HOLD FOR RELEASE
UNTIL PRESENTED
BY WITNESS
April 24, 2008

Statement of
William H. Gerstenmaier
Associate Administrator for Space Operations
National Aeronautics and Space Administration

before the

Subcommittee on Space and Aeronautics
Committee on Science 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 the status of the International Space Station (ISS) Program. It is a pleasure to report to you the good year we have had in the human space flight program, and the progress we are making in support of the Nation's exploration goals. I would like to give you an update on the ISS, discuss the challenges over the next five years, and report to you some of our success stories. First, I would like to share with you how the ISS is helping to prepare us for our next steps in exploration.

International Space Station - Experience in Exploration

The Space Station is a place to learn how to live and work in space, which we need to do, and over a long period of time. It is also a place to conduct the research we would like to do in a better way than was possible in the more confined places we have flown in before.

Through the years of ISS design, development, test, assembly and operations, NASA has acquired the experience necessary for operating complex, multinational space vehicles. In areas ranging from international collaboration to research and technology development, crew operations, spacecraft system operations, and crew-system interfaces, the knowledge gained from the ISS can be applied directly to future long-duration exploration missions.

International Collaboration

Since 1988, the ISS international partnership has established an unprecedented level of global cooperation among the U.S., Canada, Europe, and Japan, and in 1998, Russia formally joined in this worldwide endeavor. During the 17 Expedition missions to date, for nine and a half years on orbit, and over seven years of continuous human presence, we have together assembled a research facility designed and produced around the world that now resides some 250 miles above the Earth. It is the largest spacecraft ever built; it will be 925,627 pounds at completion and measure 361 feet end-to-end. It is the length of a football field with pressurized volume greater than a five-bedroom house. By 2010, the international partnership will have managed over 80 assembly and logistics missions (including 26 Space Shuttle missions to date through STS-123), with crew rotations and cargo transfer flights on five different vehicles that will have included over 50 crew members from around the globe. Over 650 hours of assembly and maintenance activity have been performed during extravehicular activity outside the ISS. Today, the ISS is approximately 70 percent complete and has a mass of 261 metric tons.

The technical challenges of assembly, operations, and logistical re-supply have been met through the coordination of more than 100,000 workers in the U.S., Canada, Europe, Japan, and Russia, including numerous contractor facilities in the U.S. and over a dozen other countries. The globally distributed control centers supporting ISS operations will ultimately coordinate daily operations among Russia, Germany, France, Japan, Canada, and three locations in the United States -- Alabama, Florida, and Texas. In addition, Kazakhstan and French Guiana support launch and landing operations. The structural, electrical power, thermal control, data and voice communications, and environmental and life support systems have been designed and produced across international boundaries. We continually monitor ongoing challenges to safe and successful systems interoperability due to different industry and safety standards; varying life cycle development philosophies; the need for common standards during development; conversions between English versus metric units for production tooling; development of common terminology; unique engineering and management practices; export control constraints; and cultural and language differences.

The ISS international partnership has risen to all challenges thus far and forged the strong, positive relationships necessary for the next great steps in human space exploration.

Research and Technology Development

The ISS is NASA's only long-duration flight analog for future human lunar missions and Mars transit. It provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with missions to the Moon and beyond. 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 countermeasure development for exploration. The ISS crew is 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.

The ISS also provides a test-bed for studying, developing, and testing new technologies for use in future exploration missions, including advanced life support systems, environmental monitoring, energy storage batteries, strain gauges on the truss structure to measure structural loads, light-emitting diode (LED) lighting, materials exposure experiments, cabin air monitoring and environmental monitoring, robotic construction systems, and photographic inspections surveys of external surfaces and components. In the physical and biological sciences arena, the ISS is using microgravity conditions to understand the effect of the space environment on the physical processes of fluid physics, combustion and materials research, as well as environmental control and fire safety. Finally, Station is an ideal platform for observing the Earth and performing educational activities, including activities 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.

Crew Operations

High performing crews are critical to successful long-duration missions. The development of specialized skills and training for international crewmembers, as well as advanced protocols, procedures, and tools, will reduce the risks to future exploration missions. Maintaining crew health will be critical to long-duration flights, and the ISS provides a demonstration platform through the continuous operation of life support and medical systems. While much has been learned about crew health systems, crew medical care, environmental monitoring, and exercise systems critical to maintaining crew fitness, more must be learned before we undertake long-duration missions to the Moon or to Mars. Next Spring, we will have on board the ISS all of the life support, habitability and crew health maintenance hardware (water/urine processing, treadmill, galley, toilet, crew quarters, backup carbon dioxide removal) required to support six-crew operations – a continuous human presence in space that exceeds all prior human space flight programs.

