period is completed, BEAM will be released from the space station to eventually burn up harmlessly in the Earth's atmosphere.

Through the NextSTEP activity, noted in the response to Question #5, above, NASA is engaged with several commercial partners to advance and test a variety of habitation technologies. This activity, plus related technology developments and partnerships, will enable deployment of a deep space habitation capability in the

mid-2020s, which in turn will validate systems needed for the long journey to Mars in the 2030s and beyond.