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before the

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

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss NASA's plans for the development of habitation capabilities for the post-International-Space-Station (ISS) era. As you know, the Agency plans to continue ISS operations and utilization through at least 2024. The ISS and successor capabilities are essential to conduct research on human health and performance and test technologies critical for deep space missions as well as to expand our knowledge of space and test and demonstrate new space capabilities. These activities comprise the Earth-reliant portion of our Journey to Mars. The Space Launch System (SLS) and Orion will carry us into the Proving Ground of cislunar space. The next capabilities needed beyond SLS and Orion for human exploration are deep space, long duration habitation and in-space propulsion. Validation of these and related capabilities in cislunar space will mark our readiness to begin Earth-independent exploration beyond the Earth-Moon system. At that point, which we seek to reach by the end of the 2020s, we will be well along on our journey to Mars.

A deep space habitation capability is the foundation of human space missions beyond low-Earth orbit (LEO), supporting our plans for Mars-class mission distances and durations. An effective habitation capability is comprised of a pressurized volume, and an integrated array of complex systems and components that include a docking capability, environmental control and life support systems, logistics management, radiation mitigation and monitoring, fire safety technologies, and crew health capabilities. NASA's current strategy is to test these systems and components on the ground and in LEO, such as on ISS, then as an integrated habitation capability for long duration missions in cislunar space and Mars transit.

Collaborating with the private sector to leverage its growing interest and capabilities in access to and use of space is a core element of NASA's strategy. Another is testing long duration Mars-class habitation systems and components in LEO, such as on ISS. The progress and trajectory of private sector space activity is such that NASA is working toward the transition of LEO to be a commercially-led economic sphere by the mid-2020s.

Because habitation capabilities are key to both commercial activity in LEO and to human deep space exploration, and because public-private partnerships can potentially help make habitation capabilities more affordable, NASA has been undertaking substantial private-sector engagement to define habitation concepts, systems, and implementation approaches to achieve NASA's goals for deep space and enable progress towards LEO commercial space station capabilities.

Transitioning LEO

NASA is actively working transition strategies for the post-ISS era and is engaged with the private sector to foster both commercial demand and supply for LEO services. NASA's goal is to expand human presence into the solar system and to Mars, consistent with Presidential and Congressional direction. ISS operations in LEO constitute a foundation for such expansion, but once key research and technology development efforts have been completed, NASA plans to begin operating at greater distances from Earth. It is NASA's intention to transition LEO to private platforms and capabilities enabled by commercial markets, academia and government agencies, including NASA, with interest in LEO research and activities.

The Agency expects to support continued research needs in LEO after the end of the ISS program. The Agency will work with industry, academia, and other government agencies through consortia and other means to establish long-term LEO demand investment and research/technology development.

One area of technology development with potential commercial applications is habitation capability. NASA will require long duration habitation capabilities for its deep space missions, but the Agency also anticipates that commercially owned and operated habitation systems in LEO could support focused scientific research, industrial enterprises, and space tourism, to name just three potential areas. NASA's work with demonstrating habitation systems and technology aboard ISS supports both the Agency's own future exploration requirements as well as the evolution of commercial systems in LEO. The Agency is working with industry to define common interests between LEO and deep space habitation systems, architectures, requirements, common interfaces and standards, and investing in technology maturation efforts. NASA is conferring with industry to inform deep space habitation requirements while maximizing commercial capabilities for LEO. The Agency recognizes the importance of engaging stakeholders along the way to shape strategy and development approaches in this area.

One example of habitation technology being tested on ISS is the Bigelow Expandable Activity Module (BEAM), which was launched to ISS on the commercial SpaceX Dragon spacecraft on April 8, 2016, installed on April 16, and stands ready for deployment later this month, during which a pressurization system will be activated to expand the BEAM structure to its full size using air from the ISS and air stored within the packed module. BEAM will undergo a two-year demonstration period, during which station crew members and ground-based engineers will gather performance data on the module. While the BEAM demonstration supports a NASA objective to evaluate design options for the development of a long duration, deep space habitat for human missions beyond Earth orbit, the results of the demonstration will also have applications to private space stations/habitats, which is why Bigelow has co-funded the development of this module.

