NASA'S INTERNATIONAL SPACE STATION PROGRAM: STATUS AND ISSUES

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

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April 24, 2008

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NASA'S INTERNATIONAL SPACE STATION PROGRAM: STATUS AND ISSUES

THURSDAY, APRIL 24, 2008

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

The Subcommittee met, pursuant to call, at 10:34 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mark Udall [Chairman of the Subcommittee] presiding.

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

Hearing on

NASA's International Space Station Program: Status and Issues

April 24, 2008
10:30 a.m. – 12:30 p.m.
2318 Rayburn House Office Building

Panel 1

Dr. Edward Knipling
Administrator
Agricultural Research Service
Department of Agriculture

Dr. Louis Stodieck
Director
BioServe Space Technologies
Aerospace Engineering Science
University of Colorado at Boulder

Dr. Cheryl A. Nickerson
Associate Professor of Life Sciences
Arizona State University

Mr. Thomas Pickens, III
President and CEO
Spacehab, Inc.

Panel 2

William H. Gerstenmaier
Associate Administrator
Space Operations Mission Directorate
National Aeronautics and Space Administration

Ms. Cristina T. Chaplain
Director
Acquisition and Sourcing Management
Government Accountability Office

Dr. Jeffrey Sutton
Director
National Space Biomedical Research Institute

HEARING CHARTER

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

NASA's International Space Station Program: Status and Issues

THURSDAY, APRIL 24, 2008
10:30 A.M.–12:30 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, April 24, 2008 at 10:30 a.m., the House Committee on Science and Technology's Subcommittee on Space and Aeronautics will hold a hearing to examine the status of the International Space Station (ISS) and issues related to its operation and utilization, including the planned and potential uses of the ISS to meet both NASA and non-NASA research needs.

Witnesses

Witnesses scheduled to testify at the hearing include the following:

William Gerstenmaier, Associate Administrator, Space Operations Mission Directorate, National Aeronautics and Space Administration

Ms. Cristina Chaplain, Director, Acquisition and Sourcing Management, Government Accountability Office

Dr. Jeffrey Sutton, Director, National Space Biomedical Research Institute

Dr. Edward Knipling, Administrator, Agricultural Research Service, U.S. Department of Agriculture

Thomas B. Pickens III, CEO, SPACEHAB, Inc.

Dr. Louis Stodieck, Director, BioServe Space Technologies, Aerospace Engineering Sciences, University of Colorado

Dr. Cheryl Nickerson, Associate Professor, Center for Infectious Diseases and Vaccinology, The Biodesign Institute, Arizona State University

Potential Issues

The following are some of the potential issues that might be raised at the hearing:

Status and Risks of ISS Assembly and Logistics Flights

- What is the status of ISS construction and logistics flights and what issues could impact the planned construction schedule and sequence?
- What are the main risks and challenges to successfully assembling the ISS by the time the Shuttle is retired?
- What is the impact on programmatic risk of the low level of reserves ($32 million) requested for FY09?
- What are NASA's options if scheduled and proposed ISS assembly and logistics fights are not completed by the end of 2010 and how will this impact future ISS utilization and operations?
- What challenges, risks and assumptions does each option pose?
- Do any of the options require prior action by the Congress?
- What has been the progress in securing a commercial cargo transportation capability?
- What planned actions have the international partners indicated they will take to maintain access to the ISS during the "gap"?
- Will operational, wear, or failure data now available have an impact on NASA's current ISS logistics strategy?

