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Committee on Science, Space and Technology
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Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the status of the International Space Station (ISS) Program. This has been a remarkable year, as we have completed assembling and outfitting of the U.S. On-orbit Segment (USOS) of the ISS, allowing us to focus on full utilization of the Station's research capabilities; taken key steps in moving forward into the future of exploration beyond Low Earth Orbit (LEO); celebrated the 50th anniversary of human spaceflight; and witnessed the successful conclusion of the historic Space Shuttle Program. Today, I would like to provide you with information on the current health of the ISS, our plans for transporting cargo and crew to Station, our efforts to promote ISS as a National Laboratory, and research being done aboard Station that will support the Nation's exploration goals.

International Space Station – USOS Assembly Complete and Research-Ready

The ISS is the culmination of the efforts of the United States and its Canadian, European, Japanese, and Russian partners to work together to construct a highly complex and capable spacecraft with components built in many nations around the globe, launched from four different space centers, and assembled on orbit by astronauts conducting over 160 spacewalks. It represents an unparalleled capability for human space-based research. The STS-135 mission, flown by Space Shuttle Atlantis in July of this year, marked the conclusion of the successful Space Shuttle Program after 30 years of flight, as well as the completion of major assembly and outfitting activities on the ISS. The Station, including its large solar arrays, spans the area of a U.S. football field, including the end zones, and weighs over 860,000 pounds, not including visiting vehicles. The complex has more livable room than a conventional five-bedroom house, and has two bathrooms, a fitness center, a 360-degree bay window, and, most importantly, state of the art scientific research facilities. These research facilities can support a large variety of research disciplines. Examples include high-energy particle physics, Earth remote sensing and geophysics experiments, protein crystallization 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. Since November 2, 2001, when the crew of Expedition 1 docked with the ISS, the Station has been visited by more than 200 people, and has been continuously crewed for almost 11 years. By way of comparison, the first U.S. space station, Skylab, hosted 3 crews – a total of 9 people – with the longest mission duration being 84 days.

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. It is a place to conduct research & development (R&D) that cannot be pursued on Earth due to our gravitational field. The three major science laboratories aboard the ISS -- the U.S. *Destiny*, European *Columbus*, and Japanese *Kibo* facilities, and external test beds – enable astronauts to conduct a wide variety of experiments in the unique, microgravity and ultra-vacuum environment of LEO. It is important to note that the Station supports R&D across an array of disciplines, including biology and biotechnology, Earth science, space science, human research, physical and materials science, and technology development. This means that R&D conducted aboard Station holds out the promise of new discoveries not only in areas directly related to NASA's exploration efforts, but in fields that have terrestrial applications, as well. The ISS will provide these opportunities to scientists and technologists through at least 2020.

In addition to the direct research benefits to be gained by the ISS as a National Laboratory, this innovative arrangement also supports NASA's effort to promote the development of a LEO space economy. National Lab 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 ISS as a National Laboratory will help establish and demonstrate the market for research in LEO beyond the requirements of NASA.

Supporting Assets – The Current Cargo and Crew Vehicles of the ISS

In order to realize the full potential of the ISS' capabilities, the platform is serviced by a fleet of operational international vehicles, and the U.S. cargo vehicles are in the final stages of development to help ensure robust operations. U.S. commercial crew transportation is being advanced with the recent release of a draft Request for Proposals (RFP) for the integrated design phase of the Commercial Crew Program. The international spacecraft currently include the Russian Soyuz crew transport, the Russian Progress cargo vehicle, the Japanese H-II Transfer Vehicle (HTV), and the European Automated Transfer Vehicle (ATV).

- The Soyuz spacecraft, an evolutionary development of a vehicle that has been flying since 1967, provides transportation to and from the ISS for the Expedition crews. Soyuz also has the capability to remain docked to the Station for the six-month periods required to support these crews, providing an on-orbit rescue capability in the event of a contingency aboard the ISS. The Station can host six crewmembers on long-duration missions with the support of two Soyuz spacecraft.

- The uncrewed Progress cargo vehicle is closely related to the Soyuz, and is used to resupply the ISS with dry cargo, propellant, water, and gas; it is also used to boost the orbit of the ISS and control the orientation of the Station. At the end of its mission, Progress is filled with trash, undocks from the ISS, and is incinerated in Earth's atmosphere in a controlled re-entry.

- The HTV can carry dry cargo, gas and water to ISS, and has both pressurized and unpressurized cargo carriage capability. Like the Progress, HTV can also provide trash removal at the end of its mission.