Habitation capability – whether for LEO or long duration, deep space application – includes technology development efforts beyond the pressure vessel or module involved. A habitation module must be outfitted with robust, reliable environmental control and life support systems, including those that provide breathable air (and the concomitant removal of carbon dioxide), thermal control, food and potable water, waste reclamation or removal, power generation and storage, overall crew health systems, and shielding from radiation and micrometeoroid/orbital debris (MMOD), among other systems. In order to support habitation capabilities, NASA will leverage information gathered through its Next Space Technologies for Exploration Partnerships (NextSTEP) Broad Agency Announcement (BAA), which supports such integrated and system development, coupled with a number of other internal and external development efforts to develop the vast number of habitation systems required for the overall habitation capability.

NextSTEP BAA

NASA's journey to deep space will include key partnerships with commercial industry for the development of advanced exploration systems. NextSTEP is a public-private partnership model that seeks commercial development of long duration, deep space exploration capabilities to support more extensive human spaceflight missions in the cislunar Proving Ground and beyond. NASA issued the original NextSTEP BAA to U.S. industry in late 2014. In March 2015, NASA 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, including technical/payment milestones, periodic technical interchange meetings with NASA, and regular status meetings with the contractors. Key components of NextSTEP are an emphasis on the contribution of private corporate resources to achieve goals and objectives, and leveraging LEO commercial capabilities. For Phase 1, NASA required a contribution of at least 50 percent of the overall effort to be provided by the awardees, and for Phase 2, a threshold of at least 30 percent is to be met through company investments which continues to demonstrate their commitment toward developing potential commercial applications. NextSTEP Phase 1 consists of 10-12-month studies. Deliverables include proposals for NextSTEP Phase 2 (which could include ISS demonstrations), along with an explanation of how the company would commercialize the developing technology and overall capability.

Of the seven habitation awards (with a total amount awarded of about $10 million), four focus on integrated habitation concepts, and three on advanced life support systems and integrated concepts:

- Lockheed Martin - Denver, CO: Habitat to augment Orion's capabilities. Design will draw strongly on LM and partner Thales Alenia's heritage designs in habitation and propulsion;
- Bigelow Aerospace LLC - Las Vegas, NV: The B330 for deep space habitation will support operations/missions in LEO, distant retrograde orbit, and beyond cislunar space;
- Orbital ATK - Dulles, VA: Habitat that employs a modular, building block approach that leverages the Cygnus spacecraft to expand cislunar and long duration deep space transit habitation capabilities and technologies;
- Boeing - Houston, TX: Developing a simple, low cost habitat that is affordable early on, allowing various technologies to be tested over time, and that is capable of evolving into a long-duration crew support system for cislunar and Mars exploration;
- Dynetics, Inc - Huntsville, AL: Miniature atmospheric scrubbing system for long duration exploration and habitation applications. Separates CO2 and other undesirable gases from spacecraft cabin air;
- UTC Aerospace Systems - Windsor Locks, CT: More modular ECLSS subsystems, requiring less integration and maximize component commonality; and
- Orbital Technologies Inc. - Madison, WI: Hybrid Life Support Systems integrating established Physical/Chemical life support with bioproduction systems.

Through these partnerships, NextSTEP contractors will provide advanced concept studies and technology development projects. In addition to advancing capabilities for NASA required for beyond-Earth-orbit habitation, the advances made through this effort by the selected commercial companies may be applicable to any private space stations or habitats.

NextSTEP-2 and Beyond

In April 2016, NASA issued a Next Space Technologies for Exploration Partnerships-2 (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. Specific research areas are announced by issuing Appendices to this BAA, to include, but not be limited to: long duration, deep space habitation system capabilities, studies to support mission architecture definition, new approaches to rapidly develop prototype systems, demonstration of key capabilities, validation of operational concepts for future human missions beyond LEO, and end-to-end design, development, test, and in-space evaluation of future flight systems.

The April release of the NextSTEP-2 BAA included Appendix A: Habitat Systems, which is focused on developing long duration, 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 components 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 and beyond while encouraging application to commercial LEO habitation capabilities. NASA plans to continue some or all of the NextSTEP Phase 1 habitation studies into Phase 2, but Appendix A of the omnibus NextSTEP-2 BAA provides opportunity for other companies not selected previously to participate in Phase 1 to be added to the Phase 2 efforts. In moving forward with NextSTEP-2, a NASA-led standards working group will be implemented to ensure interoperability of the aggregate system. The Agency will work with industry to define common interfaces and standards to ensure that components provided by different companies can be integrated and function together.