Utilization of the ISS and the ISS National Laboratory

- How does ISS research contribute to reducing risk in human space exploration? How much of that risk will be retired by the Administration's proposed 2016 ISS end date?
- How much of NASA's on-orbit research facilities and racks are currently being used to support research?
- Does NASA have a plan with priorities for ISS research to be conducted in the post-2010 period, and if so, what is NASA doing now to prepare that research for flight?
- How many experiment facilities/ hardware to support research investigations have been completed but are not planned for flight, and what if any plans does NASA have to fly that hardware on the ISS, free-flyers or other microgravity platforms?
- What advantages does the ISS National Laboratory provide to Laboratory partners, public and private?
- How will agency or commercial participants in the ISS National Lab get access to the ISS and who will pay for transportation?
- When will NASA know how much up-mass and down-mass is available to support research through commercial cargo vehicles?
- Will NASA's decision to support investigations on ISS be determined by commercial logistics availability or will NASA seek to supplement, if necessary, logistics requirements for research needs through non-U.S. launch capabilities?
- What lead time is required for potential ISS users, including other governmental agencies, to prepare experiments to fly on the ISS?
- What impact does the uncertain status of the ISS past 2016 have on potential users being able to plan long term research using the station?
- What will NASA do with the unused capacity and capabilities of the ISS if other agencies decide not to make significant use of it?
- What is the status of NASA's (1) development of educational projects to be conducted on the ISS, and (2) plan for research that supports national competitiveness in science, technology, and engineering, as directed in the *America COMPETES Act* (P.L. 110–69)?

BACKGROUND

Overview

The ISS is the most complex international scientific and technological endeavor ever undertaken, involving the United States, Russia, Japan, Canada, and 10 nations of the European Space Agency. One of the fundamental objectives of the ISS is to enable astronauts to learn how to live and work in space for long duration missions. When President Bush announced his *Vision for Space Exploration* in 2004, he made completion of the ISS an important part of the overall exploration initiative. The ISS has been continuously crewed for over six years; a six-person crew capability is planned to start in 2009. At assembly complete, the ISS will have a pressurized volume of over 33,000 cubic feet and a mass of over 925,000 pounds.

Development and construction of the ISS has been a difficult journey. In addition to schedule delays of its own, the ISS was severely impacted by the loss of the Shuttle *Columbia* and its crew. The ISS was in the midst of assembly when the accident took place. Today, construction is over 65 percent complete. Development is mostly done and components only await their turn on the Shuttle manifest for on-orbit assembly. The most recent additions to the ISS happened in March with the attachment of the Canadian-built Special Purpose Dextrous Manipulator and the Kibo Japanese Experiment Logistics Module—Pressurized Section. Later next month, STS–124 will take up the Japanese Experiment Module's Pressurized Module and the Japanese Remote Manipulator System.

The retirement of the Shuttle currently scheduled for 2010, will cause the U.S. to rely on partners such as Russia to provide routine transportation and emergency crew return from the station or acquire commercial services. That period of time during which the U.S. will have no crew transportation capability is referred to as "the gap." While NASA is encouraging the development of a commercial crew and cargo capability, the availability of such a capability is uncertain at this time. The Commercial Crew and Cargo Program is NASA's effort to foster the development of a cost-effective commercial space transportation capability for the post-Shuttle Era.

Initially, this capability will be used to carry cargo to the ISS; future options could involve developing a crew transportation capability. The development of the commercial cargo/crew transportation capability is being funded in the Constellation budget managed by the Exploration Systems Mission Directorate (ESMD). While the services will be demonstrated through the Commercial Orbital Transportation Systems (COTS) project, the operational responsibility for the program will move to the ISS program within the Space Operations Missions Directorate (SOMD).

NASA is seeking partnerships with other government agencies and the commercial sector to utilize the ISS as a National Laboratory, as designated by the *NASA Authorization Act of 2005.* NASA's plan for the ISS National Laboratory, the National Lab Report, was submitted to Congress in May 2007. Interest in ISS use has been demonstrated in the areas of education, human health-related research and defense sciences research. A Memorandum of Understanding for "Cooperation in Space-Related Health Research" between the National Institutes of Health (NIH) and NASA was signed on September 12, 2007. This could be the first in a series of Memorandum of Understandings with U.S. Government agencies that have expressed interest in access to the ISS for research and development purposes. In addition, NASA issued an announcement of "Opportunity for Use of the ISS by Non-Government Entities for R&D and Industrial Processing Purposes" on August 14, 2007, and is planning to enter into several Space Act Agreements as a result.