- The ATV can carry dry cargo, atmospheric gas, water and propellant, and also provide trash removal at the end of its mission. As with the Progress, the ATV can boost the Station's orbit and control the orientation of the ISS.

The ISS is a highly robust platform for scientific research and technology development. This is due in part to the design of the Station itself and its ability to be operated from the ground. In addition, the ISS has been well provisioned by pre-positioning of key spares and supplies on ISS by the Space Shuttle, and will be supported by the current fleet of vehicles available to provide cargo and crew transportation. With the retirement of the Shuttle, the United States is temporarily without a domestic vehicle for carrying crew or cargo to the ISS. (Even when the Shuttle was transporting crew to the ISS, NASA still needed the Russian Soyuz to serve as a crew rescue vehicle.) NASA and its commercial partners are working to field the next American spacecraft to service the Station, helping to ensure that its full potential can be realized.

ISS Robustness and Possibility of Un-crewed Operations

Since its inception, the ISS has been designed and built to be operated without onboard crew, to be crew-tended, and to be permanently crewed. Critical systems that are required to maintain a stable orbit, such as guidance, navigation and control, and communications, are multi-failure tolerant and have dissimilar redundancy across the U.S. and Russian elements. This active control architecture provides for robust and failure-tolerant operations that do not require crew intervention, as the Station can be commanded through both the U.S. and Russian Mission Control Centers. Other systems, such as power generation and thermal systems, are also failure tolerant and have excess capacity to accommodate off-nominal or failure conditions. Under most operating conditions, the crew is not required to maintain the Station in orbit and, much like robotic spacecraft, the ISS is operated exclusively by ground control. The crew is normally active in maintaining crew systems such as exercise equipment and life support systems; however, these systems are not required during extended un-crewed operations.

Over the long term, the on-orbit crew has a key role to play in maintenance of the systems aboard ISS, as astronauts can address anomalies and perform repairs to critical ISS systems – both inside and outside the vehicle. In the summer of 2010, a coolant pump module on the exterior of the Station failed. The module was critical to the full operation of the ISS, as it was used to move ammonia through the Station's thermal control system, enabling the dissipation of heat that would otherwise force the shut-down of various systems. Spacewalking astronauts were on hand to remove the faulty module and replace it with a new pump, thus ensuring continued nominal operations.

On August 24 of this year, a Progress cargo ship was lost when the upper stage of its launch vehicle shut down before reaching orbital velocity. Our Russian partners formed a commission to investigate the anomaly, and – as has been the case with previous investigations – have kept NASA well informed about the progress of their review. The launch vehicle involved, which is used for both Progress and Soyuz spacecraft, is a highly reliable booster based on a design that has been flying for many decades. NASA is confident that our Russian partner will resolve the root cause of the accident and safely return the Soyuz booster to flight.

While the need to de-crew is not anticipated, NASA has a set of standard procedures in place for de-crewing the Station, should it become necessary to return the Soyuz currently on orbit before the next mission is flown. NASA is once again reviewing these procedures to ensure they are optimized for the current configuration of, and situation on, ISS. While this is not a likely scenario, NASA is nonetheless prepared for the contingency. It should be noted that the current three-person crew aboard ISS is in no danger, and that the Station itself can be flown, uncrewed, from mission control. While human-tended

research would have to cease until crew were able to return to the Station, a number of experiments could be run autonomously, including the recently-installed Alpha Magnetic Spectrometer (AMS) experiment. The design of ISS and its control interfaces help ensure the maintenance and operation of the laboratory.

With the recent Progress launch failure, the ISS Partners began preparations for the possibility of short-term de-crewing the Station in the event that the Soyuz 27 crewmembers would have to leave the ISS untended on their return to Earth on November 22, 2011. The plan includes such items as closing module hatches, stowing equipment, configuring systems such as Environmental Control and Life Support System (ECLSS) for re-crewing, and providing additional cross-strapping between power and command and control systems. Since Expedition 1 in November 2000, the ISS has been prepared for short-term uncrewed operations 22 times due to extravehicular activities (EVA) operations during the period of two-crew (post-Columbia) and Soyuz relocations. In addition, plans are also in place for long-term uncrewed operations in the remote event of an extended gap in crew transfer capabilities. These plans are codified in the Flight Rules and include such crew actions as reconfiguring elements and distributed systems, checking switch positions and re-setting limit set-points, topping off or draining fluids, inspecting seals, disposing of batteries, repositioning equipment necessary to re-crewing, and environmental sampling. These procedures have been established for every domestic and international element in the ISS configuration.