Effective on-board training is another key to future long-duration exploration missions. The ISS provides a platform to develop efficient methods for conveying new information to crew members and influence the volume and types of preflight crew training. Computer-based training can be utilized to supplement ground training and provide refresher training for the on-orbit crew.

Exploration missions will also require advances in Extra Vehicular Activity (EVA) suits, technologies, capabilities and procedures. To date, Station and Shuttle crews have performed 109 U.S. and Russian assembly and maintenance EVAs, totaling more than 650 hours. Our evolving EVA procedures enable us to set the standard for in-space assembly, repair, and maintenance.

The interaction of the crew with Mission Control is another element critical to mission success. The ISS provides an environment to improve the interaction between crew and ground to make missions safer and more effective through planning and communication. The evolving operations protocols and support tools are increasing crew autonomy and reducing ground support infrastructure. The coordination of Station support facilities is all the more remarkable because the launch, operations, training, engineering, and development facilities are dispersed around the globe.

Spacecraft Systems Operations

The ISS provides a unique opportunity to flight test components and systems in the space environment and to optimize subsystem performance. Station is the only space-based test-bed available for critical exploration spacecraft systems such as closed-loop life support, EVA suit components and assemblies, advanced batteries and energy storage, and automated rendezvous and docking. Efficient, reliable spacecraft systems are critical to reducing crew and mission risks. Characterizing and optimizing system performance in space reduces mission risks and yields next-generation capabilities for long distance and autonomous vehicle and systems management.

As a direct result of the ISS Program, the inventory of space-qualified materials, piece-parts, components, assemblies, subsystems, and systems has expanded rapidly to serve future exploration needs. These include:

- The ISS environmental control and life support systems include water electrolysis for oxygen generation and carbon dioxide removal.
- The thermal control systems include heat rejection and management using multilayer insulation, heat exchangers, strip heaters and radiators.
- The electrical power system includes energy collected by solar arrays and stored in nickel hydrogen batteries.
- The command and data systems include computer systems using standard 1553B data buses and networks using the 802.4 Ethernet protocol.

- The U.S. Control Moment Gyroscopes (CMGs) and Russian motion control systems provide guidance and propulsion.
- Station communication and tracking systems use S Band, Ku Band, UHF, global positioning satellite system (GPS), and Russian capabilities.
- The robotics capabilities include a seven-degree-of-freedom robot arm.
- The EVA systems include U.S. and Russian airlocks and suits, tools, translation aids, and training facilities.

Demonstrating and developing confidence in systems for water and waste recovery, oxygen generation, and environmental monitoring technologies is important as the distance and time away from Earth is extended. U.S. and Russian life support systems represent dissimilar yet redundant capabilities for carbon dioxide removal, oxygen generation, and waste management. The ISS is currently recycling approximately 14 pounds of crew-expelled air each day and using the processed water for technical and drinking purposes. The ISS is well on the way to demonstrating closed-loop life support for oxygen generation and water recovery systems following the oxygen generation system activation in July 2007, in conjunction with the water recovery system demonstration targeted for October 2009. In 2010, the ISS plans to incorporate a *Sabatier* system that will combine carbon dioxide and excess hydrogen from the oxygen generation system to produce water for the generation of oxygen. When the closed-loop life support system is operational, it will reduce the amount of consumables needed by about 80 percent. This demonstration is critical for future exploration missions.

To generate power, the ISS has the largest solar arrays ever deployed on a spacecraft. Understanding how these arrays and other power system components perform is important to moving toward longer stays on the Moon and transiting to Mars. The solar arrays cover an area of 27,000 square feet (an acre of solar panels, and arrays with 240-foot wingspans) and are generating approximately 76 kW of electrical power, or 708,000 kW hours per year -- enough to power 50 homes. Forty-eight nickel hydrogen rechargeable batteries are used for energy storage, and gimbal mechanisms allow solar tracking and thermal radiators to maintain battery temperature. The operating experience being accrued on the ISS in solar arrays, mechanical gimbal, and rotary joint technologies will be directly applicable to future power systems in space.

