LIVE FROM SPACE: THE INTERNATIONAL SPACE STATION

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE

HOUSE OF REPRESENTATIVES

ONE HUNDRED NINTH CONGRESS

FIRST SESSION

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June 14, 2005

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LIVE FROM SPACE: THE INTERNATIONAL SPACE STATION

TUESDAY, JUNE 14, 2005

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE,
Washington, DC.

The Committee met, pursuant to call, at 2:05 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Ken Calvert [Chairman of the Subcommittee] presiding.

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

Live from Space: The International Space Station

Tuesday, June 14, 2005
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. John Phillips
NASA Astronaut
Science Officer and Flight Engineer
ISS Expedition 11 (April 2005- present)

Dr. Peggy Whitson
NASA Astronaut
Science Officer and Flight Engineer
ISS Expedition 5 (June - December 2002)

Lt. Col. Michael Fincke (pronounced: "Fink") **(USAF)**
NASA Astronaut
Science Officer and Flight Engineer
ISS Expedition 9 (April - October 2004)

HEARING CHARTER

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

Live From Space: The International Space Station

TUESDAY, JUNE 14, 2005
2:00 P.M.–4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Tuesday, June 14, at 2:00 p.m., the Committee on Science, Subcommittee on Space and Aeronautics, will hold a hearing via satellite with National Aeronautics and Space Administration (NASA) astronaut John Phillips, a member of the current crew of the International Space Station (ISS). The other crew member on board ISS is Russian Cosmonaut Sergei Krikalev, the Commander of Expedition 11, who will not be participating in the hearing.

In addition to Phillips appearing via satellite, there will be two astronauts appearing in-person who have flown in space as part of the ISS program. The hearing will provide Members with the opportunity to interact directly with those who are operating and performing research on ISS.

This is the first hearing in Congressional history with a witness testifying from space. It is possible because of advanced communications technology on ISS and significant preparation and coordination by NASA and the Committee. For technical reasons, the video communication link will only be available for a limited period of time, approximately 15 minutes.

Overarching Questions

The hearing will review the current activities onboard ISS, accomplishments of the crew, status of current research on the Station, and observations on extended human space flight, and explore the following overarching questions:

1. What are the biggest challenges and opportunities of living and working on ISS?
2. What are the scientific (research) and engineering accomplishments that have resulted from operation of ISS?

Witnesses

The hearing will feature the following witnesses.[1]

Dr. John Phillips is a NASA astronaut and is currently living and working aboard ISS as the Science Officer and Flight Engineer of Expedition 11.

Dr. Peggy Whitson is a NASA astronaut, and was formerly a member of the ISS crew during Expedition 5 (June–Dec. 2002).

Lt. Col. Michael Fincke (USAF) is a NASA astronaut, and was formerly a member of the ISS crew during Expedition 9 (April–Oct. 2004).

Background

In-orbit assembly of ISS began in 1998 with the launch of the first two segments: the Zarya ("Dawn") module, built and launched by Russia, but paid for by NASA; and the Unity module, built by NASA and launched on the Space Shuttle in late 1998. In total, there have been 16 Shuttle missions to ISS (for assembly, logistics and utilization), as well as 30 Russian launches to ISS (which includes three launches of ISS modules, 10 Soyuz crew launches and 17 unmanned Progress resupply launches). In addition, astronauts have performed 58 spacewalks in conjunction with ISS (25 Shuttle-based, and 33 ISS-based), totaling more than 348 hours.

[1] Detailed biographies of the witnesses are included in Appendix A.

ISS has been permanently occupied by joint U.S.-Russian "Expedition" crews, rotating on four to six month shifts, since November 2000. The current crew is the 11th rotation, or increment, and is thus designated Expedition 11.

The United States is building ISS in partnership with Russia, Canada, Japan, and 10 European countries. In addition, Brazil has a bilateral agreement with NASA to participate in the program. The attached diagram illustrates the layout of the various segments of ISS.

ISS assembly was approximately 50 percent complete (by mass) before the loss of the Space Shuttle *Columbia* in February 2003 halted construction. Because the Shuttle is the primary means of both assembly and re-supply for ISS, this has presented the ISS program with substantial challenges in conducting normal operations for the past two years. Without Shuttle, ISS crews have relied on unmanned Russian Progress vehicles as the primary means for re-supply of spare parts and consumables (water, food, etc.). Additionally the Russian Soyuz vehicles have been the only means of ferrying crew to and from ISS. (A single Soyuz vehicle is always docked at ISS at any one time to provide the crew with a lifeboat in case of emergency. Each Soyuz must be replaced every six months.)

Prior to the *Columbia* tragedy, ISS Expedition crews were composed of three members: two Russians and one American or one Russian and two Americans. After *Columbia,* the crew size was reduced to two (one Russian and one American) to reduce the need for ISS to be re-supplied. The partners plan to restore the three-person crew size this fall with the addition of a crew member who would be transported to ISS on STS–121 (the second Shuttle mission after return-to-flight), scheduled for later this year.

Despite the reduction in crew size, ISS Expedition crews have continued to conduct research while the Shuttle is grounded, primarily using equipment already aboard ISS. (For a list of experiments being conducted by the Expedition 11 crew, see Appendix B.) The post-*Columbia* accident Expedition crews have dealt with a variety of equipment failures, such as repeated shutdowns of the Russian oxygen generating device, known as the Elektron. According to NASA, there are sufficient alternate supplies of oxygen aboard ISS, or scheduled to be delivered by re-supply missions, that the Elektron failure is not currently a safety issue. A new Elektron unit is scheduled to be delivered to ISS later this summer.

There have also been failures of two of the four Control Moment Gyros (CMGs) that help keep the space station oriented properly. One CMG failed permanently and is scheduled to be replaced on the next Shuttle flight. A second CMG was repaired by crews on spacewalks, but has failed again. NASA hopes to repair this second unit on the next Shuttle flight as well. Only two CMGs are required to maintain the Station's proper orientation. If another were to fail, however, proper orientation can be maintained using rocket thrusters on one of the Russian modules. In order to conserve rocket propellant, though, such an arrangement is not preferable.

NASA also is currently reformulating its scientific research program for ISS in light of President Bush's directive that the research be focused on projects that support the Vision for Space Exploration. In addition to gaining information about human adaptation to weightlessness that may be needed for eventual human trips to Mars, NASA Administrator Mike Griffin has cited the importance of the Station's potential role in testing hardware intended to go to the Moon or Mars. One example could be closed-loop life support systems.

The Crew

NASA astronaut **John Phillips** currently serves as Science Officer and Flight Engineer for ISS Expedition 11. Phillips flew aboard the Space Shuttle in 2001 on STS–100, logging nearly 12 days and five million miles in space. He also served as a backup crew member to ISS Expedition 7, completing that assignment in February 2003.

The other crew member on board ISS is Russian Cosmonaut **Sergei Krikalev,** the Commander of Expedition 11, who will not be participating in the hearing. As commander, Krikalev is responsible for the overall safety and success of the mission. Krikalev is a veteran of five previous space flights, including two missions to the Russian space station Mir and two Shuttle flights. He was a member of the first ISS crew (Expedition One), serving aboard a much smaller ISS than that of today, from Nov. 2, 2000, to March 18, 2001. Before Expedition 11, he had spent a year, five months and 10 days in space. At the conclusion of this mission, he will be the world's most experienced space traveler.

Expedition 11

Phillips and Krikalev are currently living and working aboard ISS on a six-month tour of duty. Expedition 11 was launched from the Baikonur Cosmodrome in

Kazakhstan on April 14, 2005 aboard a Russian Soyuz, which docked with ISS on April 16, 2005.

Expedition 11 replaced Expedition 10, which was on ISS from October 2004 until April 2005 (191 days). Expedition 11 is scheduled to return to Earth in October after approximately 180 days on orbit. Plans call for Phillips and Krikalev to perform one spacewalk. The astronauts will continue outfitting the exterior of ISS and work with scientific experiments.

Phillips and Krikalev will also welcome the arrival of two Russian Progress unmanned supply vehicles, one of which is scheduled for launch on June 16 (and should reach the Station on June 18), and the other is scheduled for launch near the end of August.

Highlights of the Expedition 11 crew's mission are scheduled to include welcoming the return of Space Shuttle crews, STS–114 (Discovery) and STS–121 (Atlantis), if the current Return-to-Flight schedule holds. The Shuttle missions will deliver several tons of supplies and research equipment to ISS, and the Shuttle crews also are expected to conduct spacewalks. As noted, STS–121 may leave a third astronaut aboard ISS to serve as a long-duration crew member.

Questions for the Witnesses

The witnesses were asked to address the following questions in their testimony:

Questions for Dr. John Phillips

In your testimony, please describe (and, to the extent possible, show during the hearing) how you conduct a typical day on the International Space Station and what are the greatest challenges, with specific attention to the following questions:

1. How have the loss of the *Columbia* Shuttle and the inability to use the Shuttle to re-supply the Station affected its operations during the last two years?
2. How do you deal with safety-related issues while on board ISS, such as taking shelter from solar flares, maintaining oxygen supplies, or keeping fit to reduce the bone loss associated with long-duration space flight?
3. What research does the crew of Expedition 11 plan to conduct while on board the Station?

Questions for Dr. Peggy Whitson

In your testimony, please describe your most important accomplishments (both for assembly and operations) during your stay on the International Space Station, as well as problems you may have experienced, with particular emphasis on the following questions:

1. What are the challenges of performing extravehicular activity (EVAs, or spacewalks) from the Station? What can EVAs from the Station teach us that we can apply to future Exploration-related activities?
2. What role does the micrometeoroid shielding you helped to install play in the operation and maintenance of the Station?
3. What impacts did your stay aboard the Station have on your health? How quickly did you become re-acclimated to Earth? How did your experience in that regard compare to that of other astronauts?
4. What did you learn about the psychological dynamics and stresses of living with a small crew in space? What was most unexpected about your experience?

Lt. Col. Michael Fincke was added to the witness list after the delivery of the formal invitation letters, and thus did not receive questions to address for the hearing.

Appendix A

Expedition 11 Crew Bio

John Phillips (Ph.D.), ISS Science Officer and Flight Engineer, Expedition 11

John Phillips, 54, received a Bachelor of Science degree in mathematics and Russian from the U.S. Naval Academy in 1972 (where he graduated second in his class), a Master of Science degree in aeronautical systems from the University of West Florida in 1974, and a Master of Science and doctorate in geophysics and space physics from the University of California, Los Angeles (UCLA) in 1984 and 1987 respectively. He has been awarded the NASA Space Flight Medal and various military awards.

Phillips received a Navy commission upon graduation from the U.S. Naval Academy in 1972 and was designated a Naval Aviator in November 1974. He trained in the A–7 Corsair Aircraft at Naval Air Station Lemoore, California and made overseas deployment with Attack Squadron 155 aboard the USS Oriskany and USS Roosevelt. Subsequent tours of duty included navy recruiting in Albany, New York, and flying the CT–39 Sabreliner Aircraft at Naval Air Station North Island, California.

After leaving the Navy in 1982, Phillips enrolled as a graduate student at UCLA. While at UCLA he carried out research involving observations by the NASA Pioneer Venus Spacecraft. Upon completing his doctorate in 1987, he was awarded a J. Robert Oppenheimer Postdoctoral Fellowship at Los Alamos National Laboratory in New Mexico. He accepted a career position at Los Alamos in 1989. While there, Phillips performed research on the sun and the space environment. From 1993 through 1996 he was Principal Investigator for the Solar Wind Plasma Experiment aboard the Ulysses Spacecraft as it executed a unique trajectory over the poles of the sun.

After being selected as an astronaut by NASA in 1996 and completing astronaut candidate training, Phillips has held various jobs in the Astronaut Office, including systems engineering and as International Space Station Spacecraft Communicator (ISS CAPCOM).

In addition to his current space flight experience as Science Officer for ISS Expedition 11, Phillips flew aboard Space Shuttle Endeavour on the STS–100 mission (April 19 to May 1, 2001). During the 12-day, 187 orbit mission, the Shuttle crew successfully delivered and installed the Canadarm-2 Robotic Arm on ISS. They also delivered experiments and supplies aboard the Multi-Purpose Logistics Module *Raffaello* on its maiden flight. Phillips was the Ascent/Entry Flight engineer and was the intravehicular activity coordinator during two space walks. Phillips also served as a backup crew member to ISS Expedition 7, completing that assignment in February 2003.

Witnesses Appearing In-person

Peggy Whitson (Ph.D.), NASA Astronaut, ISS Science Officer, Expedition 5

Peggy Whitson received a Bachelor of Science degree in biology/chemistry from Iowa Wesleyan College in 1981, and a doctorate in biochemistry from Rice University in 1985. She has received numerous awards and honors, including the NASA Space Flight Medal, and the Group Achievement Award for Shuttle-Mir Program. Dr. Whitson has also had two patents approved.

Upon completion of her graduate work, Whitson continued at Rice University as Postdoctoral Fellow until October 1986, at which point she began her studies at NASA Johnson Space Center, as a National Research Council Resident Research Associate.

In 1992, Whitson was named the Project Scientist of the Shuttle-Mir Program (STS–60, STS–63, STS–71, Mir 18, Mir 19) through 1995. From 1993–1996 she held the additional responsibilities of the Deputy Division Chief of the Medical Sciences Division at NASA–JSC. From 1995–1996 she served as Co-Chair of the U.S.–Russian Mission Science Working Group.

In April 1996, Whitson was selected as an astronaut candidate. Upon completing two years of training and evaluation, she was assigned technical duties in the Astronaut Office Operations Planning Branch and served as the lead for the Crew Test Support Team in Russia from 1998–99. From November 2003 to March 2005 she served as Deputy Chief of the Astronaut Office.

Whitson served as NASA Science Officer on the Expedition 5 crew for ISS, which launched on June 5, 2002 aboard STS–111 (Endeavour) and docked with ISS on June 7, 2002. During her six-month stay aboard ISS, Whitson installed the Mobile

Base System, the S1 truss segment, and the P1 truss segment using the Space Station remote manipulator system, performed a four hour and 25 minute spacewalk to install micrometeoroid shielding on the Zvezda Service Module, and activated and checked out the Microgravity Sciences Glovebox, a science payload rack. She conducted 21 investigations in human life sciences and microgravity sciences, as well as commercial payloads. The Expedition 5 crew (one American astronaut and two Russian cosmonauts) returned to Earth aboard STS–113 (Endeavour) on December 7, 2002. Completing her first flight, Whitson logged over 184 days in space.

Michael ("Mike") Fincke (Lt. Col., USAF) NASA Astronaut, ISS Science Officer, Expedition 9

Lt. Col. Fincke graduated from the Massachusetts Institute of Technology on an Air Force ROTC scholarship in 1989 with a Bachelor of Science in Aeronautics and Astronautics as well as a Bachelor of Science in Earth, Atmospheric and Planetary Sciences. He then received a Master of Science in Aeronautics and Astronautics from Stanford University in 1990 and a second Master of Science in Physical Sciences (Planetary Geology) from the University of Houston, Clear Lake in 2001. He is the recipient of two United States Air Force Commendation Medals, the United States Air Force Achievement Medal, and various unit and service awards.

In April 1996, Lt. Col. Fincke was selected as an astronaut candidate. Upon completing two years of training and evaluation, he was assigned technical duties in the Astronaut Office Station Operations Branch serving as an International Space Station Spacecraft Communicator (ISS CAPCOM), a member of the Crew Test Support Team in Russia and as the ISS crew procedures team lead. He also served as backup crew member for the ISS Expedition-4 and Expedition-6 and is qualified to fly as a left-seat Flight Engineer (co-pilot) on the Russian Soyuz spacecraft.

Lt. Col. Fincke served as NASA Science Officer on the Expedition 9 crew for ISS, which was launched from the Baikonur Cosmodrome, Kazakhstan aboard a Soyuz spacecraft, docking with ISS on April 21, 2004. He spent six-months aboard the station during which time he continued ISS science operations, maintained Station systems, and performed four spacewalks. The Expedition-9 mission concluded with undocking from the Station and safe landing back in Kazakhstan on October 23, 2004. Lt. Col. Fincke completed his first mission in 187 days, and logged over 15 hours of EVA time.

Appendix B

Expedition 11 Science Overview

(The following section is adapted from the Expedition 11 press kit, available from: *http://www.shuttlepresskit.com/EXPEDITION11/index.htm*)

Expedition 11—the 11th long-duration crew on ISS—began in April 2005, when the 11th crew arrived at the Station aboard a Russian Soyuz spacecraft. NASA ISS Science Officer Phillips and Russian Commander Krikalev, will maintain the Station and work with science teams on the ground to operate experiments and collect data.

During Expedition 11, two Russian Progress cargo flights are scheduled to dock with ISS. The Progress re-supply ships will transport supplies to the Station and carry scientific equipment. Much of the research activities for Expedition 11 will be carried out with scientific facilities and samples already on board ISS, as well as with new research facilities transported by the next two Space Shuttle missions—STS–114 scheduled for launch in July 2005, and STS–121 scheduled for launch later in 2005. Additional experiments are being evaluated and prepared to make use of limited cargo space on the Soyuz or Progress vehicles. The research agenda for the expedition remains flexible. While most equipment and samples can remain on board the Station with minimal or no detrimental effects, a few perishable samples—urine samples, for example—may be returned to Earth on the Soyuz.

The Expedition 11 crew has more than 100 hours scheduled for U.S. payload activities. Space Station science also will be conducted by remote "crewmembers"—the team of controllers and scientists on the ground, who will continue to plan, monitor and operate experiments from control centers across the United States. A team of controllers for Expedition 11 will work in the ISS Payload Operations Center—NASA's science command post for the Space Station—at NASA's Marshall Space Flight Center Huntsville, Ala. Controllers work in three shifts around the clock, seven days a week in the Payload Operations Center, which links researchers around the world with their experiments and the crew aboard the Station.

EXPERIMENTS USING ON-BOARD RESOURCES

Many experiments from earlier Expeditions remain aboard the Space Station and will continue to benefit from the long-term research platform provided by the orbiting laboratory. These experiments include:

Crew Earth Observations (CEO) takes advantage of the crew in space to observe and photograph natural and man-made changes on Earth. The photographs record Earth surface changes over time, as well as more fleeting events such as storms, floods, fires and volcanic eruptions. Together they provide researchers on Earth with vital, continuous images needed to better understand the planet.

Dust Aerosol Measurement Feasibility Test (DAFT) tests the ability of different equipment to measure the levels of dust and air quality in order to improve fire detection capabilities in space.