Since the return of the Soyuz 26 crewmembers in September of this year, the ISS has been occupied by three crewmembers. Lessons learned on how to operate the ISS in a reduced crew capacity after the Columbia accident have been incorporated into NASA's planning. As a result, during the current three-crew operations period, the crew is able to meet utilization objectives that were previously planned. In the event of an actual de-crewing, scientific results that require crew action would be secured in a recoverable configuration prior to departure. Additionally, utilization that does not require crew action, such as the AMS, will continue as normal.

On September 15, 2011, the ISS Partners held a Space Station Control Board meeting to baseline a new Progress and Soyuz flight plan based on the results of the Russian commission that was chartered to investigate the root cause of the Progress failure and to recommend recovery and remediation activities. The new plan provides for the launch of Soyuz 28 on November 14, 2011, which will allow approximately five days of handover between the 27S and 28S crewmembers. With the successful execution of the new flight plan, de-crewing the Station is considered unlikely.

The Shape of Things to Come – U.S. Commercial Cargo and Crew Transportation Services for the ISS

The ISS Program has made LEO a venue for international cooperation in the construction and operation of large space structures and for R&D across many disciplines. Now, the Station will also serve to promote the growth of a LEO space economy by operating as a customer and a destination for U.S. companies capable of transporting of crew and cargo into orbit.

In the area of commercial cargo transportation, NASA has implemented a two-phased approach for developing and procuring services: Commercial Orbital Transportation Services (COTS) to develop and demonstrate commercial cargo transportation systems; and Commercial Resupply Services (CRS) to procure cargo resupply services to and from the ISS.

Commercial Orbital Transportation Services

As part of COTS, NASA has partnerships with Space Exploration Technologies, Inc. (SpaceX) and Orbital Sciences Corporation (Orbital) using funded Space Act Agreements (SAAs). These agreements include a schedule of fixed payment performance milestones culminating in a demonstration mission to the ISS that includes vehicle launch, spacecraft rendezvous, ISS berthing, and re-entry for disposal or return safely to Earth.

Both COTS partners continue to make progress in developing and demonstrating their systems.

- On December 8, 2010, SpaceX successfully completed their first COTS demonstration flight, by launch of the Falcon 9 booster with Dragon spacecraft, separation of the Dragon spacecraft, completion of two orbits, orbital maneuvering and control, reentry, parachute descent, and spacecraft recovery after splashdown. NASA is reviewing a SpaceX proposal to combine the flight test objectives of the second and third demonstration flights into a single mission.

- The pad complex at Wallops Flight Facility in Virginia is being readied for the start of tests of the Taurus II vehicle and the first hot-fire test on the pad is on track for November/December 2011. Orbital is currently performing first-stage integration and check-out, and beginning the process of mating the engines to the stage in preparation for hot-fire testing. The first flight is still on target by the end of this year.

Commercial Resupply Services

On December 23, 2008, NASA awarded CRS contracts to Orbital and SpaceX for the delivery of cargo to the ISS after the retirement of the Shuttle. NASA anticipates that both providers will have their systems operational in 2012.

- NASA ordered 12 CRS flights from SpaceX. The first SpaceX CRS flight is scheduled for Spring 2012 and the company is slated to fly three CRS missions each fiscal year from 2012 through 2015. The January 2012 date is dependent on SpaceX's successful completion of its COTS demo flight(s).

- NASA ordered 8 CRS flights from Orbital. The first Orbital CRS flight is scheduled for Winter 2012 and the company is slated to fly two CRS missions each fiscal year from 2012 through 2015.

NASA is pleased with the steady progress both companies continue to make in their cargo development efforts. We need to anticipate the inevitable start-up challenges associated with a technologically ambitious endeavor. Both NASA and these providers have spent many years preparing for the full utilization phase of ISS. Now is the time when we will begin to see the fruits of this planning and development. NASA is engaged in ISS utilization and with the help and dedication of these providers; ISS will be more extensively utilized and positioned to demonstrate the benefits of space-based R&D more widely to the world.

