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Statement of
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Mr. Chairman and Members of the Committee, thank you for the opportunity to appear before you today to discuss how we are using and benefitting from the International Space Station (ISS). The ISS, created and maintained by an international partnership with Canada, Europe, Japan, and Russia, represents an unparalleled capability for human space-based research that cannot be pursued on Earth, as well as a platform for the development of exploration technologies. It provides a research and development (R&D) opportunity that allows us to investigate biological and physical processes in a very different environment than that obtainable on Earth. Observing from, and experimenting in, the environment of ISS gives us a chance to learn about our world and biological and physical processes from a very different frame of reference. We have been using the unique "reference point" of the ISS to advance Science, Technology, Engineering, and Mathematics (STEM) efforts as well.

The ISS is also an international research facility. The three major science laboratories aboard the ISS -- the U.S. *Destiny*, European *Columbus*, and Japanese *Kibo* facilities -- as well as external testbeds and observatory sites, enable astronauts to conduct a wide variety of experiments in the unique, microgravity and ultra-vacuum environment of low Earth orbit (LEO). The ISS supports research across a diverse array of disciplines, including high-energy particle physics, Earth remote sensing and geophysics experiments, molecular and cellular biotechnology experiments, human physiology research (including bone and muscle research), radiation research, plant and cultivation experiments, combustion research, fluid research, materials science experiments, and biological investigations. It is also a place to conduct technology demonstrations and development efforts. R&D conducted aboard the ISS holds the promise of next-generation technologies, not only those directly related to NASA's exploration efforts, but also those with numerous terrestrial applications, as well. The ISS will provide these opportunities to scientists, engineers, and technologists through at least 2020.

Beyond being a feat of unparalleled engineering and construction, as well as international collaboration, the ISS is a place to learn how to live and work in space over a long period of time and foster new markets for commercial products and services. The ISS will be critical to NASA's future missions of exploration beyond LEO, and the ISS offers many unique benefits to the citizens of the United States and the world.

As stated in my testimony before this Committee last month, the success of our industry partners in providing commercial cargo and crew endeavors is critical to ensuring the effective utilization of the ISS. U.S. commercial cargo resupply capability will ensure the continued operation of the ISS and the full utilization of its formidable research facilities as a U.S. National Laboratory. American commercial crew transportation and rescue services will enable the United States to fly our astronauts to and from Station, end our sole reliance on foreign governments, and provide needed redundancy in the system. Partnering with the commercial space industry to provide access to LEO is enabling the Agency to increasingly focus on developing systems for sending astronauts on missions of exploration into deep space, while promoting the development of an economy in LEO.

The ISS will continue to meet NASA's mission objective to prepare for the next steps in human space exploration. The ISS is NASA's only long-duration flight analog for future human deep space missions, and, as such, it provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with deep space missions. It is the only space-based multinational research and technology testbed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration.

Benefits to Humanity and Growth in ISS Utilization

Almost as soon as the ISS was habitable, researchers began using it to study the impact of microgravity and other space effects. In the physical and biological sciences arena, the ISS is using microgravity conditions to understand the effect of the microgravity environment on microbial systems, fluid physics, combustion science and materials processing, as well as environmental control and fire safety technologies. The ISS also provides a test-bed for studying, developing, and testing new technologies for use in future exploration missions. Although each space station partner has distinct agency goals for station research, each partner collectively shares a unified goal to extend the resulting knowledge for the betterment of humanity. There are already demonstrated benefits in the areas of human health, telemedicine, education and Earth observations from space. Vaccine development research, station-generated images that assist with disaster relief and farming, and education programs that inspire future scientists, engineers and space explorers highlight just some of the many examples of research that can benefit humanity.

ISS crews are conducting human medical research to develop knowledge in the areas of: clinical medicine, human physiology, cardiovascular research, bone and muscle health, neurovestibular medicine, diagnostic instruments and sensors, advanced ultrasound, exercise and pharmacological countermeasures, food and nutrition, immunology and infection, exercise systems, and human behavior and performance. Many investigations conducted aboard ISS will have direct application to terrestrial medicine. For example, the growing senior population may benefit from experiments in the areas of bone and muscle health, immunology, and from the development of advanced diagnostic systems.