Materials on the International Space Station Experiment (MISSE) is a suitcase-sized experiment attached to the outside of the Space Station. It exposes hundreds of potential space construction materials to the environment. The samples will be returned to Earth for study during a later expedition. Investigators will use the resulting data to design stronger, more durable spacecraft.

Protein Crystal Growth Single-locker Thermal Enclosure System (PCG–STES) will continue to process crystals that have been growing since Expedition 6, launched in October 2002. Crystals that also were grown on Expeditions 2 beginning in March 2001, as well as Expedition 4 launched in December 2001, and Expedition 5 beginning in June 2002, were returned to Earth for analysis. The facility provides a temperature-controlled environment for growing high-quality protein crystals of selected proteins in microgravity for later analyses on the ground to determine the proteins' molecular structure. Research may contribute to advances in medicine, agriculture and other fields.

Space Acceleration Measurement System II (SAMS–II) and **Microgravity Acceleration Measurement System (MAMS)** sensors measure vibrations caused by crew, equipment and other sources that could disturb microgravity experiments.

HUMAN LIFE SCIENCE INVESTIGATIONS

Many continuing experiments will use measurements of Expedition 11 crewmembers to study changes in the body caused by exposure to the microgravity environment.

Chromosomal Aberrations in Blood Lymphocytes of Astronauts (Chromosome), will study space radiation on humans. The expected results will provide a better knowledge of the genetic risk of astronauts in space and can help to optimize radiation shielding.

Promoting Sensorimotor Response to Generalizability: A Countermeasure to Mitigate Locomotor Dysfunction After Long-duration Spaceflight (Mobility) studies changes in posture and gait after long-duration space flight. Study results are expected to help in the development of an in-flight treadmill training program for Station crew members that could facilitate rapid recovery of functional mobility after long duration space flight.

Behavioral Issues Associated with Isolation and Confinement: Review and Analysis of Astronaut Journals collects behavioral and human factors data for analysis, with the intention of furthering our understanding of life in isolation and confinement. The objective of the experiment is to identify equipment, habitat and procedural features that help humans adjust to isolation and confinement and remain effective and productive during future long-duration space expeditions.

Advanced Diagnostic Ultrasound in Microgravity (ADUM) involves crew members conducting ultrasound exams on one another with minimal training and with direction from a ground based sonographer. Verification of these advanced ultrasound techniques and telemedicine strategies could have widespread applications in emergency and rural care situations on Earth.

The **Biopsy** experiment allows researchers to take biopsies of the astronauts' calf muscles before and after their stay on board the Space Station. This will allow scientists to begin developing an in-space countermeasure exercise program aimed at keeping muscles at their peak performance during long missions in space.

Foot/Ground Reaction Forces During Space Flight (Foot) studies the load on the lower body and muscle activity in crew members while working on the Station. This study will provide better understanding of the bone and muscle loss in the lower extremities experienced by astronauts in microgravity. The results of this experiment will help in future space flights, as well as have significance for understanding, preventing and treating osteoporosis on Earth.

The **Renal Stone** experiment collects urine samples from the crew and tests a possible countermeasure for preventing kidney stone formation.

A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft (Swab) will use generic techniques for the first time to comprehensively evaluate microbes on board the Space Station, including pathogens, and to study how the microbial community changes as spacecraft visit the Space Station and modules are added. This study will monitor Station modules prior to launch to evaluate sources of new germs and find ways of preventing additional contamination onboard spacecraft.

Space Flight-Induced Reactivation of Latent Epstein-Barr Virus (Epstein-Barr) performs tests to study changes in human immune function using blood and urine samples collected before and after space flight. The study will provide insight for possible countermeasures to prevent the potential development of infectious illness in crew members during flight.

DESTINY LABORATORY FACILITIES

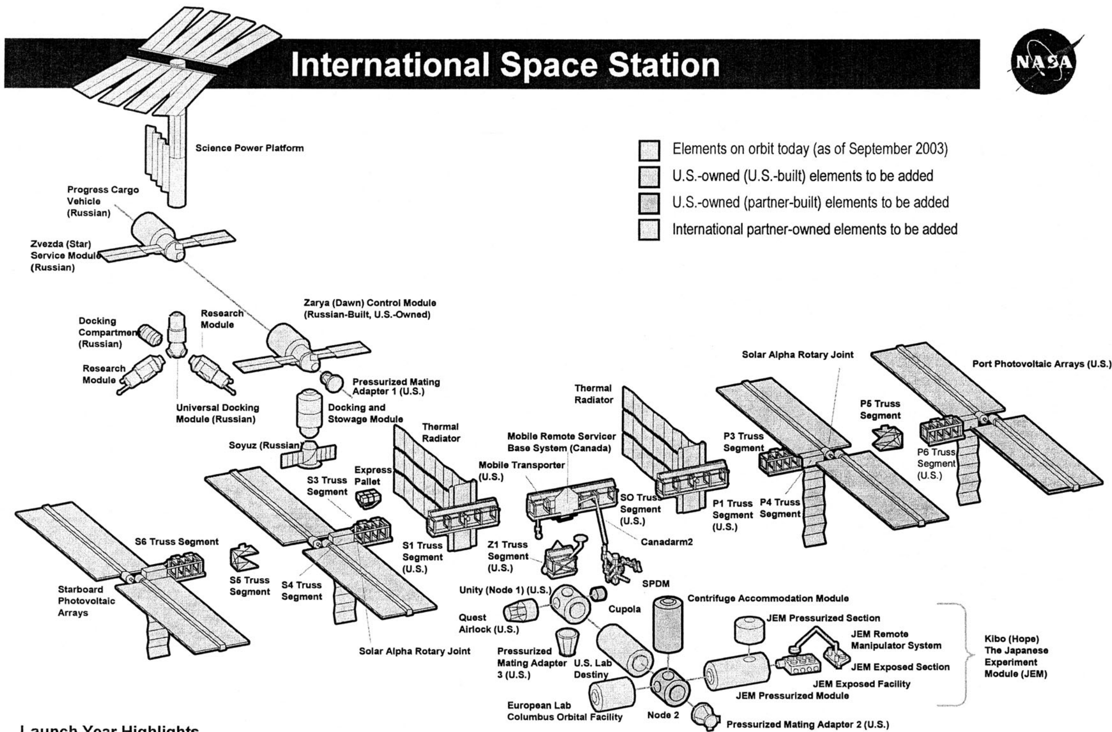
Several research facilities are in place aboard the Station to support Expedition 11 science investigations:

The **Human Research Facility** is designed to house and support a variety of life sciences experiments. It includes equipment for lung function tests, ultrasound to image the heart and many other types of computers and medical equipment.

The **Microgravity Science Glovebox** is the other major dedicated science facility inside Destiny. It has a large front window and built-in gloves to provide a sealed environment for conducting science and technology experiments. The Glovebox is particularly suited for handling hazardous materials when a crew is present. The Destiny lab also is outfitted with five EXPRESS Racks. EXPRESS (Expedite the Processing of Experiments to the Space Station) racks are standard payload racks designed to provide experiments with a variety of utilities such as power, data, cooling, fluids and gasses. The racks support payloads in a several disciplines, including biology, chemistry, physics, ecology and medicines. The racks stay in orbit, while experiments are changed as needed. EXPRESS Racks 2 and 3 are equipped with the Active Rack Isolation System (ARIS) for countering minute vibrations from crew movement or operating equipment that could disturb delicate experiments.

International Space Station

- Elements on orbit today (as of September 2003)
- U.S.-owned (U.S.-built) elements to be added
- U.S.-owned (partner-built) elements to be added
- International partner-owned elements to be added



Launch Year Highlights
ISS assembly launches are on hold awaiting the Space Shuttle's return to flight following the Columbia accident.

U.S. Elements based on President's FY 2004 budget

Chairman CALVERT. I call this meeting of the Space and Aeronautics Subcommittee to order.

Without objection, the Chair will be granted authority to recess the Committee.

Today, we are going to have a special experience. We are going from Capitol Hill "Live to Space Aboard the International Space Station." We will be talking to Dr. John Phillips, the current U.S. astronaut on the Space Station. From his current abode in low-Earth orbit, 218 miles above the Earth, Dr. Phillips will be answering some of our questions about what it is really like to live in space. This is the first hearing in Congressional history with a witness testifying from space.

Our goal today is to hear first hand from the astronauts what it is like to live and work in space. We will hear directly from the astronauts on how they are dealing with the challenges of operating and maintaining the International Space Station as well as hear about the research they are conducting. This hearing gives us a chance to learn about what is really going on in space from those directly involved, rather than delve into the programmatic and budgetary details of the ISS program.

Members, you will notice that you have information in your packets on special considerations in communicating with Dr. Phillips and today's hearing schedule. The other ISS crewmember who is currently on board is Cosmonaut Sergei Krikalev, the Commander of Expedition 11, will not be participating in the hearing. We also have two astronauts who have joined us, each of whom have lived on the ISS previously. First is Dr. Peggy Whitson, who was on the ISS on Expedition 5 from June through December of 2002. Our final witness is Lieutenant Colonel Mike Fincke, who was a member of Expedition 9 from April through October of 2004.

We are going to have a very—we will be very brief in today's opening statements, so that when we get the connection with the International Space Station we can move right on to the questions. Dr. Peggy Whitson has agreed to deliver the opening statement on behalf of the three astronauts, giving us more time for questions for each of the astronauts. Keep in mind that our connection with International Space Station is a total of only 15 minutes. So instead of the usual five minutes for each member, we are going to give each member only two minutes, which I will strictly enforce to be fair for everyone. If we have time, we will go back around again. That means you have two minutes totally for the question and the answer.

Although we will be able to see Dr. Phillips on the International Space Station, he will be unable to see us, so I ask that when you ask your questions, please identify yourself. There will be a transmission delay, so please wait about a second after you turn on your microphone before beginning to speak. There is also about a three-second transmission delay before Dr. Phillips will hear you and will respond. Be sure to speak clearly into the microphone. Again, please ask only one question to Dr. Phillips in order to accommodate everyone. When we lose the connection to the International Space Station after 15 minutes, members will have an opportunity to ask questions with the standard five-minute rule of our two former ISS astronauts that we have here with us today.

[The prepared statement of Chairman Calvert follows:]

PREPARED STATEMENT OF CHAIRMAN KEN CALVERT

Today, we are going to have a special experience. We are going from Capitol Hill Live to Space Aboard the International Space Station. We will be talking with Dr. John Phillips, the current U. S. astronaut on the Space Station. From his current abode in Low-Earth Orbit, 218 miles above the Earth, Dr. Phillips will answer some of our questions about what it is really like to live in space. This is the first hearing in Congressional history with a witness testifying from space.

The International Space Station (ISS) has been permanently occupied by joint U.S.–Russian "Expedition" crews since November 2000. Dr. Phillips is a member of the 11th Expedition. ISS is approximately 50 percent complete and we are waiting to see what NASA plans to do for the final assembly complete. Since the Columbia accident, the Russian Soyuz has been the means to ferry crew, and the Russian Progress launch vehicle has been the means for re-supply of spare parts and consumables. Prior to the *Columbia* tragedy, the ISS Expedition crews were composed of three members—two Russians and one American or two Americans and one Russian.

After *Columbia,* crew size was reduced to two persons—one American and one Russian. Despite this reduction in crew size, ISS Expedition crews have continued to conduct research while the Shuttle is grounded, primarily using the equipment that is already aboard. NASA will be reconfiguring the scientific research program for the ISS to focus on projects that support the Vision for Space Exploration. The ISS will be a great platform to study humans and their potential adaptation to weightlessness as well as for testing hardware intended to go to the Moon or other destinations.

Members, you will notice that you have information in your packets on special considerations in communicating with Dr. Phillips and today's hearing schedule. The other ISS crew member who is currently on board is Cosmonaut Sergei Krikalev, (pronounced sir-gay kree-ka-loff) the Commander of Expedition 11, who will not be participating in the hearing. We also have two astronauts who have joined us—each of whom has lived on the ISS previously. The first is Dr. Peggy Whitson who was on the ISS on Expedition 5 from June through December 2002. Our final witness is Air Force Lt. Col. Michael Fincke (USAF) (pronounced fink) who was a member of Expedition 9 from April through October 2004.

We are going to be very brief in today's opening statements, so that when we get the connection with the ISS, we can move right on to questions. Dr. Peggy Whitson has agreed to deliver the opening statement on behalf of the three astronauts, giving us more time for questions for each of the astronauts. Keep in mind that our connection with the ISS a total of only 15 minutes to the ISS. So instead of the usual five minutes for each Member, we are going to give each Member only two minutes, which I will strictly enforce to be fair to everyone.

Although we will be able to see Dr. Phillips on the ISS, he will be unable to see us, so I ask that when you ask your questions, please identify yourself. There will be a transmission delay, so please wait about a second after you turn on your microphone before beginning to speak. There is also about a three second transmission delay before Dr. Phillips will hear you and will respond. Be sure to speak clearly into the microphone. Again, please ask only one question to Dr. Phillips in order to accommodate everyone. When we lose the connection to the ISS in 15 minutes, Members will have an opportunity to ask questions with the standard five-minute rule of our two former ISS astronauts that we have here with us today.

Chairman CALVERT. And with that, Mr. Udall, you may begin your opening statement.

Mr. UDALL. Thank you, Mr. Chairman.

I want to join the Chairman in welcoming today's witnesses, especially Dr. John Phillips, who will be with us from the International Space Station. I would also like to take a moment to express my personal appreciation to our witnesses, and to all of the astronaut corps for the service that you render to our nation.

Human space exploration involves risk, yet it is an undertaking that I and you, obviously, believe is important to the future of our nation. You have been willing to accept the risk, because you also believe in the importance of human space exploration.

Fundamentally, NASA's science and exploration programs are about pushing back the boundaries of our ignorance. And, properly utilized, that is what I believe that we can do with the International Space Station, push back the boundaries of our ignorance across a range of scientific and technological disciplines.

The advances we make on the ISS have the potential to prepare us for the challenging human missions beyond low-Earth orbit. They also have the potential to benefit life back here on Earth if we are willing to invest in the necessary fundamental and applied research.

To that end, I would hope that as NASA contemplates a restructuring of the ISS research program, it does not unduly narrow its focus. We have spent too much time to build the Space Station not to try to make optimal use of its capabilities. However, that is an issue for another day.

At today's hearing, I look forward to learning more about what it is like to actually live and work in space. And I would also like to learn more about how the astronauts on the Station are coping with the impact of the Shuttle fleet's grounding.

Mr. Chairman, today's hearing should be fascinating. I want to thank you for holding it, and I look forward to the testimony of our witnesses.

[The prepared statement of Mr. Udall follows:]

PREPARED STATEMENT OF REPRESENTATIVE MARK UDALL

Good afternoon. I want to join the Chairman in welcoming the witnesses to today's hearing—especially Dr. John Phillips, who will be talking to us live from the International Space Station. And I'd also like to take a moment to express my personal appreciation to our witnesses—and to all of the astronaut corps—for the service that you render to our nation.

Human space exploration involves risk. Yet it is an undertaking that I believe is important to the future of our nation. You have been willing to accept the risk, because you also believe in the importance of human space exploration.

Fundamentally, NASA's science and exploration programs are about pushing back the boundaries of our ignorance. And, properly utilized, I believe that that is what the International Space Station program can do—push back the boundaries of our ignorance across a range of scientific and technological disciplines.

The advances we make on the International Space Station have the potential to prepare us for challenging human missions beyond low-Earth orbit. They also have the potential to benefit life back here on Earth, if we are willing to invest in the necessary fundamental and applied research.

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At today's hearing, I look forward to learning more about what it is actually like to live and work in space. I'd also like to learn more about how the astronauts on the ISS are coping with the impact of the Shuttle fleet's grounding.

Mr. Chairman, today's hearing should be fascinating. I want to thank you for holding it, and I look forward to the testimony of our witnesses. Thank you.

Chairman CALVERT. I thank the gentleman for his testimony.

Without objection, the additional statements of other Members will be put into the written record, so we can get right to the questions. Hearing no objection, so ordered.

[The prepared statement of Ms. Jackson Lee follows:]

PREPARED STATEMENT OF REPRESENTATIVE SHEILA JACKSON LEE

Chairman Calvert, Ranking Member Udall,

I am honored to be here today for this historic Subcommittee hearing with American astronauts who have been on the International Space Station. I want to welcome our distinguished panel of witnesses to the Subcommittee on Space and Aeronautics. Indeed, we have a unique opportunity to interact with Dr. John Phillips who will be testifying live from the ISS; the first time in history such testimony has taken place.

While I appreciate the Chairman and Ranking Member of this subcommittee for organizing this hearing, I would be remiss if I did not reiterate my belief that we need to hold a hearing on safety. After the tragic *Columbia* Space Shuttle accident safety has been the number one priority of this subcommittee. I believe there should be a safety hearing not only for our Space Shuttle which is returning to flight, but also for safety on-board the ISS.

I have long been a supporter of the ISS and its mission. Indeed, this mission is unique among other space exploration missions because of the cooperation between nations. The ISS is truly an international program with the original partnership being established in 1988 including the U.S., Japan, and the European Space Agency. Russia was later invited to joint the partnership in 1993, and revised international agreements governing the program were signed in 1998. Since that time, the ISS has pushed the boundaries of what had been previously achieved in space. The first ISS modules were launched in 1998 and astronauts began continuous occupation of the ISS in November 2000. At the start permanent crews consisted of three astronauts, however, since the tragic *Columbia* Space Shuttle accident grounded the Shuttle fleet in 2003, crew size has been limited to only two astronauts.

Because of the current limitations of our Space Shuttle program and that of the Russian space program, the ISS has undergone some recent challenges in maintaining safe and sustained operations. In fact recently the Russian Elektron oxygen generator has been having repeated problems. Water and food have also been carefully rationed. In late 2004, the Expedition 10 crew had to limit its food intake due to shortages on-board the ISS. These problems are being addressed but they only underscore the fact that safety on-board the ISS must be more closely scrutinized.

At this time the ISS assembly is scheduled to be completed around 2010, but little is certain as far as a timetable as NASA is currently reviewing the assembly schedule and content. As I stated, I am a strong supporter of the ISS and hope that we can move forward with its mission. However, our mission for discovery can not be done in haste; instead we must ensure that all steps have been taken to minimize the risk to astronauts on-board.

Chairman CALVERT. I also ask unanimous consent to insert at the appropriate place in the record, the background memorandum prepared by the Majority staff for this hearing. Hearing no objection, so ordered.