The fixed price NextStep-2 contracts will be incrementally funded with payments based on milestone achievements; the milestones mark substantive technical achievements that buy down or retire risks. NASA will have insight into progress through quarterly and monthly status briefings or reports, as well as bi-weekly telecons. The Agency plans to select multiple proposals under NextSTEP-2, Appendix A, in August 2016, with an estimated period of performance to begin in September 2016 and extended out to about April 2018. NASA intends to integrate functional systems into a prototype habitat for ground testing in 2018. While funding levels will depend upon the availability of appropriated funds and proposed content, it is anticipated that the total amount of funding that could potentially be available in FY 2016-FY 2017 is about $65 million, with potential additional funding in FY 2018. There is a cost-sharing threshold for NextSTEP Phase 2 proposals that requires proposing companies to commit at least 30 percent contribution of corporate resources toward the total estimated cost. The corporate contribution could include direct contributions during the period of performance and may include limited prior industry investment.

Through the NextSTEP effort, NASA and industry will identify commercial capability development for LEO that intersects with the Agency's long duration, deep space habitation requirements, along with any potential options to leverage commercial LEO advancements towards meeting NASA long duration, deep space habitation needs while promoting commercial activity in LEO. The multiple phases of NextSTEP are informing NASA's acquisition strategy for its deep space, long duration habitation capability. In parallel with NextSTEP-2, NASA will define a reference habitat deep space architecture based on contractor concepts and identified overall government contributions, including Government Furnished Equipment (GFE), in preparation for Phase 3.

Preparing for the Journey to Mars in Cislunar Space

NASA's primary human spaceflight goal in the Proving Ground of cislunar space is to prepare and develop all the crew-related capabilities for long duration transit missions to Mars, culminating in a long-duration crewed validation expedition in cislunar space or beyond by the end of the 2020s. This will involve the development and deployment of an integrated habitat in cislunar space, aboard which crews will perform integration and final validation of research and technologies tested in LEO, including on the ISS. Missions in the Proving Ground will also simulate Mars transit operations through limited interaction with Mission Control (again, based on pathfinder experiments conducted in LEO), limited cargo resupply, and no crew exchanges.

Just as work in LEO is laying the foundation for human expeditions further afield, so Proving Ground expeditions will evolve the next steps in the development of knowledge and hardware required to extend human presence into the solar system in a sustainable way. NASA's Journey to Mars seeks to take advantage of capability advancements, leverage commercial investments and new scientific findings, and reuse/repurpose systems when it makes sense to do so. The Agency will gradually build up its exploration capability, create opportunities for U.S. industry to enhance its experience and business base, develop a resilient exploration architecture, and foster international and commercial partnerships. The development of long-duration, deep-space habitation capabilities will reflect these principles.

Conclusion

The Journey to Mars requires a resilient architecture that can embrace new technologies, and new international and commercial partners. There is a set of common capabilities that NASA and partners must develop over the next five to ten years, including long-duration, deep-space habitation.

It is NASA's intention that LEO eventually support private platforms and capabilities enabled by commercial markets, academia, and government agencies, including NASA, with interest in LEO research and activities, while NASA's primary human space exploration focus shifts toward deep space beyond LEO. Private enterprise and affordable commercial operations in LEO will enable a sustainable step in our expansion into space — a robust, vibrant, commercial enterprise with many providers and a wide range of private and public users will enable U.S. industry to support other government and commercial users safely, reliably, and affordably.

An important part of NASA's strategy is to stimulate the commercial space industry to help the Agency achieve its strategic goals and objectives for expanding the frontiers of knowledge, capability, and opportunities in space. A key component of the NextSTEP partnership model is that it provides an opportunity for NASA and industry to partner to develop affordable capabilities that meet NASA human space exploration objectives while also supporting industry commercialization plans. Additionally, the development of standards for habitation systems will allow for increased cooperation and ease of integration for decades of future exploration.

Mr. Chairman, I would be happy to respond to any questions you or the other Members of the Subcommittee may have.