Commercial Crew Development (CCDev)

In the area of commercial crew transportation, NASA investments have been aimed at stimulating efforts within the private sector to develop and demonstrate human spaceflight capabilities through the CCDev initiative. Since 2009, NASA has conducted two CCDev rounds, soliciting proposals from U.S. industry

participants to further advance commercial crew space transportation system concepts and mature the design and development of elements of the system, such as launch vehicles and spacecraft. The first round of CCDev awarded five funded Space Act Agreements (SAAs) in February 2010, which concluded in the first quarter of 2011. Awardees were Blue Origin, the Boeing Company, Paragon Space Development Corporation, Sierra Nevada Corporation, and United Launch Alliance (ULA). During the second CCDev competition, NASA awarded four funded SAAs that are currently being executed with the following industry partners:

- Blue Origin's work involves risk-reduction activities related to development of a Crew Transportation System (CTS) comprised of a reusable biconic Space Vehicle (SV) launched first on an Atlas V launch vehicle and then on Blue Origin's own Reusable Booster System (RBS). They are working to mature their SV design through Systems Requirements Review (SRR), mature the Pusher Escape System, and accelerate engine development for the RBS.

- The Boeing Company is maturing their commercial crew transportation system through Preliminary Design Review (PDR) and performing development tests. Boeing's system concept is a capsule-based spacecraft reusable for up to ten missions that is compatible with multiple launch vehicles. Boeing's effort will include launch abort engine fabrication and static test fire, landing air bag drop demonstration, wind tunnel testing, parachute drop tests, Service Module Propellant Tank Development Test, and Launch Vehicle Emergency Detection System/Avionics System Integration Facility Interface Simulation Test.

- Sierra Nevada Corporation (SNC) is maturing their commercial crew transportation system, the Dream Chaser, through PDR with some subsystems to Critical Design Review (CDR). The Dream Chaser is a reusable, piloted lifting body, derived from NASA HL-20 that will be launched on an Atlas V launch vehicle. SNC's effort also includes fabrication of an atmospheric flight test vehicle, conducting analysis and risk mitigation, and conducting hardware testing.

- SpaceX is maturing their flight-proven Falcon 9/Dragon transportation system focusing on developing an integrated, side-mounted Launch Abort System (LAS). The uncrewed version of Dragon is already being demonstrated as part of COTS, and will be used operationally as part of the CRS effort. Their crew transportation system is based on the existing Falcon 9 launch vehicle and Dragon spacecraft which have been designed since inception for crew carriage with relatively minimal modification. The LAS, an essential safety-critical system, represents the longest-lead portion of the Falcon 9/Dragon transportation system to prepare for crew carriage.

In addition to the four funded agreements mentioned above, NASA has also signed SAAs that execute without funding with two companies: Alliant Techsystems, Inc. (ATK) and ULA. The ATK agreement is to advance the company's Liberty launch vehicle concept. The ULA agreement is to accelerate the potential use of the Atlas V as part of a commercial crew transportation system.

Commercial Crew Program

On September 19, 2011, NASA released a draft RFP that outlines a contract to provide a complete end-to-end design, including spacecraft, launch vehicles, launch services, ground and mission operations and recovery. This draft RFP is for what NASA had been referring to as "CCDev 3." However, the Agency is no longer using that term because NASA is not doing a third round of SAAs modeled after the original CCDev agreements. Instead, NASA's strategy has evolved into an overall hybrid structure over the lifecycle of the program, building on the progress made by the SAAs and transitioning into a series of

competitively awarded contracts. NASA has formulated its approach specifically to reduce over-specification of requirements and to implement the lessons learned throughout the Agency's history regarding requirements control. Further NASA is making considerable effort to alleviate some of the administration burdens to industry associated with contracts as well as working to maximize benefits such as commercial retention of IP rights, etc. The draft RFP for this contract is for the integrated design phase of the Commercial Crew Program. NASA plans to release the final RFP for this effort by the end of 2011, and anticipates that one or more operational commercial crew systems will be available for the transportation of astronauts to and from the ISS – as well as the provision of rescue services – by the middle of this decade. Success of this program would also end the outsourcing of work to foreign providers. Together with the capabilities to explore deep space provided by the Space Launch System and the Multi-Purpose Crew Vehicle, NASA looks forward to moving forward on its robust, comprehensive U.S. human spaceflight program. NASA is mindful that reductions from the President's FY 2012 requested funding level would affect our ability to successfully implement this program and its procurement strategy, and could leave us dependent on foreign transportation services for a longer period of time at a cost of at least $480 million per year. The success of this program will ensure that U.S. companies will provide these services and create good-paying American jobs.