Today, we will begin our hearing with testimony from Dr. Peggy Whitson, a NASA astronaut who was formerly a member of the International Space Station crew during the Expedition 5 from June to December of 2002, as I mentioned earlier. If we have time before we are connected to the International Space Station, we can allow a couple of brief questions of Dr. Whitson and to Lieutenant Colonel Michael Fincke sitting at the witness table. However, once we begin the connection to International Space Station, we will immediately move to the two-minute rounds of questions to Dr. Phillips. Once we lose the connection, we will resume the questions to Dr. Whitson and Lieutenant Colonel Fincke.

And with that, Dr. Whitson, you may begin your opening statement.

STATEMENT OF DR. PEGGY A. WHITSON, NASA ASTRONAUT, SCIENCE OFFICER AND FLIGHT ENGINEER, ISS EXPEDITION 5 (JUNE–DECEMBER 2002)

Dr. WHITSON. Well, Mr. Chairman and Members of the Committee, it is a real honor for us to be here today to testify about the International Space Station. As mentioned, I am here with

Lieutenant Colonel Mike Fincke. He was Flight Engineer and Science Officer on board during Expedition 9, and Dr. John Phillips is serving in that same role on board the International Space Station right now.

I thought I would start off with just a few comments about my experience on board the International Space Station and give you a big picture of where John and Sergei's mission is on orbit and what we plan on as part of the next six months of their stay.

As a scientist, it was really exciting for me to be the on-orbit hands of the investigators on the ground. And as uniquely, probably, or nearly uniquely, as the daughter of a farmer, it was also a very exciting thing to do a soybean, commercial soybean plant growth experiment while on board the International Space Station. I think my dad had a greater yield of soybeans than I did, but it was still a lot of fun to compare stories.

We also got—I also got to participate in another experiment that I am a principle investigator on looking at the efficacy of potassium citrate and reducing the kidney stone-forming potential in astronauts. Because of the bone demineralization process that occurs on orbit, there is a greater risk of kidney stones forming. And actually, we are continuing that experiment, and John and Sergei on orbit are my next subjects, and they will be continuing that experiment.

My background in human life sciences really gave me a unique opportunity to know in advance of my space flight all of the things that might—I might experience when I went into zero gravity and actually returning back to Earth, but I would have to say that even I was surprised by how much a neuro-vestibular imbalance I felt upon returning to Earth. As you know, the International Space Station is orbiting at 17,500 miles per hour, and when I returned to Earth, I felt like the Earth was orbiting around me at approximately 17,500 miles per hour. Luckily, that recovery was relatively quick, and within a day or so, I had recovered from that particular effect of being at zero gravity for a six-month period.

I am sure John is going to be really happy to share his experience on board the International Space Station with you and some of his science background that he is working on up there. In addition to the science activities they are doing, John and Sergei are doing a space walk to set up some experiments externally. They are also going to be performing a number of maintenance tests, routine maintenance tests. They will be greeting two progress resupply vehicles. These are Russian resupply vehicles. One is actually arriving to the International Space Station later this week.

And then, of course, we are very excited about the arrival of the Discovery with Eileen Collins and her six crew members on the Shuttle return to flight. So they will be on board during that mission as well. During that time, during the docked phase of that Shuttle mission, they will do—perform three space walks and transfer, literally, tons of hardware to and from the Station.

The Expedition 11 crew has more than 100 hours of science and payload activities planned. In addition to being the subjects for my experiment, they are also doing a number of different activities looking at the human physiology and the effects of long duration and being in space. And one of the more interesting studies that, actually, Mike and I both participated in and is being continued is developing the techniques using ultrasound by non-experienced crew members or untrained professionals to do ultrasounds in a very complex manner. And actually, that is something that can apply to us here on Earth as well in real medicine scenarios or even on battlefields. So we are excited about that research as well.

In summary, I just wanted to say that the International Space Station is an incredible engineering feat, and our studies to understand how the human body responds to that and our understanding of all of the complications and problems that arise as a part of operating this Station is going to help us prepare for the longer duration missions to the Moon and Mars and beyond.

And Mike and I are really excited about taking any questions you might have, and we will get a signal here in a little bit about when we can start talking to John.

[The prepared statement of Dr. Whitson follows:]

PREPARED STATEMENT OF PEGGY A. WHITSON

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today. I consider it an honor to appear here with Mike Fincke, who was the Science Officer on Expedition 9. In just a few minutes, John Phillips, Expedition 11 Flight Engineer and Science Officer, will be appearing live, via satellite, from the ISS to answer questions about life on orbit. First, I'd like to tell you a little about my experience on the Station as part of Expedition 5 and then provide you with an overview of current activities aboard the Station.

Life and Work Aboard the International Space Station

In the over four years of continuous human presence on board the ISS, we have performed important science that will allow us to expand our presence into the solar system. We have discovered things that make our life here on Earth better. We have learned about technologies and processes which will help us meet the challenges of future exploration.

While we can to some extent simulate living conditions in space here on the ground, there is no substitute for experience in the actual space environment. Simply put, to learn how to live in space, we must live in space. Every experiment, every space walk, every repair and every piece of hardware assembled teaches us something new. A full time human presence aboard the ISS offers us a tremendous opportunity to study human survival in the hostile environment of space and assess how to overcome the technological hurdles to human exploration beyond Earth orbit, as called for in the Vision for Space Exploration.

During my time on Station (Expedition 5), we hosted three Shuttle assembly missions. Using the Station's robotic arm, we installed the S1 (starboard 1) and P1 (port 1) truss elements and the Mobile Base System, which serves as the platform for transporting the robotic arm and any attached hardware or experiments to various locations along the truss.

We also performed two extra-vehicular activities (EVA). Space walks are a physical challenge, since we work in a pressurized suit that protects us from the vacuum of space, but requires us to perform hand-intensive tasks working against this pressure. EVAs are also an operational challenge, especially now while we have only two-person crews, since both crew members are outside. From these activities we continue to learn a great deal about assembly of Station elements, repair of external components, operational processes, and spacesuit capabilities.

As a scientist, it was, of course, exciting being the on orbit hands of the investigator teams on the ground. Being the daughter of a farmer, I would have to say that the commercial experiment involving soybean growth was very, very special to me as well. I also had the unique opportunity to be the principal investigator and the subject for my own experiment to test potassium citrate ingestion as a mechanism to reduce the kidney stone-forming potential in space travelers. In fact, I am still working on this experiment, albeit from the ground, with Expedition 11 as our primary subjects. A few of the other experiments we conducted on Expedition 5 included: super-conducting crystal materials with different technical additives and in different heating profiles to better assess the crystallization characteristics in an environment where gravity is not a variable, assessing pulmonary lung function before and after EVA, and developing procedures for diagnostic ultrasound capability.

My background in the human space life sciences provided me with a lot of insight into the potential physiologic responses that a crew member might anticipate upon entering and returning from microgravity. However, I was still surprised by the low back pain as my spinal column relaxed, and the surrounding muscles stretched out on flight day four and five. Although individual crew responses can vary dramatically, I was also surprised by the neuro-vestibular imbalance I felt upon returning to Earth's gravity after six months on orbit. For the first 24 hours, I felt like the world was spinning around me; as if I were still on orbit, and I thought they should just send me back to the Station. Luckily for me, recovery was relatively quick after that first day.

As a result of a very intensive exercise regime, I lost no overall bone density. This is very promising for us in the development of exercise programs for extended exploration missions to Mars when we will need to have an exercise and/or pharmacologic plan to minimize the impacts of extended periods in microgravity.

We typically train prior to flight for three or more years. Much of that time is spent with crew mates in classroom training and simulations. I consider this a very important time to learn not only about us, but the best way to constructively interact with our crew mates and our ground support teams. The loss of *Columbia* meant that we had to reduce the Station crew size to two. As a result, our crews and ground teams have come up with creative new methods to squeeze in more work and provide better support. Although I had great respect for the work conducted by the ground team even before I flew, I was surprised by how close I felt to them during my mission. As Mike and John can tell you, the ground crew acts as a "third" crew member for our two-person crews by helping them with everything from monitoring the Station to assisting with research.

Safety is something we all take as a fundamental value in how we build and operate the Station. An intensive system safety engineering effort during the development and manufacture of the International Space Station system has mitigated the known hazards presented by living in low-Earth orbit. For example, we have design features, such as the Micro Meteoroid Orbital Debris (MMOD) shields on the Service Module to reduce the chance that orbital debris will penetrate the Station. In fact, more of these panels will be installed in the future to even further reduce this probability. We have a caution and warning system installed to alert the crew to any impending dangers, such as fire or pressure leaks that may raise the risk of injury, we have emergency equipment on the Station such as fire suppression to reduce the consequence of fire, and we have a "lifeboat," the Soyuz crew return vehicle, which we can use as a last resort if we have to abandon the Station should the living conditions become untenable. Ground-based and on-orbit safety-related training are a large part of our pre-mission preparation and during the mission. In addition, the ground team also plays a large role in ensuring the safety of the Station and the crew by providing maintenance procedures for both critical as well as non-critical equipment, by providing real-time information and pre-cautions for events like solar flares or by providing feedback on exercise regimes.

Expedition 11 Mission

In April, we sent a new crew to live on the International Space Station. Flight Engineer John Phillips and Station Commander Sergei Krikalev will perform one space walk, a number of experiments, and daily maintenance during their six-month stay. They will greet two Russian Progress resupply vehicles, including one that arrives this week, and at least one U.S. Space Shuttle flight. They will also relocate their Soyuz spacecraft from the Pirs docking port to the Zarya docking port in order to free up the Pirs airlock to support the space walk.

During the space walk from the Russian Pirs airlock in September, the crew will relocate and recover Russian science equipment.

Expedition 11 will be on board the Station when Commander Eileen Collins and her six crew members launch on the Space Shuttle *Discovery* on the first post-*Columbia* mission. It will mark the first time since the STS–113 mission in November 2002 that a Space Shuttle will arrive at the Station. The two crews plan eight days of joint docked operations, including the resupply of the Station with several tons of food and equipment, as well as three space walks out of the Shuttle's airlock by *Discovery* astronauts.

Expedition 11 Science

Much of the research activities for Expedition 11 will be carried out with scientific facilities and samples already on board the Space Station, as well as with new research facilities transported by the next two Space Shuttle missions. While most equipment and samples can remain on board the Station with minimal or no detrimental effects, a few perishable samples will be returned to Earth on the Soyuz.

The Expedition 11 crew has more than 100 hours scheduled for U.S. payload activities. In addition to the crew on the Station, a team of controllers for Expedition 11 will work in the Space Station's Payload Operations Center—NASA's science command post for the Space Station at NASA's Marshall Space Flight Center in Huntsville, Alabama. Controllers link researchers around the world with their experiments and the crew aboard the Station.

Other experiments to be conducted by Expedition 11 include:

- **Advanced Diagnostic Ultrasound in Microgravity (ADUM):**
  Advanced Diagnostic Ultrasound in Microgravity (ADUM) will be used to determine the ability of minimally trained Station crew members to perform advanced ultrasound examinations after using a computer-based training program. Verification of these advanced ultrasound techniques and telemedicine strategies could have widespread applications in emergency and rural care situations on Earth. The ADUM experiment, which uses remote guidance methodologies, has been conducted during Expeditions 8, 9 and 10 and is scheduled for completion with the Increment 11 crew.
- **Foot/Ground Reaction Forces During Space Flight (FOOT):**
  FOOT studies the load on the lower body and muscle activity in crew members while working on the Station. Previous portions of this study on earlier increments have provided better understanding of the bone and muscle loss in the lower extremities experienced by astronauts in microgravity. The results of this experiment will help in future space flights, as well as potentially improve our understanding to prevent and treat osteoporosis.
- **Dust and Aerosol Measurement Feasibility Test (DAFT):**
  DAFT releases particles in the Space Station atmosphere to test the ability of different equipment to measure the levels of dust and air quality. It will help to improve air quality and fire detection in space.
- **Hand Posture Analyzer (HPA):**
  HPA will investigate the performance degradation of the human upper limb muscle-skeletal apparatus and its morphological-functional modifications during long-term exposure to weightlessness and to study the role of gravity in how people reach, grasp, manipulate, and transport objects.
- **Passive Observatories for Experimental Microbial Systems (POEMS):**
  POEMS will study the growth, ecology and performance of diverse assemblages of micro-organisms in space. Understanding microbial growth and ecology in a space environment is important for maintaining human health and bioregenerative life support functions.
- **A Comprehensive Characterization of Micro-organisms and Allergens in Spacecraft (SWAB):**
  SWAB uses genetic techniques for the first time to comprehensively evaluate germs, including pathogens, on board the Space Station, and to study how the germ community changes as spacecrafts visit the Space Station and modules are added. This study will monitor Station modules prior to launch to evaluate sources of new germs and find ways of preventing additional contamination on board spacecraft.
- **Crew Earth Observations (CEO):**
  CEO takes advantage of the crew in space to observe and photograph natural and man-made changes on Earth, the photographs record Earth surface changes over time, as well as more fleeting events such as storms, floods, fires, and volcanic eruptions. Together they provide researchers on Earth with vital, continuous images needed to better understand the planet.

Summary

As stated at the beginning of my testimony, using the Station to study human endurance in space and to test new technologies will allow us to prepare for the longer journeys to the Moon, Mars and beyond in support of the Vision for Space Exploration. Thank you for the opportunity to testify today. My fellow witnesses and I look forward to responding to any questions you may have.

BIOGRAPHY FOR PEGGY A. WHITSON
NASA ASTRONAUT

PERSONAL DATA:

Born February 9, 1960 in Mt. Ayr, Iowa. Hometown is Beaconsfield, Iowa. Married to Clarence F. Sams, Ph.D. She enjoys weight lifting, biking, basketball, and water skiing.

EDUCATION:

Graduated from Mt. Ayr Community High School, Mt. Ayr, Iowa, in 1978; received a Bachelor of Science degree in Biology/Chemistry from Iowa Wesleyan College in 1981, and a Doctorate in Biochemistry from Rice University in 1985.

AWARDS/HONORS:

NASA Space Flight Medal (2002). Two patents approved (1997, 1998); Group Achievement Award for Shuttle–Mir Program (1996); American Astronautical Society Randolph Lovelace II Award (1995); NASA Tech Brief Award (1995); NASA Space Act Board Award (1995, 1998); NASA Silver Snoopy Award (1995); NASA Exceptional Service Medal (1995, 2003); NASA Space Act Award for Patent Application; NASA Certificate of Commendation (1994); Selected for Space Station Redesign Team (March–June 1993); NASA Sustained Superior Performance Award (1990); Krug International Merit Award (1989); NASA–JSC National Research Council Resident Research Associate (1986–1988); Robert A. Welch Postdoctoral Fellowship (1985–1986); Robert A. Welch Predoctoral Fellowship (1982–1985), *Summa Cum Laude* from Iowa Wesleyan College (1981); President's Honor Roll (1978–81); Orange van Calhoun Scholarship (1980); State of Iowa Scholar (1979); Academic Excellence Award (1978).

EXPERIENCE:

From 1981 to 1985, Whitson conducted her graduate work in biochemistry at Rice University, Houston, Texas, as a Robert A. Welch Predoctoral Fellow. Following completion of her graduate, work she continued at Rice University as a Robert A Welch Postdoctoral Fellow until October 1986. Following this position, she began her studies at NASA Johnson Space Center, Houston, Texas, as a National Research Council Resident Research Associate. From April 1988 until September 1989, Whitson served as the Supervisor for the Biochemistry Research Group at KRUG International, a medical sciences contractor at NASA–JSC. In 1991–1997, Whitson was also invited to be an Adjunct Assistant Professor in the Department of Internal Medicine and Department of Human Biological Chemistry and Genetics at University of Texas Medical Branch, Galveston, Texas. In 1997, Whitson began a position as Adjunct Assistant Professor at Rice University in the Maybee Laboratory for Biochemical and Genetic Engineering.

NASA EXPERIENCE:

From 1989 to 1993, Whitson worked as a Research Biochemist in the Biomedical Operations and Research Branch at NASA–JSC. From 1991–1993, she served as Technical Monitor of the Biochemistry Research Laboratories in the Biomedical Operations and Research Branch. From 1991–1992 she was the Payload Element Developer for Bone Cell Research Experiment (E10) aboard SL–J (STS–47), and was a member of the U.S.–USSR Joint Working Group in Space Medicine and Biology. In 1992, she was named the Project Scientist of the Shuttle–Mir Program (STS–60, STS–63, STS–71, Mir 18, Mir 19) and served in this capacity until the conclusion of the Phase 1A Program in 1995. From 1993–1996 Whitson held the additional responsibilities of the Deputy Division Chief of the Medical Sciences Division at NASA–JSC. From 1995–1996 she served as Co-Chair of the U.S.-Russian Mission Science Working Group. In April 1996, she was selected as an astronaut candidate and started training, in August 1996. Upon completing two years of training and evaluation, she was assigned technical duties in the Astronaut Office Operations Planning Branch and served as the lead for the Crew Test Support Team in Russia from 1998–99. From November 2003 to March 2005 she served as Deputy Chief of the Astronaut Office. Dr. Whitson currently serves as Chief of the Station Operations Branch, Astronaut Office.

SPACE FLIGHT EXPERIENCE:

The Expedition 5 crew launched on June 5, 2002 aboard STS–111 and docked with the International Space Station on June 7, 2002. During her six-month stay aboard the Space Station, Dr. Whitson installed the Mobile Base System, the S1 truss segment, and the P1 truss segment using the space station remote manipulator system, performed a four-hour and 25-minute Orlan EVA to install micrometeoroid shielding on the Zvezda Service Module, and activated and checked out the Microgravity Sciences Glovebox, a facility class payload rack. She was named the first NASA Science Officer during her stay, and she conducted 21 investigations in human life sciences and microgravity sciences, as well as commercial payloads. The Expedition 5 crew (one American Astronaut and two Russian Cosmonauts) returned to Earth aboard STS–113 on December 7, 2002. Completing her first flight, Dr. Whitson logged 184 days, 22 hours and 14 minutes in space.

DISCUSSION

LESSONS LEARNED FOR LONG-DURATION SPACE FLIGHT

Chairman CALVERT. Thank you. Thank you for giving us that unique perspective on life on the International Space Station.

I am going to lead off with the questions since I believe we have about 15 minutes before we link up with the Space Station.

So Dr. Whitson and Lieutenant Colonel Fincke, I think I will ask the first question.

What kinds of lessons would you draw from your time on the Space Station that you think could be applied to our next steps beyond Earth orbit or return to the Moon and then going to Mars?

And that question is for both of you.