<u>Crew-System Interfaces</u>

Demonstration and validation of the human-machine interfaces enable sustained spacecraft operations over long periods of time. Advances in crew and robotic operations, on-orbit maintenance and repair, in-space assembly, and demonstrations of new crew and cargo transportation vehicles are essential to expand human activity beyond low-Earth orbit. Many of the techniques used to assemble hundreds of ISS components in space are applicable to the assembly of components on the Moon, or at other locations in space.

Assembling six major truss segments, eight solar array wings, and four laboratory modules with interconnecting nodes demonstrates the precision and coordination necessary for in-space assembly of large structures. Autonomous rendezvous and docking capabilities, essential to complex future space missions, are demonstrated routinely in the global evolution of launch vehicles that transport crew and cargo to ISS. These vehicles currently include the Space Shuttle, Russian Soyuz and Progress spacecraft, and the new European Automated Transfer Vehicle (ATV). In the future, other transportation systems currently in development will also support the ISS. They will include the Japanese H-II Transfer Vehicle (HTV), U.S. Commercial Orbital Transportation Services (COTS), and the U.S. Orion Crew Exploration Vehicle.

The ISS robotic arms provide the ability to assemble large elements in flight, while ground control of certain robotic activities enables the more efficient use of valuable crew time. The Station's 55-foot-long robotic arm can move 220,000 lbs. -- the mass of the Space Shuttle. Canadian, Japanese, and European robotic arms work on different portions of the ISS and can be commanded via the ground or by the crew on orbit. These multi-national robotic operations are carefully choreographed between the ISS crew and the global operations teams.

Development of displays and controls is important for future spacecraft system designs. Software tools play a role in helping crews virtually practice EVA or robotic tasks before they ever don spacesuits or power up the robotic arms. The ISS has more than 50 computers to control on-board systems, and uses some 2.5 million lines of ground software code to support 1.5 million lines of flight software code. Standardized communication protocols control crew displays and software tools, while common and standardized flight software products, tools, interfaces, and protocols enhance operational practices.

ISS provides a real-world laboratory for logistics management and in-flight maintenance and repair concepts for future spacecraft. These techniques demonstrate an ability to evolve and adapt through daily operations. We have designed and implemented systems to manage limited re-supply capabilities, stowage, and consumables for long exploration journeys. Common component designs simplify sparing systems and are used to minimize the number of spares to be stored on orbit (e.g., common valve design). Our interoperable hardware systems include the common berthing mechanism, utility operations panel, international-standard payload racks, common equipment and orbital replacement units, crew equipment, and robotic grapple fixtures.

Through thousands of days of operating experience, the ISS is demonstrating the maintainability and reliability of hardware components. Models used to predict this reliability and maintainability are enhanced by measuring the mean-time-between-failure performance on hundreds of components, including pumps, valves, sensors, actuators, solar arrays, and ammonia loops.

ISS crews have had to demonstrate repair capabilities on internal systems and external systems and components, as well as hardware not originally designed for on-orbit repair. The on-orbit crews have repaired malfunctioning space suits and Russian computers; replaced CMGs, treadmill bearings, Russian Elektron oxygen generator and Vozdukh carbon dioxide removal system subassemblies, solar array system components, beta gimbal assemblies (BGAs), and remote power control mechanism (RPCM) circuit breakers. The Expedition crews and their ground maintenance counterparts have devised unique solutions that have kept the ISS functioning, including remote maintenance and sustainability procedures, and inspection and repair techniques. This experience has helped identify design flaws and re-deploy systems and hardware to orbit.

The ISS provides valuable lessons for current and future engineers and managers -- real-world examples of what works and what does not work in space, creating valuable lessons for current and future programs. The ISS gives us a glimpse of how our international partners approach building spacecraft, and NASA is learning many lessons from our partner countries in building, operating, and maintaining spacecraft as cooperative endeavors. Working for months with crewmembers from other countries and cultures is an important aspect of the ISS program. Developing methods to work with our partners on the ground and in space is critical to providing additional capabilities and solutions to design challenges.

<u>National Laboratory Opportunities</u>

While the ISS continues to meet NASA's mission objective to prepare for the next steps in human space exploration, it will also offer extraordinary opportunities for advancing science and technology to other U.S. government agencies, non-profit research foundations, and private firms. The National Institutes of

Health entered into an MOU with NASA in October of 2007 and plans to issue a formal research announcement in 2008 for use of the ISS in the post-assembly period. The U.S. Department of Agriculture, Agricultural Research Service, is evaluating a similar arrangement and may enter into an MOU in the near future for plant- and animal-related research. In the private sector, two Space Act Agreements are currently under development for pursuing proprietary research in biotechnologies, and another agreement is pending with the University of Colorado's Bioserve Center for ISS-based research.