NASA's efforts to assist in the development of U.S. commercial cargo and crew vehicles represent a new way of doing business for the Agency. Using this approach, we plan to procure domestic crew transportation services – rather than own and operate vehicles or procure services from an international partner – to support the ISS. By providing the foundation on which private industry can build, the Agency will also encourage the use of these systems by other customers as well.

Frontiers of R&D – The ISS as a National Laboratory

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 Administrator to seek to increase the utilization of the ISS by other Federal entities and the private sector. NASA has made great strides in its effort to engage other organizations in the ISS program, and the Agency now has Memoranda of Understanding with five Federal agencies and SAAs with nine companies and universities; they include:

- National Institutes of Health -- 9 participating institutes
- Department of Energy -- Implementing Arrangement for 10 year deployment of the Alpha Magnetic Spectrometer (AMS)
- National Science Foundation -- Interest in free-flying nanosat deployments from ISS visiting vehicles and external instruments
- U.S. Department of Agriculture – Plant & animal sciences and applications
- Department of Defense -- Engineering research and defense sciences
- Bioserve Space Technologies, University of Colorado, Boulder -- Limited flight opportunities on final Shuttle flights to enable National Lab pathfinder payloads
- Astrogenetix, Astrotech International, Inc. -- Vaccine development for bacterial pathogens
- Ad Astra Rocket Company -- Demonstration of VASIMR® propulsion technology

- NANORACKS, LLC -- Nanoscale payload accommodations hardware for pressurized operations

- Zero Gravity, Inc. -- Proof-of-concept for accelerated plant cultivar development

- Boeing Aerospace -- Proof-of-concept for software interface system to allow users to use their lab control systems with on board experiments

- Louisiana State University -- Continuation of previously awarded peer reviewed research in miscible fluids behavior in microgravity

NASA is exploring additional opportunities with other organizations.

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. CASIS will be 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.

Preparing for the Next Giant Leap – Supporting Beyond-LEO Exploration

While the ISS offers extraordinary opportunities for advancing science and technology to other U.S. Government agencies, non-profit research foundations, and private firms, it will also 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 the asteroids, the Moon, and eventually, Mars.

The ISS is NASA's only long-duration flight analog for future human lunar outpost missions and Mars transit missions. 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 research portfolio includes human research and the development of countermeasures to reduce the deleterious effects of microgravity for long-duration exploration missions. 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. While this research is aimed at enabling astronauts to push the boundaries of exploration beyond LEO, NASA anticipates that many investigations conducted aboard ISS will have application to terrestrial medicine, as well. 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.

In the physical and biological sciences arena, the ISS is using microgravity conditions to understand the effect of the microgravity environment on 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. Finally, Station is an available platform for observing the Earth and can support educational activities, including observations and investigations which allow students and the public to connect with the ISS mission and inspire students to excel in science, technology, engineering, and math.

Conclusion

From September 2000 to October 2010, 1,149 investigations were conducted aboard the ISS. These included U.S., International Partner, and National Laboratory Pathfinder investigations. This research involved 1,600 scientists and has already resulted in more than 310 scientific publications. Station has now entered its intensive research phase, and this phase will continue through at least 2020.

The ISS Program has been successful in large part because of the flexibility and resourcefulness of the Partnership in adapting to changing environments and challenges. NASA will pursue its exploration-related research at the same time that we are progressing to expand the use of the ISS to other Government agencies as well as commercial users – the National Laboratory effort is key to this expansion of U.S. research utilization aboard the Station. The ISS Program is also important to the development of commercial transportation services that can serve Government and non-government users in the new space economy, and vice versa. Finally, Station is an invaluable training ground for the next generation of space explorers and researchers. NASA is proud of the work the Agency and its International Partners have done in designing and assembling the ISS on orbit; Station represents a tremendous engineering achievement. However, this is only the beginning of the Program's accomplishments, and NASA looks forward to continuing work with our Partners to ensure that this remarkable research asset is available to scientists working in many disciplines for years to come.

There are many challenges ahead, some anticipated and some not. The recent loss of Progress was the latter. However, the ISS Partnership was prepared. The final Shuttle flight, STS-135, and the detailed logistics planning over the past year provided the margin that prevented the loss from having immediate logistical consequences. The Program is busy preparing and optimizing for the next contingency. The Russians are preparing for return to flight and working to make the Soyuz booster system more reliable. The Program team is also working aggressively to bring on board the new domestic commercial cargo providers. None of this is easy. NASA will need your help in ensuring that the team is allowed to do its work with full support. If we all work together, the ISS will continue to be an amazing facility that yields remarkable results and further benefits for the world.

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