Dr. WHITSON. Yeah. I will start by saying that during my mission, we hosted three different Shuttle flights, and they were all very robotically-intensive missions with the installation of hardware elements on board the International Space Station, large pieces of tress that filled the payload bay of the Shuttle, and so it was really exciting to be a part of that process of using the Station robotic arm, in one case of actually handing off one piece of hardware from one robotic arm to the other robotic arm for installation. So that robotics capability is going to be something that is important to us even in our manned exploration to the Moon and Mars.

Chairman CALVERT. Turn on your mike.

Lieutenant Colonel FINCKE. There you go. Sorry about that. I can fly a spacecraft, but I have got to learn how to do one of these.

On our mission, it was Expedition 9. It was the third mission of only two people on board. Complete resupply from Russian cargo ships. And we launched and landed on a Russian Soyuz, so it was a bit different than Peggy's mission. And we learned a few neat things that are going to really help us go to Mars and back to the Moon.

We are—we had problems with our oxygen generator, and we learned how to work and fix things that we had not trained for on the ground. We—Peggy was mentioning this medicine concept with the ultrasound machine. Well, we were using tele-engineering to be able to fix things that were broken. And that is an important lesson when we go to the Moon and Mars. We won't be able to know how to fix everything all by ourselves, but we have a strong team back on our home planet that can help us.

And also, we learned how to fix our own space suits. That was the first time we opened up an American space suit and changed out parts. And that is the kind of thing we need to know when we go to the Moon is how to fix our own space suits. So we became more self-sufficient, but also more dependent on the ground to count on them for—to help us to be able to do the things that we could do while we were up in space.

Chairman CALVERT. Thank you.
Mr. Udall.

SAFE HAVEN

Mr. UDALL. As a follow-on to Chairman Calvert's question, we talked a lot about the aftermath of *Columbia* and the Accident Investigation Board. We talked about a safe haven at the Station. Could you—both of you talked a little bit about what it would be like if the Station served as a safe haven for the Shuttle. What would be the challenges you would face, say if the Shuttle crew were there for one to two months, hopefully no longer than that?

Dr. WHITSON. Actually, before we launch STS–114, the next Shuttle to launch, we will understand how much capability in terms of crew resupplies, oxygen, carbon dioxide removal, and food that we will have on orbit. And we will have a plan in place on how long we could withstand keeping that crew up there before we could send a rescue mission. And there will actually be another Shuttle on the pad ready to go within that time frame of when we can support a crew on board the Station. So it is not ideal, obviously, but obviously we are not going to invoke the—that scenario unless it is a serious situation.

RESOURCE CONSUMPTION

Mr. UDALL. Doctor, Lieutenant Colonel may respond as well, what is the number—the resource that runs out first, is it oxygen? Is it——

Dr. WHITSON. Well, actually it is oxygen, but we make the assumption that the electron, our oxygen-generating system is not working. So it is a—kind of almost a worst case. We have taken one failure already and said the electron was not working, and so we are starting from that point.

Mr. UDALL. If it is working, is there an unlimited amount of oxygen available?

Dr. WHITSON. Then water becomes——

Mr. UDALL. Okay.

Dr. WHITSON.—inconsumable. We use water to break apart to make the oxygen. So water then becomes a limiting consumable, but——

Mr. UDALL. That's your feed stock, the water is.

Dr. WHITSON. Yeah. Yeah.

Mr. UDALL. Okay. Interesting. Oxygen is in the water. Everything stems from water, doesn't it?

Dr. WHITSON. Yeah.

Mr. UDALL. Did you want to say anything else, Lieutenant Colonel Fincke?

Lieutenant Colonel FINCKE. Certainly. I would like to add that the Space Station right now is really designed, and has enough capability, for three people. To increase by—and we have two on board. By increasing to six people, we are going to have to have all of our systems running at full bore, all of our oxygen-generation systems and the carbon dioxide-removal system and things like that. And the engineers on the ground have really looked hard into this and made some assumptions of—towards the worst case, and we can definitely support—the Space Station can support for short periods of time, enough time to get another Space Shuttle up there, and that is good news for our friends in the astronaut corps.

Mr. UDALL. Even with the converter—the oxygen converter down, two months is within the time frame?

Dr. WHITSON. Actually, I think the latest estimate they were supposed to report that in the last couple of days, and I am sorry I don't know that number, but it is on the order of 30 days.

Mr. UDALL. Okay. What about space? I don't hear you talking about any problems with space in the Shuttle itself.

Dr. WHITSON. Well——

Mr. UDALL. More crowded?

Dr. WHITSON.—the Shuttle is actually very crowded normally, but the Space Station will be much more crowded than it would be normally, but——

Mr. UDALL. Yeah.

Dr. WHITSON.—it is six different modules on orbit, each of various size, but there is plenty of room for the seven Shuttle crew members and an additional two Station crew members, if we needed to do that. And obviously this is a worst case scenario. This is not a scenario that we would plan to do except for a scenario that required it to save the lives of our crew members.

Mr. UDALL. Thank you, Mr. Chairman. I want to give other Members an opportunity, so thank you.

Chairman CALVERT. I thank the gentleman.

Mr. Bonner.

EFFECTS OF LONG-DURATION SPACE FLIGHT

Mr. BONNER. Thank you, Mr. Chairman.

I hope that the people who are in this hearing room, especially those who might be viewing it today on C–SPAN, realize how historic this is that we have got the first witness before our committee in Congress that is not here, but is in outer space.

Dr. Whitson, you were, as I recall from reading your biography, in space for 184 days. That is a long time to be away from home. And so much is made of these missions about the effects on our body, the physical effect. What were the psychological issues that you dealt with in space and then when you returned home that you dealt with in returning home? And talk to us a little bit, please, about the psychological aspects of space travel.

Dr. WHITSON. Well, I may be a little bit unique in that I loved every minute on board the Space Station. It was a phenomenal experience to me being there I think probably because I had wanted to do it since I had walked—watched the astronauts walk on the Moon. I have always wanted to be an astronaut. When I graduated from high school, it was the first year they selected female astronauts, and that is when I decided I wanted to be an astronaut. Luckily for me, I didn't know how hard it would be to get in, but I got lucky and I made it. The psychological part of being in space is actually probably less traumatic than the months and the years actually leading up to it in the training process. We do about half of our training in Russia, so we are away from our families a month or two at a time back and forth. And so I think psychologically that is kind of the building block for families to build those relationships to be able to withstand going to space for six-month periods of time. I tell my Expedition crew members in training, "This is the test. If you can make this work then being on board the Station is so much easier, because once you get there, you have such an interesting job, the best one off of this planet." So we—I really enjoyed that experience. I think probably the only long-lasting psychological impact that I have after returning to Earth is that I really, really want to go back.

Mr. BONNER. Lieutenant Colonel.

Lieutenant Colonel FINCKE. I think Peggy is not unique in that she enjoyed her 184 days. I enjoyed my 187 days I hope as much as she did. It was an amazing experience on an amazing Space Station. There were only two of us on our mission and so there was less company, but we got along great. My commander from Russia and I, we got along. He spoke to me every day in English, and I spoke to him in Russian. We saw each other eye to eye, and looking outside at the beautiful planet below, we never really got grumpy, because any time we felt anything sad or bad, we just looked outside. But we also had a space telephone, and we could call down and keep in touch with our families. And while I was on board the Space Station, my wife had our second child, our daughter, who was born while I was up there, and this is not unique to service families that are all over serving our country across the world, but this was unique in that is the first time it happened to an astronaut in space. But I was able to talk to my wife up to the point where labor was happening and keep in touch for those, you know, days afterwards when we were happy as a couple to be able to, you know, welcome our daughter into the world. And so a lot goes to our families for supporting us while we are in training in Russia and training—and flying in space. But the psychological aspects, it felt like we weren't that far away from home.

Mr. BONNER. If I may ask just a quick follow-up to both of you. When most Americans travel away from home for 10 days or two weeks and they get back home, the first thing they want to do is have X or Y. What was it for you? Was it a Big Mac? Diet Coke?

Dr. WHITSON. For me, I wanted a steak and a salad.

Lieutenant Colonel FINCKE. And I was looking forward to my mother-in-law's cooking. She came all of the way out to Russia to cook me a nice Indian meal.

Mr. BONNER. That is a very good, politically correct answer, Lieutenant Colonel.

Thank you, Mr. Chairman.

Chairman CALVERT. Thank you.

Mr. Bartlett.

NASA's Role in Inspiring Youth

Mr. BARTLETT. I can remember very well when the Soviet Union launched their first Sputnik. I can remember the excitement, October sky, watching that sky for the satellite to go over. I remember when President Kennedy challenged the Nation to put a man on the Moon within a decade. That was a big, big challenge, and we did it in something less than a decade. I remember trying to stay up at night to watch the video of the Moon landing. And somehow, since the excitement of those days, space flight has become kind of ho-hum, and it is because, I think, NASA has been so successful that the American public has been led to believe that this is a pretty routine, unexciting thing. And there are two deficits that have occurred because of that.

One is we aren't able to get the kind of funding that we need for NASA and our space programs, particularly our manned programs, because they don't have the excitement that they once had for the American people.

The other deficiency is that we desperately need something in our country that captures the imagination of our people and inspires our young people to go into careers of science, math, and engineering. Putting a man on the Moon really did that. I remember a cartoon I saw, a little freckle-faced, bucktoothed kid. He said, "Six months ago, I couldn't even spell engineer and now I are one." You know, everybody wanted to be a part of that program.

It really is very hazardous duty. We have only—there is a one chance in 50 you are—roughly one chance in 50 you are not going to make it, if the past is going to predict the future in terms of our space flights. Is that not correct, two out of 100 and some missions? Is that right? And so what have we done, or what should we have done differently so that it didn't lose its luster, so that this was still exciting, so that people were still riveted to their television sets, so that our kids still wanted to be a scientist, mathematician, or engineer, or an astronaut? And you know, we are paying for that as a nation now because we have far too few of our kids going into those disciplines. How did we fail, and what do we need to do now so that we can recoup?

Dr. WHITSON. Well, that is a pretty big question, and I wish I had the answer in my back pocket on that one.

I am not sure how we failed. I do think it is just as critically important now as it was in the 1960s. I mean, I was inspired. But every time I go out to talk to young school children, you know, I feel it is my job to at least convince one of those young people that they can do something that they didn't think they could before I came.

Lieutenant Colonel FINCKE. One of NASA's three main mission statements is to inspire the next generation of explorers, as only NASA can. And I would certainly hate to be a witness and disagree with you, sir, but every school that I have gone to, and since I have come back from space I have talked to over 16,000 school kids across our country, and I haven't found anybody that was not interested in space and not interested in what we did aboard the Space Station and who didn't laugh when the Commander's hair stuck up and watching us play with our food and all of the joy and wonder and imagination to go fly in space. And I think that imagination is still among our youth, and it is just up to us to just close the loop and let them know that, you know, America is the land of opportunity and you, too, can be an astronaut or an engineer or a mommy or a daddy or whatever it is that you want to be when you grow up, because this is the place where dreams come true. And I think NASA is doing that.

Mr. BARTLETT. But it would be nice if we could translate that excitement that you generate in the classroom to more of our kids going into science, math, and engineering, because it is not happening, and that is our challenge. You go to our schools, like technical schools, and more than half of the students there are foreign nationals. And our country—our companies now are wanting more immigrants to come in because they can't find enough scientists, mathematicians, and engineers in this country.

So you know, thank you for inspiring our school children. I hope that it is reflected with an increased number of our young people going into these careers.

For the short-term, it threatens our economic superiority. For the long-term, it threatens our military superiority. We have got to have adequate numbers of bright young people going into science, math, and engineering. And you all are voices that are helping us do that. Thank you very much for the contribution that you are making.

LANGUAGE BARRIERS

Chairman CALVERT. I see we have been joined by our friend from Louisiana. If you would like to ask a question before we tune into our friend in outer space—well, I am just going to—we still have a few minutes, so I am going to ask a question.

I was listening to Colonel Fincke when we were talking about use of language. Is that much of a barrier? Is that a significant issue when you are up there in outer space? Do you understand each other pretty well or—I guess my question is, is everybody taking—at NASA, is everybody learning Russian and everybody in the Russian astronaut corps learning English?

Lieutenant Colonel FINCKE. Well, Mr. Chairman, like in any organization, communication is fundamental to mission success.

Chairman CALVERT. You have a point. I have a hard time understanding some of the members I serve with here, so——

Lieutenant Colonel FINCKE. And really, that is—so whatever language it takes, we have learned to communicate with each other on board. And we have learned to communicate with the long partnership with Russia to communicate with each other. And sometimes, like any other organization, the communication isn't perfect, but I think, for the most part, we really understand each other. And that is really fundamentally why things aboard the Space Station are a success is because we have good, solid working relationships. We know each other's strengths and weaknesses, and we have built off of that and have worked together as a team. Now it is not a perfect team. Sometimes there is a little bit of grumbling and the press loves to talk about that, but if you look at it right now, and you are going to see, you know. Dr. Phillips is up there with Sergei Krikalev working together in space, and that is a really nice symbol for all of us to see people working together.

Chairman CALVERT. Any add-on to that, Doctor?

Dr. WHITSON. Well, I would just like to say that in addition to the interpersonal requirements of doing something like building the International Space Station, there is also an incredible engineering level of interaction that is required. I think it is somewhat miraculous that we have done such an incredible job building the Space Station. As was mentioned a little bit earlier, sometimes we maybe make it look a little too easy. It really is quite miraculous that we have gotten all of these pieces together.

Space Suits

Chairman CALVERT. Quite an engineering feat. I always—people ask me why do you have two different space suits when you are up there? Is that make—does everything match up when you have the cosmonaut in one space suit and the Americans, of course, in our own space suit?

Dr. WHITSON. For any given EVA, we use the same space suit, but there are some tasks that we do on the U.S. side that we use the U.S. space suit for and some on the Russian side. Mike has a unique perspective on that from his real life experience.

Lieutenant Colonel FINCKE. By having two sets of things, the redundancy it makes our engineering plan—to give us success. In other words, we were getting ready to go outside in American space suits, and we were going through a dress rehearsal, and it turns out that his American space suit was broken. We ended up fixing it by the end of the mission, but because we had a spare set of space suits built by the Russians, they didn't have the same problem, and we were able to go up just a week or two later in the Russian space suits and accomplish the task. And that just goes to show having strength of a partnership and having the redundancy aboard the Space Station is teaching us those lessons that we need to so when we go back to the Moon and Mars we are taking note of all of this.

Chairman CALVERT. Great. Well, I understand that we are getting down to about the—at about one minute. So I will ask Mr. Udall if you want to ask anything in the minute we have remaining?

Radiation

Mr. UDALL. Talk a little bit, if you will, about the radiation concerns on the Station and what you do about it, and if we have any more time, what we project out on the Moon or on Mars when it comes to radiation exposure.

Dr. WHITSON. On board the Space Station itself, we actually have radiation monitoring hardware with alarm systems that will tell the crew if it is getting into a hazardous level. But before that ever happens, the ground typically will warn the crew that we anticipate that the radiation levels will go higher at a certain point in time and recommend that they would go——

Chairman CALVERT. If I may interrupt, I think we are ready to go.

Doctor, I think you need to connect with the Station.

Dr. WHITSON. Station, this is Peggy with the Subcommittee on Space and Aeronautics. How do you read?

[No response.]

Dr. WHITSON. John, this is Peggy with the Subcommittee, how do you read?

[No response.]

Dr. WHITSON. John? John, this is Peggy, how do you read?

[No response.]

Dr. WHITSON. There you are talking to him on the other channel.

Dr. PHILLIPS. Very good.

Dr. WHITSON. We have you loud and clear. How do you read us, John?

Dr. PHILLIPS. I hear you, Peg.

Dr. WHITSON. Okay. Great. I am going to hand you over to Chairman——

Dr. PHILLIPS. Loud and clear.

Dr. WHITSON. Excellent. We are going to hand you over to Chairman Calvert now.

LESSONS LEARNED FOR LONG-DURATION SPACE FLIGHT (CONT.)

Chairman CALVERT. And now we go live from space, International Space Station, with Dr. John Phillips.

Doctor, I asked the same question to your two colleagues. I want to ask you the same question that I asked them. What kinds of lessons would you draw from your time on the Space Station that you think could be applied to our next steps beyond Earth orbit and for our return to the Moon and then going on to Mars?

Dr. PHILLIPS. Yes, sir. First, welcome aboard the International Space Station. It is my pleasure to welcome aboard the ladies and gentlemen of the House Subcommittee on Space and Aeronautics. Since I am a former Navy guy, I feel an obligation to welcome you aboard.

I appreciate the opportunity to talk.

Well, I have been here about two months now, and I have learned lessons, and we have learned lessons every day. And I would like to emphasize that up here on the International Space Station, we are the experiment, not only we, the crew, but the vehicle, the equipment on it, our operations concept, our mission control operations, and even our international partnership. And I—what I have learned, I believe, is that we need to build equipment with as much attention to the low maintenance, as much attention to reliability as possible, and we need to keep doing what we are doing with our multiple layers of redundancy. We take safety very seriously, and we build things with an eye to a redundancy, multiple pipelines, multiple equipment that does the same thing. And if one thing fails, we have got another to back it up. And I think we have used that approach to very good success on the Space Station, and I want to see us keep doing it in the future in our next missions as well.

Chairman CALVERT. I thank the gentleman for his answer, and I will move on to our—to Mr. Udall who leads the Minority, from Colorado.

Mr. UDALL. Dr. Phillips, this is Mark Udall. I represent a portion of Colorado, including half the ski areas. I am sure you can see all of the snow in Colorado that we have had over the winter, which means great water supplies for my friend from California and others in the southwest.

Chairman CALVERT. Thank you.

ISS AND THE VIEW OF EARTH

Mr. UDALL. Wax philosophical and talk a little bit about what the view is like both looking into space as well as back at the Earth.

Dr. PHILLIPS. Well, as luck would have it, we traveled over Colorado a couple of hours ago, and I shot some pictures starting from the Sawtooth Mountains in Idaho and then down through Wyoming and across the front range in Colorado, and it was very beautiful, and I can see here that you had a good snow year.

The view is incredible from up here. And by the way, right now, we are moving southeast, more or less parallel to the coast of California in the north Pacific. We will be heading down along the Baja. The view is incredible. We get the white snow and the blue oceans and the tan deserts and the green forests, and what it brings home to me is that we are a pretty small planet, we are all one people, and we need to conserve the resources we have, and make sure we work together to make this place a livable for many generations to come.

Chairman CALVERT. I thank the gentleman.

Mr. Bonner, you are recognized for two minutes.

Mr. BONNER. Dr. Phillips, my name is Joe Bonner, and I am from Mobile, Alabama, and my home state is very proud of its role in manned space flights.