The transition from the ISS assembly and spares pre-positioning phase is now allowing NASA to focus directly on increasing the utilization of ISS laboratories, testbeds and observatory sites. Through the conclusion of ISS Expedition 28 in October 2011, approximately 1,250 research investigations were performed that involved 1,309 principal investigators (PIs) from 63 countries around the world. Of these, U.S. PIs under NASA sponsorship conducted 475 investigations (38 percent of the total). Expeditions 29 to 32, which cover the period from October 2011 – September 2012, included 259 total investigations. In other words, approximately 20 percent as many investigations were performed in these two post-assembly Expeditions as had been achieved in the prior 28 Expeditions combined. An impressive range of scientific research, technology demonstrations and educational outreach is underway.

In the area of scientific research, recent highlights include:

- The Monitor of All-sky X-ray Image (MAXI) instrument, a highly sensitive X-ray slit camera externally-mounted for monitoring more than 1,000 X-ray sources in space, including black holes and neutron stars, made the first observation, along with the Swift spacecraft, of a relativistic x-ray burst from a super-massive black hole destroying a star and creating a jet of x-rays. The research teams co-published their results in *Nature*, 476: 421-424 August 2011.

- The Alpha Magnetic Spectrometer (AMS) cosmic-ray particle physics experiment was installed and began science operations on May 19, 2011. AMS has recorded to date the passage of over 13 billion cosmic ray particle events originating from elsewhere in our Milky Way galaxy. The U.S. Department-of-Energy-sponsored collaboration across North America, Europe, and Asia is actively analyzing these cosmic-ray particle data for potential new physics and astronomy discoveries. The AMS Payload Operations Control Center is located at CERN, in Switzerland, which conveniently allows coordination with the ground-based Large Hadron Collider high-energy particle accelerator research activity.

- Flame tests conducted by Principal Investigator Marshall B. Long, Ph.D. of Yale University in Connecticut during the Structure and Liftoff In Combustion Experiment (SLICE) yielded stable lifted flames that can be simpler to numerically model. SLICE investigates the nature of flames under microgravity conditions and the results could lead to improvements in technologies that aim to reduce pollution emissions and improve burning efficiency for a wide variety of industries.

- Fluid physics experiments conducted by Portland State University in Oregon have led to a greater understanding of capillary flow phenomena and subsequent production of open-source code for modeling the behavior of fluids in space.

- Research on self-ordering systems (published in *Nature*, 478: 225-228 October 13, 2011), demonstrates mechanisms relevant to self-replication in primitive chemical environments. Colloidal systems for studying the behavior of self-assembling materials for photonic technologies are being used by Proctor and Gamble to develop more stable, concentrated products.

- Flight research conducted in the field of vaccine development for bacterial pathogens, such as salmonella and methicillin-resistant staphylococcus aureus (MRSA), has been completed for the first target drug candidate. This work was sponsored by a private firm, Astrogenetix, in cooperation with a leading scientist from the Veterans Administration (VA). The team is at the stage where additional funding is required to conduct ground-based pre-clinical trials prior to submitting an application for an investigational new drug (IND) with the Food and Drug Administration. Both the firm and VA are pursuing further funding to advance to the next stage.

- Space Act Agreements were signed with the Arizona State University Bio-Design Institute to conduct experiments initially focusing on the development of vaccines.

In the area of technology development and demonstration, recent highlights include:

- The same technology that went into building the Canadarm2 and Dextre (the Canadian robots that assembled, service, and maintain the ISS) was adapted to produce the world's first robot capable of performing brain surgery -- neuroArm™ -- on a patient while the patient undergoes magnetic resonance imaging. This technology has since been licensed to a private, publicly-traded medical device manufacturer who will produce a two-armed version that allows surgeons to see three-dimensional images, "feel" tissue, and apply pressure during neurosurgical operations.