International Space Station Assembly and Resupply Operations

At this point, ISS is approximately 70 percent complete, and the only major structural elements left to be flown are the remaining two components of the Japanese Kibo laboratory; the final truss segment, Node 3; and the cupola, which will provide observation capabilities for operations such as docking/undocking, spacewalks, robotic activities, and earth/celestial observations. In addition to flying these components, the Shuttle will also provide important logistics support to the Station, delivering EXPRESS Logistics Carriers and spares.

NASA's Station and Shuttle teams have proven resourceful and effective at addressing challenges that have arisen in both programs, from using new solder points to resolve the Shuttle's recent Engine Cut-Off (ECO) sensor issue, to performing a spacewalk to free the snagged Space Station solar array last November. In endeavors which are complex both in terms of engineering and organization, there will always be the potential for events that could impact planned schedules. Currently, the Shuttle Program is addressing challenges connected to the manufacture of External Tanks (ETs). This series of tanks includes the first set of entirely new ETs that have been built since Hurricane Katrina, and we are experiencing some delays in the processing flow, though this issue now has been largely resolved. NASA has a history of successfully dealing with such eventualities, and the Agency has built margin into the Shuttle manifest to minimize impacts from these events. NASA is on track to complete assembly of the ISS and retire the Space Shuttle by the end of FY 2010.

Over the past year, there have been 12 flights to the ISS, including two crewed Soyuz flights, four Progress cargo flights, five Space Shuttle assembly flights, and the initial flight of the European ATV, which successfully docked to the ISS on April 3, 2008, in its initial attempt. Over the past year, including the launch of the Expedition 17 crew aboard the Soyuz 16 on April 8, there have been 44 people aboard ISS from 9 countries, including the U.S., Russia, Canada, Germany, Italy, Japan, France, Malaysia, and South Korea (the latter two countries represented by Space Flight Participants flying under contract with Russia).

The June 2007 flight of Atlantis on STS-117 added a truss segment and new solar arrays to the starboard side of the Station to provide increased power. In August, Endeavour brought up another truss segment and supplies, and became the first Orbiter to use a new power transfer system that enables the Space Shuttle to draw power from the Station's solar arrays, extending the duration of the Shuttle's visits to Space Station. On the same mission, STS-118, teacher-turned astronaut Barbara Morgan conducted a number of education-related activities aboard the Space Station, inspiring students back on Earth and realizing the dream of the Teacher In Space Project for which she and Christa McAuliffe trained more than two decades ago. In October 2007, Discovery flew the STS-120 mission, which added the Harmony node to the Station and featured a spacewalk to disentangle a snagged solar array.

The STS-120 mission paved the way for Station astronauts to conduct a series of ambitious spacewalks and operations using the Station's robotic arm to move the Pressurized Mating Adapter-2 and Harmony node in preparation for the addition of the European Columbus laboratory and the Japanese Kibo laboratory in 2008. These spacewalks were particularly challenging and impressive, as they were carried out entirely by the three-person Expedition crews, without benefit of having a Shuttle Orbiter, with its additional personnel and resources, docked to the Station.

NASA continues to expand the scientific potential of the Space Station in 2008, a year in which we are delivering and activating key research assets from two of our International Partners. In February, Shuttle Atlantis delivered the European Columbus laboratory during STS-122; while the recently completed STS-123 mission featured the delivery by Shuttle Endeavour of the experiment logistics module portion of the Japanese Kibo laboratory, along with the Canadian Special Purpose Dextrous Manipulator, or Dextre. Dextre is a small, two-armed robot that can be attached to the Station's robotic arm to handle smaller components typically requiring a spacewalking astronaut. At the tip of each arm is a "hand" that consists of retractable jaws used to grip objects. This will allow astronauts to conduct operations and maintenance activities from inside the Space Station, rather than via spacewalks. In May, STS-124 will deliver the pressurized module component of the Kibo lab.

The European ATV vehicle, which is currently docked to the ISS, is a welcome and vital addition to the ISS cargo transportation system. On its maiden voyage, the ATV rendezvoused and docked to the ISS nearly flawlessly. It is carrying crew supplies, fuel, water, and air that are required to sustain the crew and on-orbit operations of the ISS. The ATV technologies and capabilities that were flight-demonstrated represent a significant accomplishment for the European government and industry aerospace community. It is also a testament to the level of trust and cooperation between multiple international partners.