The Chairman has only given us two minutes to ask our question, and normally those of us from the South, it takes two minutes just to get our name out, so my question to you is very brief. After all of your training and preparation and now that you are there, what was your biggest surprise being on board the Space Station and living in outer space?

Dr. PHILLIPS. Well, I think my biggest surprise up here, and I have been here, by the way, once before on a shorter Shuttle flight, my biggest surprise I think was how much work goes into the preparation for visiting vehicles. For example, just 15 minutes ago, Commander Russian cosmonaut Sergei Krikalev, closed the hatch on a Russian supply ship, about to say goodbye to that ship, and then we are going to get another one in a couple days. And it takes a lot of work to pack that Progress vehicle with the stuff we don't need anymore and to unpack, and then as soon as we get the new one aboard in just a few days, then we are going to start in earnest preparing to support the launch of the Shuttle Discovery and its mission to dock here on Station. And that is just a whole lot of work, and for a couple weeks, it really dominates our activities up here.

Chairman CALVERT. I thank the gentleman.

The gentleman from Louisiana, Mr. Melancon.

Mr. MELANCON. My only question, and this is Congressman Charlie Melancon from Louisiana, is are your feet strapped down so you are not floating?

Dr. PHILLIPS. Yes, sir. They are not—well, they are not strapped down. Right now, I am not wearing any shoes. We only wear shoes, pretty much, for exercise, but I have got my stocking clad feet tucked under a railing on the floor, because if I didn't do that, I would just kind of float around like this.

Mr. MELANCON. That is what I was talking about.
Thank you.
Chairman CALVERT. I thank the gentleman.
The gentleman from Maryland, Mr. Bartlett.

ISS ORBIT

Mr. BARTLETT. Hi, this is Roscoe Bartlett from Maryland.
Could you tell us what type of an orbit you are in, the altitude and the parts of the world that you see from your orbit?
Dr. PHILLIPS. Sir, we are in nearly a circular orbit at a speed of about eight kilometers per second at an altitude of 350 kilometers right now. That is near the lower range of our orbit. Sometimes it is a bit higher. It takes us about 90 minutes to go around the Earth. And we are in an orbital inclination of 51.6 degrees, which is dictated by the fact that basically half of the Station plus our Russian Soyuz vehicle and supply vehicles are launched from base in central Asia that, for various orbital reasons, needs to launch to that inclination. And what that means is we see all of the Earth, the low latitudes of maybe a little bit higher than our inclination, maybe about 55 or 57 degrees. We can see that far north and that far south. And actually my crewmate, Sergei Krikalev, is taking pictures of his hometown of St. Petersburg, which is nearly at 60 degrees.
Chairman CALVERT. I thank the gentleman.
Mr. Costa from California.

ISS COMPLETION

Mr. COSTA. Thank you very much, Mr. Chairman.
Congressman Jim Costa from California from Fresno.
Dr. Phillips, obviously we are pleased that you could be here today for this presentation. You know, oftentimes the question is asked for what purpose is the Space Station. When we look at our nation's budget priorities and we look at our nation's priorities with regard to our space program, both the manned and the unmanned space program, today, as you sit there from your vantagepoint, what percentage of the Space Station is completed? And when it is completed in its entirety, what do you believe the capabilities of the Space Station will be as we try to answer the question toward these priorities?
Dr. PHILLIPS. Well, thanks for your question, sir, and by the way, I used to, I believe, live in your District down in the Navy base of Lemoore, California.
Mr. COSTA. It is a great Navy station.
Dr. PHILLIPS. I have fond memories of that place.
Mr. COSTA. I hope you are still registered to vote there.
Dr. PHILLIPS. And I would guess that the Station is maybe a little over half completed. I am just making up—we have got some more large pressurized modules to build. There is a laboratory from Europe and a laboratory from Japan. And excuse me, I just said the wrong thing. They are already built, but we have some more pressurized modules to launch. And then we have got a lot of other big pieces waiting at Kennedy Space Center right now for the resumption of Shuttle flight.

Eventually, we expect to have a crew of six up here, and right now, with Sergei and I with a crew of two, much of our work—although we are doing scientific experimentation as well. When there are six people on board, there will be a lot more scientific experimentation, experimentation designed to advance our knowledge in combustion, and material science, in biology, and I believe most importantly, just to advance our knowledge in how to push further into space.

I would like to mention that the International Space Station is maintaining our presence in space and maintaining our national credibility as a worthy partner in an international technical project. We constantly learn new lessons up here about hardware, software. The experiences we gather up here that will enable us to establish a long-term station on the Moon and to go on to Mars.

Mr. COSTA. Thank you very much, Mr. Chairman.

Chairman CALVERT. Thank you.

Mr. Rohrabacher.

ISS RESEARCH ACCOMPLISHMENTS

Mr. ROHRABACHER. Hello. I am Congressman Dana Rohrabacher from California, Huntington Beach, California. And greetings.

Okay. I will proceed.

We have learned a lot about human habitation of space by what we have done at the Space Station and by you and others who have spent time there. You are right there right now. Could you tell us if you believe that there is any further commercial potential for Space Station? And number two, you mentioned the research potential a few moments ago. Could you go into some specific detail about what type of accomplishments—research accomplishments we could expect if we continue supporting the Station?

Dr. PHILLIPS. Well, sir, as I mentioned, right now our experimental time is somewhat limited, but I am going to give you an example of an experiment we are working with. It is called advanced diagnostic ultrasound in microgravity. Now this experiment uses medical ultrasound and high data—plus a team of specialists on the ground to enable non-specialists like me to provide state-of-the-art diagnostic imaging of heart, lungs, abdomen, and arteries. This has great potential for use in remote areas in places where you don't have diagnostic specialists and for military uses on battlefield diagnostics, for example. That is an example of one kind of experiment we are going to do—we are doing up here now. When we have three full operational laboratories, the Japanese, European, and American laboratory up here with teams of scientists working in those labs pretty much full time, I believe we will have the potential for advancements in pharmaceuticals, for example, and we have pharmaceutical research going on right now, and also material science. I think those are the two biggest areas. It is hard for me to put—to predict the kind of results of these things, but I want to emphasize once more that from my perspective, the most important thing up here is that we are the experiment. We are learning how to fly in space.

Mr. ROHRABACHER. Thank you very much.

Chairman CALVERT. Thank you very much.

Mr. Miller, I think we are going to break up, but try to get as much in as you can.

THE IMPACT ON ISS FROM THE SHUTTLE GROUNDING

Mr. MILLER. Yes, this is Brad Miller from North Carolina.

What has been the impact on your mission of the grounding of the Shuttle fleet? Has that affected your procedures in any way?

Dr. PHILLIPS. I would describe the gravity of the Shuttle fleet in sort—first and foremost, the assembly, as I have mentioned, there are tresses, solar rays, and new pressurized modules as well as a lot of laboratory equipment and spare parts waiting at Kennedy Space Center in Florida to be launched. Two of the modules scheduled for launch in the next couple of years are laboratories that belong to Japan and Europe.

The second impact, the use of ISS has been limited to two persons since the *Columbia* accident with the limitations on delivery of consumables, such as oxygen, water, and food.

Third, although our Russian partners have done an admirable job in keeping the Station supplied, without the Shuttle, we have been operating on somewhat—there are certain spare parts that can only be delivered by the Shuttle, plus only the Shuttle has the capability of carrying large cargo back to Earth. So we are really looking forward to seeing the Discovery about a month from now.

Chairman CALVERT. I thank the gentleman.

Mr. Green.

RUSSIAN COOPERATION

Mr. GREEN. Thank you, Mr. Chairman.

Dr. Phillips, I had the good fortune about two weeks ago to be in Russia and to meet with the Deputy Head of the space agency. One of the things that we talked about was the great spirit of cooperation that has been engendered as a result of this noble mission that you find yourself a part of. Could you kindly make some comments about the spirit of cooperation that has manifested itself as you go about your business there in the outer part of our world?

Dr. PHILLIPS. Speaking from the standpoint of an astronaut, not a manager, not a negotiator, I would say that cooperation is wonderful. I have got my crewmate, Sergei Krikalev, 10 feet away from me right now. We work together and live together. We did about 50 percent of our training in the United States and 50 percent in Russia, and it is almost a situation without boundaries. We go from one to the other, trained equally well. And we—just this morning, we have both been talking to our mission control center in Houston, our mission—our American payload center in Huntsville, Alabama, and our mission control center in Moscow. So I think, from an operational standpoint, our two countries have really merged their programs very, very well. And I can't really speak to the diplomatic and financial negotiation end of it, because that is way above my pay grade.

Chairman CALVERT. I thank the gentleman.

Ms. Jackson Lee, any last questions?

SAFETY

Ms. JACKSON LEE. Thank you.

Congresswoman Jackson Lee from Houston, Texas. Johnson Space Center is in our neighborhood.

Thank you for your service.

My question is how comfortable are you with the safety record of the International Space Station and are you seeing improvement in the safety review and, of course, the quality of safety on the Station?

Thank you.

Dr. PHILLIPS. I have always been confident about the quality of safety up here. We take safety very seriously. We safeguard our health through an exercise program involving bikes, treadmills, resistive devices. We have multiple levels of redundancy. I think one of the lessons that was brought home from the *Columbia* accident is that we have got to stamp out complacency wherever we find it. We have got to remember that this is a risky business, not like getting on an airliner. We strap ourselves on rockets, and it still has some risks. I think our safety record on the Station has been good since the onset, and I think it is continuing to improve.

Chairman CALVERT. I want to thank you, Doctor, for your hospitality and allowing us to visit with you up there in outer space and for answering our questions. We have about 10 seconds left, so I wanted to say goodbye, and would love it if you said goodbye to us, too. Be safe.

Dr. PHILLIPS. I thank you very much, sir. And it has been a pleasure talking to the ladies and gentleman of the Committee, from the testing module in the American laboratory aboard the International Space Station, I hope you have a wonderful day down there in Washington. The weather is great up here.

Chairman CALVERT. It is probably clearer there than it is here. Thank you. God bless, and I guess we are out.

Dr. PHILLIPS. Thank you very much, sir. International Space Station out.

JOHNSON SPACE CENTER. Station, this is Houston ACR. That concludes the event.

Chairman CALVERT. Well, that was exciting.

Mr. Udall, you are recognized for a question.

RESEARCH ABOARD THE ISS

Mr. UDALL. Would you talk a little bit more about the research possibilities as well as, perhaps, some of the experiments you conducted and some of the lessons that you have learned, Dr. Whitson, Lieutenant Colonel?

Dr. WHITSON. Sure, I think John introduced it very well. Sometimes it is very hard for us to predict what the outcome is and what will be the best research to do on board the Station. That is true of research here on the ground as well. Sometimes the most interesting questions are, "I wonder why that happened." But I think, you know, there is a lot of potential. I had the opportunity to work on zeolite crystal formations. Zeolites are used in petroleum processing and in pollution control, and we actually used them on board the Space Station as part of our carbon dioxide removal system. I had the opportunity to melt superconductor crystals under different conditions to try and optimize crystal growth and get the biggest superconductor crystals possible. And John talked about the—ultrasound is another one that obviously also has direct ground applications as well.

Anything to add, Michael?

Lieutenant Colonel FINCKE. One thing there was a big difference between Dr. Whitson's mission and the one I was on was they—we didn't have as much cargo mass up and cargo mass down, so even though we could have done some really very interesting experiments, we couldn't bring down all of the results. So we have learned, during the two-person crew post-*Columbia* missions of how to send down video at higher qualities. We have learned how to do—make due with the experimental materials we have on board and to do research that way and to also get the high-quality results down without actually having to send down the pieces, the experimental samples themselves. However, when the Space Shuttle starts flying again, and it is going to fly again soon, it is going to represent a big boom in the capabilities of science, because we will be able to take up a whole bunch of experiments that have been waiting and bring down the experimental results that are on board right now.

RADIATION

Mr. UDALL. If I could, I would like to go back to the radiation question that we—but I do want to just mention that I thought Dr. Phillips and you—both of you have been very compelling in pointing out that the whole enterprise is an experiment. Sometimes we are looking for these specific outcomes, but just the fact that we are there and have been there for as long as we have been there is a case and a story we ought to continue to tell. It is pretty remarkable what we have succeeded in doing.

The—I have read concerns expressed on the radiation question that it is still undetermined to what extent we can live on a place like the Moon or Mars given the potential radiation exposures. You were talking a little bit about the Station and what you do. You have suits that you put on and so on when there would be radiation episodes. But would you just talk in the two minutes we have remaining about the radiation and your concerns?

Dr. WHITSON. Sure. As I mentioned, we have procedures on board to minimize the effects of the crew, but the magnetosphere of the Earth actually provides a lot of radiation protection to us, so even understanding this, we have to take it another level up to understand the risks that we are going to be taking on the Moon and on Mars. And radiation shielding is going to be one of the important factors in whatever vehicles we develop, whatever modules we have, you know. We may have to—we may choose to do safe havens, you know, within a small compartment area, because that might be logistically easier to accomplish. So—but we do have to do some sort of radiation protection in our future missions. It is going to be critical, because it is a much higher radiation level outside the Earth's magnetosphere. And even in 250 miles, we are still protected, even though it is much higher than it is here in Washington, DC.

Mr. UDALL. There might be some people saying there is a lot of radiation in this town, but Lieutenant Colonel.

Lieutenant Colonel FINCKE. Once we get on to a planetary surface, and that is the trick, we can actually use some of the resources there. We can—I don't want to say live underground on the Moon, but we can use some of the lunar regolith, the soil that is there, and use it to help protect us. And some of the tricks that we are going to learn on the Moon are going to be applicable to Mars, because Mars doesn't have a magnetosphere to protect it like we do here on planet Earth. So there are a lot of tricks and a lot of neat things that we don't even completely understand now, but we are going to understand as we take this voyage together.

Mr. UDALL. The experiment would continue on the Moon?

Dr. WHITSON. Exactly.

Mr. UDALL. Thank you very much. Again, I am in awe of your service and your commitment to pushing the envelope, looking out over the horizon. Thank you.

Chairman CALVERT. I thank the gentleman.

Mr. Bonner.

BENEFITS OF HUMAN SPACE FLIGHT

Mr. BONNER. Mr. Chairman, thank you.

I would like to follow-up with the question that Congressman Bartlett asked both of you but phrase it a little bit differently.

Clearly, I grew up watching Apollo as well. It was a community-wide event. We would all go to the house that had the color TV, if we were fortunate enough to have one in our town, to sit and watch, as a community and as a nation and as a world, in awe of what was happening. And perhaps because you all were so successful and your predecessors were so successful, we did begin to take things for granted until tragedy came our way.

I guess my question to you is, there are a lot of media here, this is being broadcast on C–SPAN. You have got four minutes and 16 seconds to give a PSA on the advances in arthritis, the advances in aging, advances in kidney stone that NASA has played a role in helping our physicians, our scientists, our engineers here on Earth make big progress up in space.

Dr. WHITSON. Well, it is always kind of awesome to try and think about all of the different things that we have actually had input into in terms of sensor technologies that applied in medical scenarios. But one of the more interesting stories I always like to tell is the one about the development of the artificial assisted heart pump, because that developed because they needed a mechanism to reduce the bubbling flow in the artificial hearts. And they used similar technologies that we used in the engines on the Shuttle. And so it is actually a very indirect application of some engineering thing that we learned to go to space that was applied to people's—saving people's lives and giving them an artificial heart until they could get a transplant.

So there are just some really interesting stories out there. I hope that some of the experiments that I was involved in will have some potential payoff in the future. I think in particular, on my study, on the renal stones, we are interested in applying something that we know here on Earth and hopefully maybe there will be some payback later on after we have tested it in zero gravity as well.

Lieutenant Colonel FINCKE. I am a pretty healthy guy, but aboard the Space Station for 187 days and 24 hours—21 hours, I lost a fair amount of bone mass, roughly about six percent, and I exercised a lot. In fact, that is what we have seen with humans in space is we lose, without gravity, now matter how hard we exercise, somewhere between one and two percent of our bone mass per month. Now that is accelerated osteoporosis. And by understanding that—and fortunately it all came back for me, but by understanding how we lose it, the mechanisms, and how we can get it back, is very important to a lot of our population who are suffering with osteoporosis right now. There is a direct tie. We—on our mission, we were the first mission to actually image our bones as they changed over time with this ultrasound machine that we have been mentioning. So these are some direct applications to the science of osteoporosis.

But space is definitely an investment in the country's future. When I was up there, I saw four hurricanes—or actually, I saw them all last summer, and John is going to see, unfortunately, some this year. But it—I always reflected that we lost very few people's lives, especially American lives, because of the space program. We knew ahead of time that these hurricanes were coming. Back in the 1940s and 1950s, you would only get 18 hours. Now we let people know when hurricanes are coming days in advance. They have a chance to pack up their stuff and move if they need to or batten down wherever they need to. So this space technology is protecting lives every day, especially during the summer hurricane season on planet Earth.

Mr. BONNER. Well, as someone who experienced one of those hurricanes in my back yard, I want to thank you, because that is a very good point. We were able to, with advanced notice, avoid the loss of life that we saw, for instance, in the tsunami. So thank you both for what you do and for what you have done.

Thank you, Mr. Chairman.

Chairman CALVERT. I thank the gentleman.

Mr. Costa.

ISS CONFIGURATION AND SCHEDULE

Mr. COSTA. Thank you very much. And I am not sure if this question is appropriately addressed to Dr. Whitson or Lieutenant Colonel Fincke. What I asked Dr. Phillips about the level of completion of the Space Station currently, I thought he said approximately 40 percent plus. What is the exact level of completion currently today? And it goes to my larger question that is under the timeline that we are currently looking at when the—hopefully the Shuttle becomes operative again here in the next couple of months, when do we believe that we will be able to complete the Space Station to then have the full complement of the six persons on the Station and to be able to take advantage of all of the capacity that is—we hope is built into the Station to perform not only the science but the additional research that has been contemplated?

Dr. WHITSON. It will take approximately six Shuttle flights to complete the assembly of the truss element, which holds the solar rays on either end. And that capability will allow us to add on the different laboratory—the two additional laboratory modules and then connecting node modules. So there will be three more additional large modules in addition to the six already on orbit.

Mr. COSTA. So that is nine Shuttle flights?

Dr. WHITSON. Yes.

Mr. COSTA. Okay.

Dr. WHITSON. Yes.

Mr. COSTA. Over what length of time?

Dr. WHITSON. Well, the Shuttle assembly rate is something that I think a lot of folks are working on now, and we will do whatever we feel is safe and——

Mr. COSTA. I understand that part. Yeah.