- The Robotic Refueling Mission (RRM) began operations March 7-9, 2012, and continued operations from June 19-22, 2012, marking an important milestone in satellite-servicing technology. RRM is designed to demonstrate technologies, tools, and techniques needed to robotically service and refuel satellites in orbit that were not designed for on-orbit servicing. During the gas fittings removal task, robot tele-operators at Johnson Space Center directed Dextre to retrieve tools and go through the tasks required to cut safety wires and remove representative fittings located on the RRM module on board ISS. These fittings are used on many spacecraft for filling fluids and gases prior to launch. Future RRM operations will demonstrate robotic satellite refueling, including opening fill valves, transferring fluid, and other servicing tasks.

- Robonaut 2 (R2) was launched to ISS on February 24, 2011. This dexterous humanoid robot was developed in partnership with General Motors. It is designed to duplicate the manipulation capabilities of a human so that it can handle tools and assist astronauts in performing tasks in space, or help workers build cars on the assembly line. Like Dextre, R2 will be tele-operated from the ground, and it will test a different way to grip and manipulate objects with its human-like, five-digit hands.

- The Multi-User System for Earth Sensing (MUSES) platform started development to provide a commercially managed platform for Earth observation instruments. The platform provides high accuracy pointing capabilities. It can hold up to four separate instruments at once including visible, near infrared, and hyperspectral instruments. Instruments can be changed out robotically as new technologies and new instruments are developed.

In the area of educational outreach, recent highlights include:

- Literally thousands of two-minute video submissions were received in areas of physics or biology from more than 80 countries for the first YouTube Space Lab global contest sponsored by YouTube, Lenovo Computers, and Space Adventures, Inc. in cooperation with NASA, the European Space Agency , and the Japan Aerospace Exploration Agency . This educational project challenges 14-18-year-olds to design a science experiment that can be performed in space. The top two experiments will be conducted on ISS.

- The Program also conducts experiments that involve student participation. One example is the Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) facility. SPHERES are three bowling-ball sized spherical satellites that are used inside the Station to test telerobotics operations in addition to spacecraft formation flight, autonomous rendezvous and docking maneuvers. NASA, along with the Defense Advanced Research Projects Agency with implementation by the Massachusetts Institute of Technology, have co-sponsored three "Zero Robotics SPHERES Challenge" competitions for high school and middle school students from the U.S. and abroad. The competitions challenge students to write software code, which is uploaded to the robots on ISS, and the SPHERES satellites then execute the instructions, such as formation flight and close proximity operations. Student finalists were able to watch their flight program live on NASA-TV.

- Astronauts aboard ISS participate in educational downlinks with schools, and engage in communicating with people around the world using "ham" radio.

A National Laboratory in Orbit

In the NASA Authorization Act of 2005 (P.L. 109-155), Congress designated the U.S. segment of the ISS as a National Laboratory, and directed the Agency to seek to increase the utilization of the ISS by other Federal entities and the private sector. NASA has made solid strides in its effort to engage other organizations in the ISS program. Subsequently, in the NASA Authorization Act of 2010 (P.L. 111-267), Congress directed that the Agency enter into a cooperative agreement with a not-for-profit organization to manage the activities of the ISS National Laboratory. To this end, NASA issued a cooperative agreement notice on February 14, 2011, and on August 31, 2011, the Agency finalized a cooperative agreement with the Center for the Advancement of Science in Space (CASIS) to manage the portion of the ISS that operates as a U.S. National Laboratory. The CASIS organization is located in the Space Life Sciences Laboratory at Kennedy Space Center in Florida. The independent, nonprofit research management organization will help ensure the Station's unique capabilities are available to the broadest possible cross-section of U.S. scientific, technological, and industrial communities.

CASIS will develop and manage a varied R&D portfolio based on U.S. national needs for basic and applied research; establish a marketplace to facilitate matching research pathways with qualified funding sources; and stimulate interest in using the national lab for research and technology demonstrations and as a platform for science, technology, engineering and mathematics education. The goal is to support, promote and accelerate innovations and new discoveries in science, engineering, and technology that will improve life on Earth.

The transition of the National Laboratory management function to CASIS is progressing. Earlier this year, NASA, with the help of the Office of Science and Technology Policy, put out a request for candidates for the permanent board that will guide CASIS' efforts in this groundbreaking enterprise. NASA is working with CASIS' interim Board of Directors to identify and evaluate a diverse group of outstanding individuals for that board, and the Agency is also in the process of transitioning existing National Laboratory agreement holders to CASIS.