NASA is planning to address the issue of Space Station crew transportation and cargo resupply after the retirement of the Space Shuttle in FY 2010 through a variety of methods. On April 11, 2008, NASA submitted a proposed amendment to Congress to extend the exception under the Iran, North Korea and Syria Nonproliferation Act (INKSNA) that allows the Agency to pay Russia for Soyuz crew transportation and rescue services. Under the proposed amendment, this relief would be extended until the Orion Crew Exploration Vehicle reaches Full Operational Capability (planned for 2016) or a U.S. commercial provider of crew transportation and rescue services demonstrates the capability to meet ISS mission requirements. The proposal would also continue to allow payments, in cash and in kind, for Russian-unique equipment and capabilities through the life of the Station; these would include sustaining engineering and spares (for example, acquiring Russian equipment for use in training in the U.S., and hardware, such as spares, to outfit the Russian-built, but U.S.-owned, Zarya module).

NASA is not seeking INKSNA relief to purchase Progress cargo capability beyond 2011, however. The Agency is encouraging the development of U.S. commercial cargo resupply capabilities through the Commercial Orbital Transportation Services (COTS) effort, and released a Request For Proposals (RFP) for commercial resupply services on April 14, 2008. We also have agreements for use of the European ATV and the Japanese HTV. In using multiple service providers, NASA hopes to minimize the risk to continued Station viability and promote the development of a competitive, low Earth orbit space economy, which will grow as both government and non-government users increase the demand for on-orbit services. If U.S. commercial cargo capabilities are not available as early as desired, the Agency will depend solely on the cargo upmass capability of the ATV and HTV and rely on pre-positioned important spares, delivered by the Shuttle before its retirement in 2010, until U.S. commercial cargo capabilities are available.

The ISS Program continues to evaluate the upmass requirements and spares procurement strategy to sustain nominal system and research operations. Evaluations are based on actual flight performance of on-board systems as well as estimates of component lifetimes. Internal and external system performance continues to perform better than expected except for a few notable components, including the CMGs, Beta Gimbal Assembly and the Solar Array Rotary Joint. Further reductions in upmass requirements and crew time allocations required to maintain safe on-board operations continue to be aggressively pursued.

Conclusion

Recent ISS assembly accomplishments are the direct result of years of careful planning, diligence through tragedy and challenges, and the efforts of a worldwide human space flight community dedicated to the completion of a goal -- to build and operate a world-class research facility in low-Earth orbit. The ISS Program has been successful because of the flexibility and resourcefulness of the Partnership in adapting to changing environments, including challenges such as the retirement of the Space Shuttle in FY 2010, elimination of habitation and centrifuge facilities, and schedule delays with Space Shuttle flights and the deployment of new transportation capabilities.

The efforts of thousands of people around the world over the past two decades are about to pay off. The ISS Program is entering its intensive research phase. The same careful planning, diligence, stable goals, and dedicated efforts that have resulted in the accomplishments to date are now required to be employed in the development of a robust U.S. research program. The Agency will continue 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. NASA's National Laboratory effort is key to this expansion of U.S. research utilization aboard the ISS. Yet, the U.S. is not alone in utilizing the ISS for research; Station partners Japan and Europe have maintained a broad-based research program in basic physics, material sciences, pharmaceuticals, biology, technology, and other areas. The groundwork for the U.S. utilization of the ISS is being laid today. The continued stability of the Program is important to both the realization of the research potential of the Station and to the development of commercial transportation services that can serve Government and non-government users in the new space economy.

NASA's leadership has been instrumental in developing and maintaining a truly remarkable worldwide partnership in human space flight. The ISS is currently being operated from the ground from six countries: Russia, Japan, Canada, Germany, France, and the United States. This partnership has demonstrated its ability to be flexible and take on challenges when required to do so by unforeseen circumstances. As the ISS is completed later this decade, not only will the Partnership have completed its goal to build a world-class orbiting research platform, but it will also have built an unprecedented global community committed to human space flight exploration. The ISS has played a key role in advancing U.S. leadership in space operations and has the potential to provide an even larger role in the commercialization of space transportation and research. ISS is an invaluable training ground for the next generation of space explorers and researchers.

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