Dr. WHITSON. Well, we anticipate that we will also be having to provide the resupply. As John mentioned, we have very limited resource capability. The Russian Progress vehicles have provided a lot of resupply capability, but if we want to increase the crew size, we are going to be required to provide resupply missions as well.

Mr. COSTA. So it sounds like approximately 14 or 15 Shuttle flights.

Dr. WHITSON. Well, I think we will take that question for the record and get you an official answer on that.

Mr. COSTA. And if we are doing how many a year—we hope to be doing a year——

Dr. WHITSON. Hopefully——

Mr. COSTA. Six?

Dr. WHITSON. Yeah, five to six would be, I think, a good estimate, but I think there is a lot of——

Mr. COSTA. So we are talking about a three- to four-year period, at least, to complete the Station?

Dr. WHITSON. At least, yes.

Mr. COSTA. Once we become operational with Shuttle. And then after it is complete, how long do we believe that the Station will be able to perform at that level?

Dr. WHITSON. Well, it is going to depend a lot on the maintenance resupply capability that we have provided at that point, because we will have to provide capability to repair the hardware on orbit.

Mr. COSTA. And do you have cost estimates?

Dr. WHITSON. I am not familiar with——

Mr. COSTA. Okay.

Dr. WHITSON.—those numbers.

Mr. COSTA. I would like to submit that, for the record, Mr. Chairman, as well.

Chairman CALVERT. Without objection.

Mr. COSTA. Thank you. I defer—yield the balance of my time.

Chairman CALVERT. I thank the gentleman.

Mr. Rohrabacher.

ISS RESUPPLY

Mr. ROHRABACHER. Well, let us hope we aren't that dependent on the Shuttle, because at $1 billion a flight, I guess that would mean we are not going anywhere. But when we talk about resupply, we are not really thinking that the Shuttle is going to be the instrument for resupply, are we?

Dr. WHITSON. We can take that question for the record, too, but I think there are lots of different plans out there for alternatives. With the ATV module being built by the Europeans and the HTV module being built by the Japanese, we have lots of options.

Mr. ROHRABACHER. Realizing that perhaps these nine flights that you spoke about, for the completion of Space Station, that is the only vehicle we have that can handle that kind of load, but when it comes to resupply, might not the private sector be able to be contracted in other craft that cost us less than $1 billion a flight, not counting what the cargo is that is in there? Might we go to that direction and be able to do more with less?

Dr. WHITSON. And we will take that question for the record, also, but I do know that the program is working on various alternatives that do include commercial resupply.

Mr. ROHRABACHER. All right. And about your bone loss, six percent. You lost six percent of your bone mass when you were—would that also happen on the Moon?

Lieutenant Colonel FINCKE. Well, the—sir, we are not exactly sure. We think it will be diminished on the Moon, because there is gravity. Gravity on the Moon is roughly about one-sixth on the Earth, and we think that the reason why we are losing some of that kind of bone is because we are not stimulating our muscles and our bone by walking. And that is mainly where we lose it is in our hips. And so by having a chance to walk on the Moon, we may be able to trick our bodies into thinking to get more—to continue, but we don't know that for sure. But when we go to the Moon, that is definitely, I think, one of the things we will learn. And the gravity on Mars is one-third, so maybe there is another equation there.

RESUPPLY: ISS VS. MOON

Mr. ROHRABACHER. Well, like we say, we have—the most—one of the most important contributions of Space Stations is learning about how to live in space, and this is our first step of humankind living in space. The next step we see, the President has outlined this plan very well, and I, of course, commend the Administration on—finally, after so long, in so many years presenting to us a strategy, a long-term strategy. The President's next step in his strategy for space is the Moon. And when we talked about resupply for the Station, how expensive it is, would resupply for a Moon mission, how would that compare to the cost for resupply for people who are in Station?

Dr. WHITSON. Well, I am not dealing with the budget numbers on that, but I think what this opportunity offers us is the lessons we have learned that we have to build hardware at a much higher level of maintainability, you know. Our requirements for resupply have to be reduced. We can't support Moon or Mars missions at the same re-supply level that we are doing currently. And I think that is an important lesson. And where we can try and reduce that is something that we are practicing on board the Station every day.

Mr. ROHRABACHER. So we might be trying to find things on the Moon that we could actually generate power from or find water sources, et cetera? We can talk—I am sure we will—as this goes on, we will be having hearings about the potential of water on the Moon and other resources, but we are looking——

Chairman CALVERT. So we can export it to California.

Mr. ROHRABACHER. That would be good. This is the man who made sure we had water for the last six years.

Lieutenant Colonel FINCKE. But if I may add, it is that there is a lot of oxygen that is connected in the regolith, the soil on the Moon. And right now, in kind of like an X–Prize, NASA has set out this new program where we are offering a reward for the cleaver team that can figure out how to use, perhaps, like solar energy and get that oxygen that is trapped in the minerals on the Moon so that we won't need to send up oxygen, that we would be able to use the resources on the Moon. So NASA is trying to be innovative in trying to figure out how we can live off the land as best we can.

Mr. ROHRABACHER. That is just the type of creative approach that we are applauding your new Director for, and we expect to see more of that from him and are very happy that—when people come up with those kinds of ideas, because the cost to resupply, we can't be spending $1 billion a flight for the Shuttle and expect us to have a space program all based on $1 billion a flight, and that's just the cost of the transportation. We have got to get these costs under control and find some creative ways of accomplishing the mission in a more cost-effective way.

So thanks for throwing that in, Colonel, and thank you very much, Mr. Chairman.

Chairman CALVERT. I thank the gentleman.

Mr. Wu, from Oregon. We will try to get some water out of you, too.

ISS CONFIGURATION AND SHUTTLE LAUNCH RATES

Mr. WU. Well, we Oregonians think that California ought to be able to get all of the water that California wants. We will just peg it to the price of a gallon of gasoline, and we are happy to sell however much California can buy, Mr. Chairman.

I want to follow up on the questioning of Mr. Rohrabacher and Mr. Costa. I was just doing, you know, a quick back-of-the-envelop calculation based on Dr. Whitson's answers about how many lift missions it would take to complete the International Space Station, and then—well, it seems to me that if you count up the number of missions and the mission rate, assuming five or six missions per year, we are pretty much hard up against the 2010 retirement date that the Administrator has said. Is that roughly correct?

Dr. WHITSON. Well, 2010 is the date that we are working to, and there are groups that are now doing assessments and analyzing what would be the best final configuration for the Station. And so I think you will be getting some answers from NASA later in the summer on what that configuration will be and how we could do that.

Mr. WU. But what I am concerned about the 2010 constraint being something that, A, shapes the International Space Station, whether that would be an appropriate or inappropriate limitation on the International Space Station, and B, that the 2010 date, aside from its effect on the International Space Station, also becomes a push date for the crew exploration vehicle. And in my readback of the history of the space program in the 1960s is that because we were in a race with the Russians, the types of vehicles that we used took a certain shape, and that became a limitation of you all going forward, because we were in a hurry. And I am concerned that the same kind of hurry about the crew exploration vehicle will perhaps be a limitation on that vehicle going forward.

Chairman CALVERT. I might point out to the gentleman that the astronaut corps is probably not prepared to answer policy questions, but I appreciate the gentleman asking.

Mr. WU. Well, one thing that I have found is that if you ask lower in the organization, sometimes the people doing the rowing will give you more accurate answers than the people who are trained to deal with the public, if you will.

Dr. WHITSON. Well, I definitely think there is another group that is working on the crew—our new crew vehicle, and they are trying to take all of those lessons that we learned in the early programs into account and trying to make fewer mistakes. That is part of our hope and goal is to make fewer mistakes than we made the first time around and to come out more successful than we have even in the past. So I anticipate that NASA will have a plan for you later this summer on what we think we will be able to do.

Mr. WU. Well, Lieutenant Colonel Fincke, Dr. Whitson, Mr. Chairman, I want to support your efforts fully, but I also want to state for the record that I am concerned about artificial constraints, be they of a date or other nature, and how those constraints can shape the Space Station or shape future space exploration. And I just want to lay that out there, not as an item of concern for you all, but as, really, an item of support for what your mission should be in the long-term is if there is anything that I have observed from my student days to the present is that there is nothing quite as permanent as temporary solutions, and they—you tend to rely on them for a lot longer than one expects to when first going in. And you all and your successors wind up, you know, having to live with that—with those constraints.

Chairman CALVERT. I thank the gentleman.

Mr. WU. I yield back my time.

Chairman CALVERT. Mr. Feeney from Florida.

CHALLENGES OF HUMAN SPACE FLIGHT

Mr. FEENEY. Thank you, Mr. Chairman.

And for both Dr. Whitson and Lieutenant Colonel Fincke, with respect to the expertise that you uniquely have as astronauts on the physiological impacts of space travel in low Earth orbit, do you have some experiences or guess about what that portends for the future of mid Earth orbit or high Earth orbit for human beings? We have got lots of technological challenges. We have talked a little bit about the exercise to levels. I know we are doing some experiments on the current Expedition 11 astronauts when they get back, but based on your experience so far, do you have some scientific challenges that you can help us deal with, or do you just have some good guesstimates of problems that we are going to face as we move into further mid and outer Earth orbit?

Dr. WHITSON. Well, the human body responds very individually unfortunately for us, because it would be so much easier for us to answer the question with one person. Mike's experience on bone loss was very different from mine. I lost no overall bone density during my space flight, but I had a different exercise regime. And so we are learning from that. Maybe it was the exercise. Maybe it was something else as part of what we were doing during the mission. We have to pick those pieces apart to find out the best solutions to going further out to the Moon and Mars. I think we are well on our way. We have seen a lot of promise, and we are getting the information and data that we need to make the conclusions and to develop the right procedures to protect and minimize our bodies against those risks in space. But there are lots of things we have to work on, the radiation we talked about before. We have to have exercise hardware that is reliable enough to get us all of the way there and back and so that when we get to the Moon or Mars we have that capability to perform well once we are there.

Lieutenant Colonel FINCKE. That is the—we are—we don't think we have the bone loss problem licked, but we think we have a good handle on it. We understand it. The radiation shielding, that is something we are—that is a little bit right now a long pole in the tent, and we are spending efforts appropriately to try to figure that out, how to come up with radiation shields that don't weigh a lot, because every kilogram, every pound that you send up costs a lot of money. And that is one of the tricks, especially as we get out of low Earth orbit and away from our magnetosphere that we are really going to have to understand, and we are working towards it. And hopefully there is going to be some things that we learn about these lightweight radiation shields that we are going to come up with that will be applicable for radiation shielding that we need on the ground, because every hospital I know has an x-ray machine and things like that, and maybe there are some things that we can feed back into our industry.

FUTURE CEV DESIGNS

Mr. FEENEY. One of the things I am excited about the new Administrator's proposal is to shorten the window or eliminate it when we are out of manned space flight from the original proposal of 2010 to 2014 and maybe have no window at all, which I am excited about. But the challenge is to design and then produce the right CEV to replace the Shuttle and to do some more types of missions that are more flexible and more—with different and more exciting capabilities for outer Earth orbit. What do your experiences, including the exercise, including the psychological impacts as well as the physiological, what do they tell you about the way, if you were a designer, you would try to design the next living quarters? Obviously, you would like to be floating around in a comfortable RV with a TV and all of the rest of it, but given the reasonable limitations, what do your experiences tell you designers ought to be thinking about?

Lieutenant Colonel FINCKE. One thing in the psychological area, we just like having a telephone. It was really important. I talked to my wife once or twice a day, not for a long period of time, I was busy, but it was still just being able to say hi, especially with our new baby that came. And being able to be able to still be in contact with your friends and family while you are in low Earth orbit or high Earth orbit or on the Moon is going to be important. It is going to be a little trickier when you go to Mars, but just having something as simple as that, because it doesn't cost very much mass to put a voice-over IP telephone on with your communication system. That doesn't even cost that much money. I can get one at home really cheap. It is one of these things that makes a big difference yet it doesn't cost very much in terms of time and money. And that is a—those are the kinds of things that we are learning aboard Space Station, what we really need and the things that we don't need. Exercise equipment, boy, that is definitely an important thing, and we had some really good ideas going into it, and now we are—we have learned from it, and we are moving—you know, making improvements onto the next series of designs.

Mr. FEENEY. Well, you should run for Congress. A lot of us spend half our time avoiding the telephone here on terra firma.

Thank you, Mr. Chairman.

Chairman CALVERT. I thank the gentleman.

MICROGRAVITY RESEARCH

I have one question. The issue of the problems with gravity and you are saying you need to understand that. But we really don't understand microgravity, do we, because we haven't been able to do, really, any experiments of any note, as far as I know, in on the International Space Station, is that true?

Dr. WHITSON. Actually, during my mission, the zeolite crystal growth experiment that I had conducted was actually done in a special rack called the ARIS, Active Rack Isolation. And it has got accelerometers that null out. And so basically, the rack itself was floating inside the Space Station, which is, of course, going around the Earth. And it has got accelerometers on it to null out any vibrations from the Station itself and to optimize, in that particular case, the crystal formation that we were looking for. So we have had a limited capability there with individual racks and experiments within those racks and those special racks.

Chairman CALVERT. How about upon organisms, on living organisms? Have there been any experiments on microgravity on—as far as the effects of, say, as you mentioned one-third gravity, which you would have on—or one-sixth gravity that you would have on the Moon or the one-third gravity that you would have on Mars, whether it has a zero effect as far as bone loss or no effect at all? I mean, have there——

Dr. WHITSON. No.

Chairman CALVERT.—been any experiments on any of that at all?

Dr. WHITSON. Not to this point there have not been any experiments. It was planned to have those experiments conducted when we get the Centrifuge Accommodation Module up on board.

Chairman CALVERT. Now that is where I was——

Mr. ROHRABACHER. Will the Chairman—excuse me.

Chairman CALVERT. That is where I was just moving toward. Is the Centrifuge, I believe that is in conjunction with the Japanese, as far as you know, going ahead?

Dr. WHITSON. As far as I know.

Chairman CALVERT. As far as you know? Okay.

Mr. ROHRABACHER. Would the Chairman yield?

Chairman CALVERT. Sure.

Mr. ROHRABACHER. Thank you very much.

When the Space Station docks with their—you know, you noted that we have a number of resupply missions that are required, and every time there is a docking required, does this or does this not interfere with some of these microgravity experiments that are taking place and will take place on the Station? What have we noted?

Dr. WHITSON. We actually do have hardware that monitors and calibrates the vibrations on board the Space Station, some specific for the docking events and large events like that, but we also have a continuous monitoring at various frequency levels so we can monitor what the environment is. And it has been interesting, because we have found some interesting results relative to that in some of our exercise activities that have been going on. So we are learning as we go along where we might be perturbing the microgravity environment on board the Station. As I mentioned, we have the specific area that was specifically designed for those microgravity experiments where it is very important and key not to have those vibrations interfere.

Mr. ROHRABACHER. And thus we have overcome by those protections that we you are talking about, we have overcome the jolt that might take place with a——

Dr. WHITSON. Yeah. It minimizes those effects dramatically. Yes.

Mr. ROHRABACHER. All right. Thank you very much, Mr. Chairman.

Chairman CALVERT. Thank you.

Well, with that, I want to thank you, Dr. Whitson and Lieutenant Colonel Fincke, for your attendance here today and, of course, Dr. Phillips, who came from—to us from outer space. It was an exciting hearing and historic, I understand the first time we have actually had a hearing and heard from our—or heard from a witness from outer space. So this was a new and exciting thing.

Mr. FEENEY. Mr. Chairman, if I could, I have a point of personal privilege. I was speaker of the Florida House when we had the Shuttle astronauts actually take questions from Governor Bush, Lieutenant Governor Brogan, and the House Speaker, who happened to be me at the time.

Chairman CALVERT. Well, Florida is ahead, once again, of the rest of us in the country, and so—but this is the first time in the U.S. House of Representatives, I suspect.

But with that, I thank you, and we appreciate your commitment and dedication to this country, and we look forward to hearing from you in the future.

With that, we are adjourned.

[Whereupon, at 3:30 p.m., the Subcommittee was adjourned.]

Appendix:

ADDITIONAL MATERIAL FOR THE RECORD

Congressional Research Service

NASA'S SPACE STATION PROGRAM: EVOLUTION OF ITS RATIONALE AND EXPECTED USES

Testimony before the
Subcommittee on Science and Space
Committee on Commerce, Science, and Transportation
United States Senate

Marcia S. Smith
Specialist in Aerospace and Telecommunications Policy
Resources, Science, and Industry Division
Congressional Research Service

April 20, 2005

Testimony of Marcia S. Smith
Congressional Research Service
April 20, 2005

Madam Chairwoman, members of the subcommittee, thank you for inviting me to testify here today about the space station program. You asked that I focus my remarks on how the rationale behind the program has changed over the years, particularly in terms of its expected benefits — essentially, what was promised, and whether those promises are likely to be met under the current plan.

The space station program has been an international endeavor since its inception. Today, Russia, Canada, Japan, and 10 European countries[1] are partners with the United States in building the International Space Station (ISS). My testimony will not address how the non-U.S. partners have won support from their governments, or what benefits they expect, however. The focus here is on how NASA and the White House have explained the rationale for and expected benefits from the program to the U.S. Congress. My testimony would not be complete, though, without noting that the other partners are vital to NASA's use of the space station. NASA is dependent on Russia for crew and cargo transportation to and from ISS while the space shuttle is grounded. Under President Bush's Vision for Space Exploration, NASA will continue to be dependent on Russia to enable NASA astronauts to remain aboard the space station for long duration missions, and to have them there at all once the space shuttle is terminated in 2010. In addition, some of the research facilities that will be available to U.S. researchers are in Europe's Columbus module and Japan's Kibo module. Also, Japan is building a centrifuge and its accommodation module for NASA in exchange for NASA launching Japanese hardware. However, NASA reportedly is reconsidering whether it needs the centrifuge.

RATIONALE FOR AND EXPECTED USES OF THE SPACE STATION

Four Presidents have shaped the space station program — Ronald Reagan, George H.W. Bush, Bill Clinton, and George W. Bush — so I have separated this historical discussion into the time periods of those administrations. This is not meant to suggest that they were the only forces affecting the program. Congress has played a strong role in the space station's evolution through funding decisions and oversight. The two space shuttle tragedies — *Challenger* in 1986 and *Columbia* in 2003 — also impacted the program. Perhaps the biggest influence has been the incessant cost growth and schedule delays that have characterized the program since its earliest days. Assembly was originally planned for completion by 1994; now it is 2010. NASA estimated the space station would cost $8 billion

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[1] Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland. The United Kingdom signed the Intergovernmental Agreement that governs the program, but is not financially participating in it, so the number of participating European countries is sometimes listed as 11.