To help facilitate U.S. National Laboratory opportunities aboard Station, on June 26, 2012, CASIS launched its first solicitation for proposals. Through this solicitation, CASIS aims to enable next-generation research in the area of protein crystallization and life science breakthroughs. The current request for proposals calls for crystallography investigations—studies using three-dimensional structures of protein molecules.

NASA's National Laboratory partners can use the unique microgravity environment of space and the advanced research facilities aboard Station to enable investigations that may give them the edge in the global competition to develop valuable, high technology products and services. Furthermore, the demand for access to the ISS will support the providers of commercial crew and cargo systems. Both of these aspects of the U.S. segment of ISS as a National Laboratory will help establish and demonstrate the market for research in LEO beyond the requirements of NASA.

International Partnership Progress

The ISS Multilateral Coordination Board (MCB) and Heads-of-Agency (HOA) met in Quebec City, Canada, February 28 and March 1, 2012, to discuss future plans for the ISS, progress on utilization, and potential contributions to future human exploration missions. The International Partners reported progress on identifying potential technology demonstrations that could be conducted on the ISS. These demonstrations correlate closely with the recent report issued by the National Research Council, Aeronautics and Space Engineering Board on NASA Space Technologies and Priorities.

In addition, the MCB and HOA released two documents related to ISS utilization:

- *"ISS Utilization Statistics,"* Fall 2011 (inaugural issue), which documents the number and thematic areas of research being conducted by each partner.
- *"ISS Benefits for Humanity,"* which launches a new international web portal describing achievements of the ISS partnership in the areas of human health, Earth observation and disaster response, and education.

Copies of both documents are available at:

http://www.nasa.gov/mission_pages/station/research/index.html

Conclusion

We have many challenges and opportunities ahead as we continue to sustain and productively utilize the ISS. These include training the next generation of scientists, engineers, and technologists for greater challenges as human presence is extended further into the solar system. This mission pull drives us to develop innovative solutions that benefit humans on the Earth today. We have two extraordinary assets that have never before existed in the history of human space exploration – an experienced international partnership encompassing Canada, Europe, Japan, Russia, and the U.S., and a permanently crewed, full-service space station in low-Earth orbit. Our ability to continue working together as a global team, while making the best applied use of our assets, will pace the future progress of space exploration and expansion of benefits on Earth.

Great nations explore in order to advance. Throughout history, nations have progressed and benefited from exploration. Exploration drives technological breakthroughs and scientific discoveries that benefit society; without exploration, the cycle of innovation and advancement is broken. This innovation is well documented in the U.S. patent record. In the past 30 years, the U.S. Patent and Trademark Office has granted over 818 microgravity-related patents, and in the past decade over 587 further applications have been filed. The same holds true for Space Station, where 1,722 patents have been granted and 1,107 applications are pending, and for the Space Shuttle, where 2,384 patents have been granted and 1,285 applications remain pending. These 7,903 patent actions are historic evidence of the promise for the future.

The ISS has now entered its intensive research phase, and this phase will continue through at least 2020. Station will continue to meet NASA's mission objective to prepare for the next steps in human space exploration – steps which will take astronauts beyond LEO to destinations such as near-Earth asteroids, and eventually, Mars. The ISS is NASA's only long-duration flight analog for future human deep space missions, and it provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with deep space missions. It is the only space-based multinational research and technology test-bed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration.

The ISS Partnership has transformed exploration from an effort for the advancement of individual nations, to an endeavor committed to the advancement of humankind. Closer to home, NASA's National Laboratory partners can use the unique microgravity environment of space and the advanced research facilities aboard Station to enable investigations that may give them the edge in the global competition to develop valuable, high technology products and services. Furthermore, the demand for access to the ISS will support the providers of commercial crew and cargo systems. Both of these aspects of the U.S. segment of ISS as a National Laboratory will help establish and demonstrate the market for research in LEO beyond the requirements of NASA.

NASA appreciates this Committee's ongoing support of the ISS as we work together to support this amazing facility that yields remarkable results and benefits for the world.

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