(FY1984 dollars) when it first came to Congress to obtain approval for the program. Congress now has appropriated approximately $35 billion (FY1985-2005, in current dollars), and NASA estimates it will cost another $10 billion through the end of construction in FY2010. (Estimates do not include shuttle launch costs.)

The cost growth and schedule delays over the past 21 years have subjected the space station to repeated downsizings and consequent reductions in its capabilities.

It is not possible in this short statement to review comprehensively the record of statements made to Congress by the White House and NASA about the rationale for building a space station and what could be expected from it. The examples herein are illustrative. For your convenience, I have summarized the various changes to the space station's configuration in a table appended to this statement.

Reagan Administration

The space station program, today known as the International Space Station (ISS), was formally initiated by President Ronald Reagan in his January 25, 1984 State of the Union Address. President Reagan directed NASA to build a permanently occupied space station "within a decade" and to invite other countries to join in the project. He explained his reasons for wanting to build such an orbiting facility in this way:

> America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade.
>
> A space station will permit quantum leaps in our research in science, communications, in metals, and in lifesaving medicines which could be manufactured only in space. We want our friends to help us meet these challenges and share in their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals.[2]

NASA officials at this time articulated the need for a new space station[3] by using the motto that it was "the next logical step" in the space program. Indeed, in 1969, Vice

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[2] Ronald W. Reagan. State of the Union Address. January 25, 1984. Text available on the University of California Santa Barbara (UCSB) American Presidency Project website at:[http://www.presidency.ucsb.edu/ws/index.php?pid=40205].

[3] The space station approved in 1984, and currently under construction, is NASA's second space station. The first NASA space station was Skylab, launched in 1973. Skylab was not intended to be permanently occupied. Visited by three 3-person crews in 1973-1974, it made an uncontrolled reentry through Earth's atmosphere in 1979, spreading debris on Australia and the Indian Ocean. The space station approved in 1984 was intended to go beyond Skylab, to a permanently occupied facility with sequential crews onboard year-round. Meanwhile, the Soviet Union had launched the world's first space station in 1971 (Salyut 1). By 1984 when President Reagan announced the plan to build NASA's space station, the Soviets were operating their sixth successful space station (Salyut 7). In 1986, they launched the first element of the modular Mir space station. Several other modules were added to the Mir complex over many years, and Mir was permanently occupied from 1989-1999 (including multi-month visits by seven NASA astronauts, and nine dockings between Mir and NASA's space shuttle). Mir made a controlled deorbit into the Pacific Ocean in 2001.

President Agnew had chaired a Space Task Group to recommend goals for the post-Apollo space program. Briefly, the plan was to build a space station, a reusable space transportation system to service it, and to send people to Mars. Budget constraints led President Nixon to approve only one element of that plan in 1972 — development of a reusable space transportation system, which became known as the space shuttle. NASA declared the space shuttle "operational" in 1982, and then was ready to proceed with the next step, building a space station.

Two months after the State of the Union Address, then-NASA Administrator James Beggs testified to the House Appropriations Committee that the cost estimate for the space station was $8 billion (FY1984 dollars), and identified the eight functions that the space station would serve:

- a laboratory in space, for the conduct of science and the development of new technologies;
- a permanent observatory, to look down upon the Earth and out at the universe;
- a transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
- a servicing facility, where these payloads and vehicles are maintained, and if necessary, repaired;
- as assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out;
- a manufacturing facility where human intelligence and the servicing capability of the Station combine to enhance commercial opportunities in space;
- a storage depot where payloads and parts are kept on orbit for subsequent deployments; and
- a staging base for more ambitious future missions.[4]

This original concept envisioned three separate space station facilities: an occupied base for eight crew members in a 28.5° orbit, an automated co-orbiting platform nearby, and an automated "polar platform" in orbit around Earth's poles (an orbit typically used for earth observations). By the fall of 1985, NASA had settled on a "dual-keel" design for the facility, with four laboratory and habitation modules. Over the next several months, NASA approved other details, including a few changes from that baseline design. Among the changes was reducing the number of U.S. modules from four to two (but the new U.S. modules would be larger so the total habitable volume was relatively unchanged), with plans for two more modules to be provided by Europe and Japan. NASA also agreed to add a U.S. Flight Telerobotic Servicer at congressional urging, to supplement Canada's planned Mobile Servicing System.

In 1985, as you may recall Senator Nelson, NASA's Associate Administrator for Space Station, Phil Culbertson, told you at a hearing you convened on the space station and space science, that a "fundamental concept upon which the space station has been and will continue to be defined is that it will be designed, operated, and evolved in response to user

[4] U.S. Congress. House. Committee on Appropriations, Subcommittee on HUD-Independent Agencies. Department of Housing and Urban Development — Independent Agencies Appropriations for 1985, Part 6, National Aeronautics and Space Administration. March 27, 1984. Washington, U.S. Govt. Print. Off., p. 8

requirements."[5] Mr. Culbertson explained that NASA had worked closely with prospective users for the previous three years, and established a Task Force on Scientific Uses of the Space Station, to advise NASA on what the scientific community wanted and needed. He listed the following as examples of the planned scientific uses: earth observations; astronomical observations; basic biological and physiological research, including the effect of long duration exposure to microgravity conditions; research on the processing and behavior of materials in microgravity, including crystals and pharmaceuticals (with research to be conducted on the occupied base, and full scale commercial production either on the occupied base or on spacecraft serviced from the occupied base); and applications and technology research such as advanced communications, energy conversion, propulsion, controls, and human factors.

Funding challenges, and the January 1986 Space Shuttle *Challenger* tragedy, soon impacted the space station design. In late 1986, the dual-keel design was reaffirmed, but emphasis was placed on building a single-keel first because of the reduction in the number of shuttle flights, and the reduced amount of cargo that would be allowed aboard the shuttle, in the wake of the *Challenger* tragedy. An emphasis on early accommodation of experiments, fewer spacewalks, an extended "safe haven" concept with the possibility for "lifeboats" for emergency return to Earth (not made a requirement at this time reportedly for cost reasons), and increased use of automation and robotics, were made part of the program.

In 1987, in response to continued cost growth, the program was split into two phases. Phase I, to be completed by 1996, would include a single keel of the occupied base (including the four modules), and the polar platform. The second keel, the co-orbiting platform, and solar dynamic power were deferred to Phase 2, on which further decisions were anticipated in 1991.

In 1988, Canada, Europe, and Japan formally joined the program after three years of negotiations. Canada agreed to build a Mobile Servicing System (Canadarm2), while Europe and Japan each agreed to build laboratory modules (Columbus and Kibo, respectively). The partners named the space station *Freedom*. In return for providing services such as electrical power and crew and cargo transport, NASA obtained utilization rights to half of the research facilities in the European and Japanese modules.

George H.W. Bush Administration

On July 20, 1989, six months after taking office, the senior President Bush made a major space policy address on the 20th anniversary of the Apollo 11 landing on the Moon. He called on the United States to return humans to the Moon and someday go to Mars. Space Station *Freedom* featured prominently in the President's vision for the future of the space program. This excerpt may be helpful in comparing the role envisioned for the space station as part of a program of human space exploration at that time, versus today. The senior President Bush said:

> In 1961 it took a crisis — the space race — to speed things up. Today we don't have a crisis; we have an opportunity. To seize this opportunity, I'm not proposing a 10-year

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[5] U.S. Congress. House. Committee on Science and Technology. Space Science and the Space Station. September 24, 1985. Washington, U.S. Govt. Print. Off., 1985, p. 6.

plan like Apollo; I'm proposing a long-range, continuing commitment. First, for the coming decade, for the 1990's: Space Station Freedom, our critical next step in all our space endeavors. And next, for the new century: Back to the Moon; back to the future. And this time, back to stay. And then a journey into tomorrow, a journey to another planet: a manned mission to Mars.

Each mission should and will lay the groundwork for the next. ...

And to those who may shirk from the challenges ahead, or who doubt our chances of success, let me say this: To this day, the only footprints on the Moon are American footprints. The only flag on the Moon is an American flag. And the know-how that accomplished these feats is American know-how. What Americans dream, Americans can do. And 10 years from now, on the 30th anniversary of this extraordinary and astonishing flight, the way to honor the Apollo astronauts is not by calling them back to Washington for another round of tributes. It is to have Space Station Freedom up there, operational, and underway, a new bridge between the worlds and an investment in the growth, prosperity, and technological superiority of our nation. And the space station will also serve as a stepping stone to the most important planet in the solar system: planet Earth. ...

The space station is a first and necessary step for sustained manned exploration.... But it's only a first step. And today I'm asking ... Vice President, Dan Quayle, to lead the National Space Council in determining specifically what's needed for the next round of exploration. ... The Space Council will report back to me as soon as possible with concrete recommendations to chart a new and continuing course to the Moon and Mars and beyond.

... Why the Moon? Why Mars? Because it is humanity's destiny to strive, to seek, to find. And because it is America's destiny to lead.[6]

Despite this glowing endorsement of Space Station *Freedom*, on a practical level, the program continued to experience cost and schedule problems, resulting in more changes that further reduced its capabilities. In 1989, the same year as the President's speech, NASA indefinitely postponed Phase 2, and the polar platform was transferred out of the space station program and into NASA's Office of Space Science and Applications.

By this time, five years after the program began, of the eight functions identified by Administrator Beggs in his 1984 testimony, only one remained: a single-keel occupied base to serve as a laboratory. Construction of that base was, in turn, divided into two phases: an "initial phase" with reduced capabilities (crew size was reduced from eight to four, electrical power reduced from 75 kw to 37.5 kw, and an open-loop instead of a closed-loop life support system would be used); and an "assembly complete" phase when full capabilities would be restored. NASA asserted that the capabilities envisioned in the 1987 Phase 2 program (dual-keel etc.) could still "evolve" sometime in the future to support expeditions to the Moon and Mars.

In 1990-1991, the space station was further downsized because of continued cost problems, weight growth, and growing estimates of the number of spacewalks needed for its

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[6] George H. W. Bush. Remarks on the 20th Anniversary of the Apollo 11 Moon Landing. Text available from the Bush Library website at:
[http://bushlibrary.tamu.edu/research/papers/1989/89072000.html].

construction. The U.S. modules were reduced in size from 44 feet to 27 feet in length; the total length of the facility was reduced from 493 feet to 353 feet; the Flight Telerobotic Servicer was canceled; crew size was formally reduced to four; and electrical power was formally reduced from 75 kw to 56 kw. A "lifeboat" was added to the station's design, but was not included in the cost estimate. The "assembly complete" designation was abandoned in favor of a concept that the station would continually evolve in an undefined and unbudgeted "follow-on phase."

The 1990-1991 downsizing raised concern in the scientific community. Among other things, the redesign excluded plans for a centrifuge. The Space Studies Board (SSB) of the National Research Council issued a report saying that the limited microgravity research that could be conducted on the redesigned station did not merit the investment required. The SSB said that while it strongly endorsed the need for a space station to study the physiological consequences of long-term space flight, the redesigned station did not have the necessary facilities to do so. It cited the following as "absolutely fundamental to the acquisition of the data necessary to determine the feasibility of long-term human space exploration" —

- a dedicated life sciences laboratory with adequate scientific crew to conduct research;
- a variable speed centrifuge of sufficient radius to accommodate small primates;
- sufficient numbers of experimental subjects (humans, plants and animals) to address the stated scientific goals; and
- sufficient laboratory resources, i.e. power, equipment, space, and atmosphere, to support the above research requirements.[7]

In testimony to this subcommittee on April 16, 1991, SSB Chairman Louis Lanzerotti noted that "For over twenty years, virtually every internal and external life sciences advisory group to NASA has emphasized the absolutely critical need for a centrifuge in space. A variable force centrifuge (VFC) is the single most important facility for space biology and medicine research."[8]

The White House Office of Science and Technology Policy issued its own report, which essentially agreed with the Academy's findings, and similarly emphasized the need for a centrifuge.[9] In response, NASA restored a 2.5 meter centrifuge to the design.

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[7] U.S. National Academy of Sciences. National Research Council. Space Studies Board. Space Studies Board Position on Proposed Redesign of Space Station Freedom. Letter report to NASA Administrator Richard Truly, March 14, 1991. pp 1-3.

[8] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. NASA's Plan to Restructure the Space Station Freedom. Hearing. April 16, 1991. S. Hrg. 102-268. Washington, U.S. Govt. Print. Off., 1997, pp. 52-53.

[9] White House. Letter from Dr. D. Allan Bromley, Assistant to the President for Science and Technology, to the Honorable Dan Quayle, Vice President of the United States. March 11, 1991. Dr. Bromley's report called not only for a centrifuge able to accommodate animals, but a larger one for human subjects.

Clinton Administration

As President Clinton took office in 1993, NASA announced $1 billion in cost growth in the Space Station *Freedom* program. In response, the President directed NASA to redesign the space station again to reduce costs. Many in the space community consider this to be the most crucial year in the space station's history, as the continued cost growth, schedule delays, and redesigns took their toll on congressional support for the program.

Ultimately, a scaled-down version of the *Freedom* design was selected. President Clinton issued a statement announcing the decision on June 17, 1993 that included the following rationale for proceeding with the program:

> At a time when our long-term economic strength depends on our technological leadership and our ability to reduce the deficit, we must invest in technology but invest wisely, making the best possible use of every dollar. That's why I asked for a review of NASA's space station program. ... I instructed NASA to redesign the space station program in a way that would preserve its critical science and space research and ensure international cooperation, but significantly reduce costs and improve management.
>
> NASA has met that challenge ...
>
> I am calling for the U.S. to work with our international partners to develop a reduced-cost, scaled-down version of the original Space Station Freedom. At the same time, I will also seek to enhance and expand the opportunities for international participation in the space station project so that the space station can serve as a model of nations coming together in peaceful cooperation....
>
> To make maximum use of our investments and meet the scientific goals we have set, the specific design we will pursue will be a simplified version of Space Station Freedom...
>
> There is no doubt that we are facing difficult budget decisions. However, we cannot retreat from our obligation to invest in our future. Budget cuts alone will not restore our vitality. I believe strongly that NASA and the space station program represent important investments in that future and that these investments will yield benefits in medical research, aerospace, and other critical technology areas. As well, the space station is a model of peaceful international cooperation, offering a vision of the new world in which confrontation has been replaced with cooperation.[10]

A week later, on June 23, 1993, the House voted to continue the space station program by a one-vote margin as it considered a NASA authorization bill. A week after that, on June 28, it voted to support the program by a somewhat wider (24 vote) margin when considering NASA's appropriations bill for that year. Two months later, on September 21, 1993, the Senate voted to continue the program 59-40.

By the time of the Senate vote, the space station had changed again, however. On September 2, Vice President Gore announced that Russia had agreed to join the space station partnership as part of broader cooperation in human space flight and other science and technology areas. Some of the expected benefits of bringing Russia into the space station

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[10] William J. Clinton. Public Papers of the President. June 17, 1993. Available from the Government Printing Office at: [http://www.gpoaccess.gov/pubpapers/index.html].

program were in the foreign policy arena and, while important, are not the focus of your hearing this morning, so I will not discuss them here. In terms of the capabilities of the new space station design, NASA said that, in comparison with the design announced in June 1993, the space station would be ready one year sooner, cost $2 billion less,[11] have 25% more usable volume and 42.5 kilowatts more electrical power, and accommodate six[12] instead of four crew members.

Mr. Daniel Goldin, the Administrator of NASA from 1992-2001, often stated that this redesigned space station — now referred to simply as the International Space Station (the name *Freedom* was dropped in 1993) — would have "world-class" research capabilities. In 1997, he articulated the expected scientific payoff in response to questions posed at a hearing before this subcommittee:

> ... We happen to be building a station in Earth orbit that has unique characteristics where we could do research in biomedicine, biotechnology, advanced materials, combustion research, advanced communications and advanced engineering and Earth science that we could do on no other platform.
>
> We already have results back from our very early missions on the Mir space station... [W]e have been getting absolute breakthroughs in the kind of science we have in the areas of cancer research, pharmaceutical research.
>
> We have even built a half-centimeter piece of human cartilage in the bioreactor .... We have done incredible research in combustion.
>
> The key to it is time on orbit and the absence of gravity. The International Space Station is going to provide that capacity.
>
> Furthermore, we're going to have exploration of space.... In the process of understanding how people can adapt to space, we study healthy physiology in an abnormal environment and compare it to abnormal physiology or sick people in a normal environment here. This is yielding great results, and, in fact, it is so exciting that the American Medical Association has signed a cooperative agreement with NASA to take advantage of the International Space Station to help upgrade medical techniques right here on Earth.
>
> ....This is a place where we use the absence of gravity to understand the laws of physics and chemistry and biology much better and rewrite textbooks.[13]

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[11] Initially, NASA and the White House said that Russia's participation would save 2 years and $4 billion, but later lowered it to 1 year and $2 billion. The estimated savings were based on the fact that NASA was spending about $2 billion per year on the program, so accelerating the schedule by one year would save that amount. For more information, see CRS Issue Brief IB93017.

[12] Although NASA said six at the time, the revised intergovernmental agreements that formally brought Russia into the program in 1998 call for a permanent space station crew of seven.

[13] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. International Space Station. Hearing. September 18, 1997. S. Hrg. 105-792. Washington, U.S. Govt. Print. Off., 1997, pp. 12-13.

After further discussion, he cautioned that "...I cannot tell you that I could give any American a cure for cancer...." or make other promises because NASA engages in long term, high risk research for which the payoff could be 10-20 years in the future.[14]

The basic design of the space station remained unchanged throughout the Clinton Administration. But cost growth and schedule delays remained a constant companion. In 1997, NASA began to shift funds from space station research into space station construction.

In 1998, the first two elements of the space station were launched. A 19-month hiatus followed, waiting for Russia to launch its "Service Module" that provides crew quarters. With the successful launch of the Service Module in 2000, successive space station crews took up residency, initiating permanent occupancy of ISS.

George W. Bush Administration

As President George W. Bush took office in 2001, NASA again announced significant cost growth, not unlike the situation when President Clinton took office in 1993. With space station construction already under way, redesign options were limited. The Bush Administration decided to truncate ISS construction at a phase called "core complete," which included the launch of certain U.S. components, and the hardware under construction by other ISS partners. The White House said that if NASA could demonstrate better program management, it would consider adding "enhancements" to the station later.

Three major U.S. elements were cancelled then or the next year: a Crew Return Vehicle for returning astronauts to Earth in an emergency; a Propulsion Module; and a Habitation Module. The Administration also cut the budget for space station research by $1 billion, and directed NASA to reprioritize its research program accordingly. NASA created a Research Maximization and Prioritization (ReMaP) Task Force to do so. Its report was completed in 2002.

Mr. Goldin, who remained Administrator for most of the first year of the Bush Administration, told the House Science Committee that the downscaled space station still would support the "high priority goals of: 1) permanent human presence in space, 2) accommodation of all international partner elements; and 3) world-class research in space."[15] One major concern was the decision to terminate the Crew Return Vehicle (CRV), which was needed if the crew size was going to increase from three to six or seven. The size of the crew was considered vital to the amount of scientific research that could be conducted there, since NASA estimated that it took "2 ½" astronauts to operate and maintain the facility, leaving only half of one person's time for research when the crew size was limited to three. Mr. Goldin said that "human-tended science would be greatly degraded" with a three-person crew, but he expressed hope that a solution would be found so that the larger crew size could be restored.[16]

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[14] Ibid, p. 15.

[15] U.S. Congress. House. Committee on Science. Space Station Cost Overruns. Hearing, April 25, 2001. Washington, U.S. Govt. Print. Off., p. 74.

[16] U.S. Congress. House. Committee on Science. Subcommittee on Space and Aeronautics. NASA (continued...)

Mr. Sean O'Keefe became NASA Administrator in December 2001, with a mandate, inter alia, to "fix" the space station program. Eleven months later, he won White House support to submit a FY2003 budget amendment that called for adding $706 million to the ISS program for FY2004-2007: $660 million to boost program reserves to ensure sufficient funds to finish the core complete configuration, and $46 million in FY2004 for "long-lead" items to preserve the option of increasing crew size beyond three.[17] In December 2002, he and the heads of the other partners' agencies agreed on a process for selecting a final ISS configuration by December 2003, including how to increase the crew size.

The crew size limitation is based on the number of astronauts who can be returned to Earth in an emergency by a single Russian Soyuz spacecraft. In this context, it is referred to as a "lifeboat" or "crew return" capability. Russia is committed to having one Soyuz docked with ISS at all times throughout its lifetime to serve as a lifeboat for three people. The U.S. Crew Return Vehicle (CRV) was to serve the same function for another four. The Bush Administration had terminated the CRV, however. Without it, the only option for augmenting lifeboat services is for Russia to provide additional Soyuz spacecraft. Each Soyuz can only remain in orbit for 6 months. Today, Russia launches two Soyuzes per year. To enable crew size to increase to six, it would have to launch four per year. Russian space officials said that they could not afford to build and launch the additional Soyuzes, and needed to be compensated. NASA, however, is not permitted to pay Russia for ISS-related activities unless the President certifies that Russia is not proliferating certain technologies to Iran under the Iran Nonproliferation Act.[18] The other partners did not offer to pay for the additional Soyuzes, leaving the situation in a stalemate, where it remains today.

Debate over the long term plans for the ISS was soon complicated by the February 1, 2003 space shuttle *Columbia* tragedy. The *Columbia* tragedy has affected the space station program in many ways. One outcome is that it led to a review of the reasons that the United States engages in human space flight at all. That review resulted in an announcement by President Bush of a new Vision for Space Exploration on January 14, 2004. The President said:

> Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress — one mission, one voyage, one landing at a time.
>
> Our first goal is to complete the International Space Station by 2010. We will finish what we have started, we will meet our obligations to our 15 international partners on this project. We will focus our future research aboard the station on the long-term effects of space travel on human biology. The environment of space is hostile to human beings. Radiation and weightlessness pose dangers to human health, and we have much to learn about their long-term effects before human crews can venture through the vast voids of

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[16] (...continued)
Posture. Hearing, May 2, 2001. Washington, U.S. Govt. Print. Off., p. 31.

[17] The ISS increases were proposed to begin in FY2004. By the time Congress deliberated the FY2004 budget, ISS construction was suspended because of the *Columbia* tragedy, and Congress cut $200 million from the ISS budget. The budget amendment also initiated an Orbital Space Plane program that would have been able to take crews to and from ISS, but it was terminated a year later.

[18] The relationship between the ISS and the Iran Nonproliferation Act is discussed in CRS Report RS22072.

> space for months at a time. Research on board the station and here on Earth will help us better understand and overcome the obstacles that limit exploration. Through these efforts we will develop the skills and techniques necessary to sustain further space exploration.
>
> To meet this goal, we will return the Space Shuttle to flight as soon as possible, consistent with safety concerns and the recommendations of the Columbia Accident Investigation Board. The Shuttle's chief purpose over the next several years will be to help finish assembly of the International Space Station. In 2010, the Space Shuttle — after nearly 30 years of duty — will be retired from service.[19]

A NASA budget chart released the same day as the President's speech showed NASA completing its use of the space station by FY2017. Funds now devoted to the space shuttle and space station programs could thereby be redirected to fulfilling the "Moon/Mars" goals enunciated in the Vision. So although the *Columbia* tragedy was a catalyst for a new Vision for the human space flight program, if that Vision is implemented, it also would spell the end of the space shuttle and ISS programs (from a U.S. perspective that is; the other partners might continue to use ISS after NASA completes its utilization).

If the Vision is adopted, the full extent of its impact on U.S. use of ISS is not yet clear. What is known is that the scope of research would be narrowed to only that which supports the Vision; there would be fewer years during which NASA will conduct research[20]; and the shuttle would not be available to support scientific operations by taking experiments and equipment up to the ISS ("upmass") or back to Earth ("downmass") once construction is completed. NASA's ReMaP Task Force cited lack of upmass capacity as one of the limiting factors on conducting high priority research.

What is not known is details of the new research program and therefore what benefits can be expected from it, what the ISS crew size will be, whether the centrifuge will be completed, and what capabilities may be available from other partners or the U.S. commercial sector to take cargo to and from ISS instead of the shuttle.

Conclusion

The space station was originally presented to Congress as a facility that would have eight functions. Within five years, that had been reduced to one — a laboratory for world-class research. That research program has been affected by reductions in funding (in the late 1990s by shifting funds from research into construction, and in 2001 as part of the cost-cutting in response to cost growth in the overall program), and now by the direction of President Bush, narrowing the scope to only research that supports the Vision.

The extent to which space station research will "rewrite textbooks" as forecast by Mr. Goldin in 1997 remains to be seen.

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[19] President Announces New Vision for Space Exploration Program. Available at: [http://www.whitehouse.gov/news/releases/2004/01/20040114-3.html].

[20] Space Station Freedom was designed with a 30 year lifetime. When the program was redesigned in 1993, NASA shortened the operational lifetime of the new station to 10 years (the modules are designed for 15 years — 5 years during assembly, and 10 years of operation). Under the Vision, NASA officials say the agency will complete its use of the ISS by 2016, six years after construction is completed.

Major Program Changes to the U.S. Portion of the International Space Station*

CALENDAR YEAR	NATURE OF CHANGE	REASON
	REAGAN ADMINISTRATION	
Fall 1985-May 1986	Original space station concept envisioned three elements: an occupied base for 8 crew members in a 28.5° orbit, an automated co-orbiting platform nearby, and an automated "polar platform" in orbit around Earth's poles. The original reference design for the occupied base was called the "Power Tower," but a "dual-keel" approach was chosen instead as the baseline design in the fall of 1985; the details were approved by NASA in May 1986. Changes included: arrangement of truss structure and modules modified to place modules at center of gravity; solar dynamic power added to photovoltaic arrays; number of U.S. laboratory and habitation modules reduced from 4 to 2, with plans for 2 more provided by Europe and Japan (the new U.S. modules would be larger than the original design, however, so total habitable volume relatively unchanged); U.S. Flight Telerobotic Servicer added at congressional urging to supplement Canada's planned Mobile Servicing System.	Cost and user requirements. NASA stated that the dual-keel design would provide a better microgravity environment for scientists, more usable area for attached payloads, and better pointing accuracy. Cost estimate maintained at $8 billion ($FY1984).
Late 1986	Dual-keel design reaffirmed, but emphasis on building single-keel first in recognition of reduced availability of shuttle flights and reduced amount of cargo that would be allowed aboard the shuttle in the wake of the Challenger tragedy. Emphasis on early accommodation of experiments; fewer spacewalks; extended "safe haven" concept with the possibility for "lifeboats" for emergency return to Earth (not made a requirement at this time reportedly for cost reasons); increased use of automation and robotics; "lead center" management approach replaced with dedicated program office for the space station in Reston, VA.	January 1986 space shuttle Challenger tragedy and concern by astronauts at Johnson Space Center about the number of hours of spacewalks, or "EVAs"; quality and quantity of living space; standard of safety for "safe havens" (to which astronauts would retreat in emergencies such as depressurization or dangerous sunspot activity); lack of "lifeboats" for emergency return to Earth when the space shuttle was not docked with the station. Cost estimate unchanged.

CALENDAR YEAR	NATURE OF CHANGE	REASON
1987	Program split into "phase 1" and "phase 2," with single keel of occupied base built in phase 1 and second keel delayed until phase 2; polar platform part of phase 1; co-orbiting platform and solar dynamic power pushed into phase 2.	Rising program costs and expected budget constraints. Cost estimate had risen to $14.5 billion ($FY1984) for research and development. New design estimated to cost $12.2 billion ($FY1984) for Phase 1 and $3.8 billion ($FY1984) for Phase 2, saving money in the near term, but costing more in the long term.
GEORGE H. W. BUSH ADMINISTRATION		
1989	Phase 2 indefinitely postponed; polar platform transferred from space station program to NASA's Office of Space Science and Applications (was for earth observation studies). Only remaining element is single-keel occupied base, divided into an initial phase with reduced capabilities (e.g. crew reduced from 8 to 4; electrical power reduced from 75 kw to 37.5 kw; use of open-loop instead of closed-loop life support system) and an assembly complete phase when "full capabilities" would be restored. NASA asserted that the capabilities envisioned in the 1987 Phase 2 program (dual-keel etc.) could still "evolve" sometime in the future to support expeditions to the Moon and Mars.	Cost growth and expected budget constraints. NASA termed this a "rephasing." Cost for Phase I estimated at $19 billion real year dollars,* or $13 billion FY1984 dollars, for R&D; NASA estimated total program costs through assembly complete at $30 billion real year dollars.
1990-1991	U.S. modules reduced in size (from 44 feet to 27 feet); "pre-integrated truss" chosen in effort to reduce EVA requirements; total length reduced (from 493 feet to 353 feet); Flight Telerobotic Servicer canceled; crew size formally reduced to 4; electrical power reduced (from 75 kw to 56 kw); "lifeboat" added to the station's design but not included in the cost estimate; "assembly complete" designation abandoned with concept that station would continually evolve in an undefined and unbudgeted "follow-on phase."	Beginning in 1990, concerns developed over rising program costs, weight, and too many EVAs for maintenance. In Dec. 1990, NASA estimated program costs through assembly complete at $38.3 billion real year dollars. Congress directed NASA to restructure the station. New plan released in March 1991. NASA stated it would cost $30 billion real year dollars through 1999, though this was no longer the time when assembly would be completed (see column to the left). GAO estimated total program costs through 30 years of operation at $118 billion.

CALENDAR YEAR	NATURE OF CHANGE	REASON
	CLINTON ADMINISTRATION	
1993	Space Station Freedom program terminated. New design developed (initially called Alpha), which NASA said would use 75% of Freedom's hardware and systems. Russia added as another international partner in a second phase of the 1993 activity. Program renamed International Space Station Alpha, and, later, simply International Space Station (ISS). Two U.S., 1 European, 1 Japanese, and 5 Russian modules (3 for science) accommodate crew of 6; Canada to build Mobile Servicing System; station located in 51.6° orbit (to allow access from Russia); operating period shortened from 30 to 10 years and annual operating costs reduced; "assembly complete" designation reinstated (but no "follow-on phase" or "evolution" or capabilities envisioned by the 1987 Phase 2 plan); space station management changed to "host center" (later "lead center") at Johnson Space Center, TX; Reston, VA office closed.	Cost growth and foreign policy considerations. There were two phases of space station program changes in 1993. The first (February-September) was prompted by $1.08 billion cost overrun (which NASA termed "cost growth") and resulted in a new design, tentatively called Alpha, involving the original space station partners (U.S., Canada, Europe and Japan). This design was released on Sept. 7, but 5 days earlier, the White House announced plans to merge the space station program with Russia's primarily for foreign policy reasons. In November, a new "Russian Alpha" design was announced including Russia as a partner. NASA said with Russian involvement, "Russian Alpha" would be ready 1 year sooner, cost $2 billion less (a figure GAO disputes), and have more scientific utility than the Sept. 7 Alpha version. NASA's current estimate of program costs for FY1994-2002 (assembly complete) is $17.4 billion real year dollars, not including launches or civil service salaries (adding those costs would raise it to $47.9 billion, using average shuttle costs). Monies spent prior to FY1993 ($11.4 billion) and operational costs for 10 years ($13 billion) are not included. [All funding figures from NASA.]

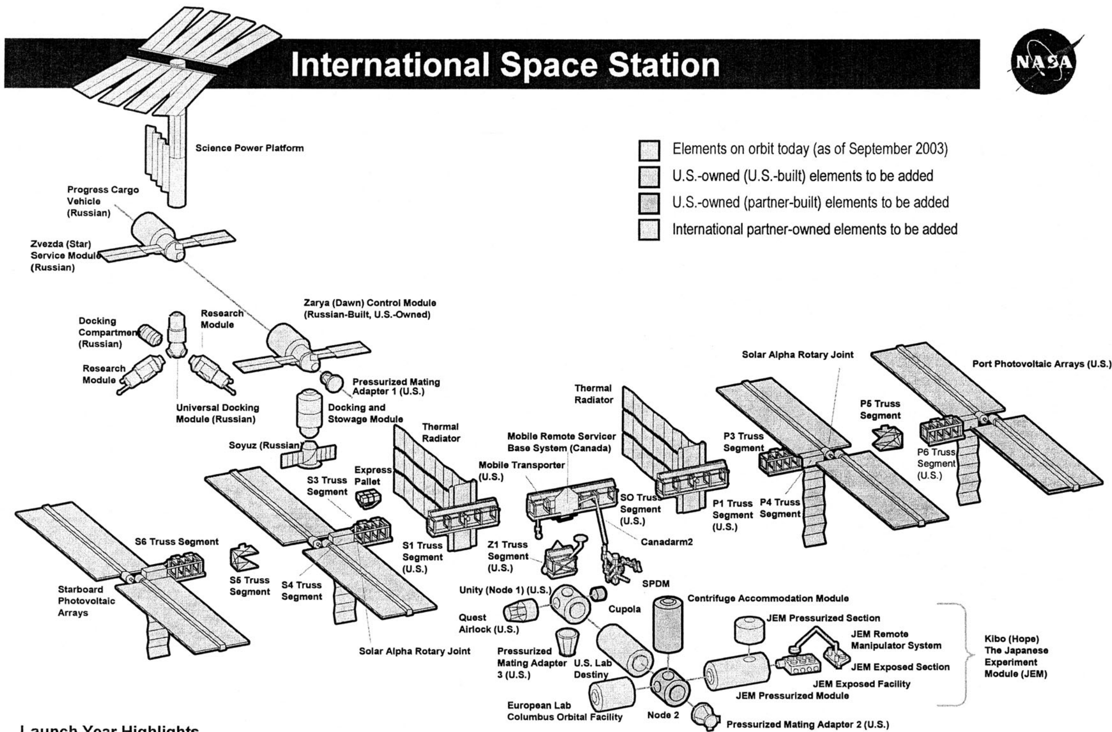
CALENDAR YEAR	NATURE OF CHANGE	REASON
GEORGE W. BUSH ADMINISTRATION		
2001-2002	ISS construction to be terminated after completion of "U.S. Core" and attachment of European and Japanese modules. Propulsion Module canceled. Habitation Module and Crew Return Vehicle indefinitely deferred pending demonstration of improved program management (later canceled). Could mean that crew size would be limited to 3 instead of 6 or 7 because only one Russian Soyuz (which can accommodate 3) would be available as a lifeboat. Smaller crew size would limit amount of science that could be conducted. Funding for research program cut $1 billion cut. At December 2002 "Heads of Agency" meeting, partners agree that crew size should be restored to six, but no details on how to accomplish it.	Cost growth of $4 billion over estimate made in its FY2001 budget submission. ISS had been estimated to cost $17.4 billion (real year dollars) when it began in 1993 (FY1994). NASA's estimate rose to $21.3 billion and then $22.7 billion in 1998, to $23.4-26 billion in 1999, and to $24.1-26.4 billion in 2000. NASA's March 2001 plan to discontinue construction after the "U.S. Core" is completed and attachment of the European and Japanese module results in a cost estimate of $22-23 billion and a "completion" date of November 2003-October 2004. Hardware being built for NASA by Europe and Japan (Node 3 and Centrifuge Accommodation Module, respectively) as part of barter agreements could be launched if NASA has sufficient funding for integration costs.
2004	Construction of ISS to be completed by 2010, and shuttle program thereupon to be terminated, so shuttle will not be available during the ISS operational phase to rotate crews, bring supplies or new equipment and experiments, return results of experiments, or return equipment needing repair. U.S. ISS research program to be reformulated to support only the Vision. If crew size is to increase, will be via additional Soyuz spacecraft, but no details on how to accomplish that (NASA prohibited from making payments to Russia for ISS because of the Iran Nonproliferation Act). New Crew Exploration Vehicle (CEV) to be built to take crews to the Moon; Earth-orbit capability by 2014. Between 2010 (when shuttle is terminated) and 2014, U.S. will rely on Russia for crew transport to ISS. NASA to rely on other partners, and U.S. commercial sector, to take cargo to and from ISS after shuttle retirement. No commitment to use CEV to service ISS, although it is an option. According to NASA budget chart, U.S. use of ISS to end by FY2017.	President Bush's announcement of the Vision for Space Exploration, which directs NASA to focus its activities on returning humans to the Moon by 2020 and someday sending them to Mars and "worlds beyond."

Notes:

Prepared by CRS, based on information from NASA, historical CRS publications, congressional hearings, and articles in the trade press.

* According to NASA's budget books (e.g., page SI-6 of the FY2001 budget book), estimates in "real year dollars," reflect current and prior year spending unadjusted for inflation, plus future year spending that includes a factor accounting for expected inflation.

International Space Station



Launch Year Highlights
ISS assembly launches are on hold awaiting the Space Shuttle's return to flight following the Columbia accident.

U.S. Elements based on President's FY 2004 budget