Fiscal Year 2009 Budget Request

NASA's FY09 budget provides $2.06 billion for the International Space Station Program under the direction of SOMD. It should be noted that NASA's FY 2009 budget has been restructured pursuant to the *Consolidated Appropriation Act,* 2008, and is now presented in seven accounts. In addition, the budget estimates presented in the FY 2009 request are in direct program dollars rather than in the full cost dollars used in previous Presidential budget requests. From a direct cost perspective,[1] the proposed FY09 budget for the ISS is an increase of $247 million from that appropriated in FY08.

The ISS Program budget funds:

- ISS operations. The FY09 request for ISS operations is $1,755.4 million, a slight increase from the $1,713.1 million enacted in FY08. The ISS Operations budget funds several key activities: Program Integration, Multi-User System Support, Avionics and flight software, and Launch and Mission Operations.
- ISS Crew and Cargo Services. The FY09 request for ISS Crew and Cargo Services is $304.8 million, an increase from the $100.1 million enacted in FY08. The purchase of ISS Cargo Crew Services was transferred from ESMD to SOMD in the FY 2008 budget. The total available funding for the purchase of cargo transportation services is $2.6 billion over five years.

Funding for research conducted on the ISS is included in the budget managed by the Exploration Systems Mission Directorate (ESMD). The FY09 request for ESMD's Human Research Program (HRP) is $151.9 million in direct program dollars. The HRP identifies risk for human exploration of space and measures to mitigate the risks. According to NASA's Fiscal Year 2009 Budget Request, the HRP includes $19.9 million for the ISS Medical Project, which *"includes current ISS biomedical research capabilities and on-orbit validation of next generation on-orbit equipment medical operations procedures and crew training concepts."* ESMD's budget request also provides $168 million for Exploration and Non-Exploration research to be conducted on the ISS, free-flyers, and through ground-based activities, of which $138 million is for Exploration and $30 million is for Non-Exploration research. Exploration research focuses on physical sciences in the areas of life support, thermal control, fire prevent, detection, and suppression, and on fluid flow. Non-Exploration research supports fundamental research in the areas of material sciences, fluid physics, combustion sciences, cellular and animal research, and microbial research, among other areas.

[1] As part of the Congressionally directed budget restructuring, NASA shifted from a full-cost budget, in which each project budget included overhead costs, to a direct cost budget. All overhead budget estimates are now consolidated into the Cross Agency Support budget line. NASA has stated that maintaining a full cost budget with seven appropriations accounts would be overly complex and inefficient. The direct cost budget shows program budget estimates that are based entirely on program content. Individual project managers continue to operate in a full-cost environment, including management of overhead costs.

Assumed Budget Growth for the ISS Program FY 2009–FY 2013

NASA's out-year projections for the ISS Program in the President's FY09 budget request show minor funding level changes through 2013.

$ in millions					
FY 2008 Enacted	FY2009 Request	FY 2010	FY2011	FY2012	FY2013
1,813.2	2,060.2	2,277.0	2,176.4	2,448.2	2,143.1

Key Challenges Related to the FY09 Budget and Five-Year Runout

Key challenges related to the FY09 budget request and five-year runout for the ISS program include:

- *Low level of program reserves.* The ISS program has depleted reserves through FY 2009 while facing the most challenging period of ISS assembly.
- *Uncertain status of the two logistics flights.* Two of the remaining Shuttle flights are listed as "contingency" and have not yet been approved by the Office of Management and Budget (OMB)—although NASA says sufficient funds have been included in the FY09 budget request. NASA has indicated that the two flights needed to deliver spares and logistics in advance of the Shuttle's retirement are necessary and of high priority.
- *Cuts in research funding.* Funding for ISS research has been cut back significantly over the last several years, and the research community that was intended to utilize the ISS has been decimated by reductions in funding. This raises the issue of reduced opportunity to attract top research scientists in the future.
- *Export control restrictions.* Current International Traffic in Arms Regulations (ITAR) restrictions on NASA *"are a threat to the safe and successful integration and operations of the International Space Station,"* according to the ISS Independent Safety Task Force (IISTF) issued in 2007. The Task Force also found that workforce interactions must enable direct interfaces to assure safe and successful operations. These interactions, including the ability to exchange and discuss technical data relevant to vehicle operation, are hampered by the current ITAR restrictions.

ISS Cargo and Crew Transportation Services in the Post-Shuttle Era

The Commercial Crew and Cargo Program is NASA's effort to foster the development of a cost-effective commercial space transportation capability for the post-Shuttle Era. This capability will initially be utilized to carry cargo to the ISS; future options could involve developing a crew transportation capability. The development of the commercial cargo/crew transportation capability is being funded in ESMD's Constellation budget. Once the services have been demonstrated (Phase 1), the operational responsibility for the program will move to the ISS program within SOMD.

As the Space Shuttle nears retirement, NASA's stated preferred solution for ISS crew and cargo delivery and return requirements is to use commercial services provided by space transportation companies. NASA's Commercial Orbital Transportation Services (COTS) project is intended to facilitate U.S. private industry's development of cargo and crew space transportation capabilities with the goal of demonstrating reliable, cost effective access to low-Earth orbit. NASA had initially selected two partners for its COTS project under Space Act Agreements. One partner failed to meet NASA's milestones, and NASA terminated the Agreement. The other partner, SpaceX, recently announced that it has delayed the first demonstration flight for their Falcon 9 rocket for six to nine months. Following GAO's decision rejecting a challenge by the terminated partner to NASA's plans to utilize a Space Act Agreement rather than a government contract, NASA made an award to Orbital Sciences Corporation in February 2008. Last week, NASA issued a Request for Proposals (RFP) for Phase 2 of the COTS program, now called Commercial Resupply Services, with a planned contract award by the end of the year. Both of the current COTS partners are working only on cargo carriers.

If NASA's preferred solution of using commercial services is not attainable by the time the Shuttle is retired, the agency has indicated that it will rely on prepositioned spares to be sent up to the ISS before the Shuttle retires. In an interview in Aviation Week last week, NASA's Associate Administrator for Space Operations said *"We recognized that there may be a little bit of a delay in the delivery of those [commercial] services,"* adding that *"Our plan is that if we have a delay we would live off the spares we flew up on Shuttle and take some limited degradation in space station capabilities until those commercial services come on line."* However, this poses a risk since the last two Shuttle flights scheduled to bring up those spares have not been approved by the Administration. As to the use of international partner cargo capabilities, NASA said last week that it will not ask Congress for permission to continue buying cargo services from Russia after 2011. European Automated Transfer Vehicles (ATV) and Japanese H–II Transfer Vehicles (HTV) are alternatives but would require some time to procure.

Regarding crew transportation during "the gap," purchases of Russian capabilities beyond 2011 will require an extension of the waiver currently granted in the *Iran, North Korea and Syria Non-Proliferation Act* (INKSNA). Last week, NASA notified the Congress that it needs to continue using Russian Soyuz capsules to deliver crew to the ISS after the Shuttle retires in 2010 and is thus seeking an extension of INKSNA waiver authority. A copy of NASA's letter to Chairman Udall transmitting the proposed waiver and the waiver itself are included as Attachment 1.

Research Objectives of the ISS

Although one NASA objective for the ISS was *to create a world-class laboratory,* cost overruns, a decision to focus on a "core complete" configuration, the elimination of several planned research facilities, and a smaller crew size led a National Research Council (NRC) committee to conclude in a 2003 report, *Factors Affecting the Utilization of the International Space Station,* that achieving that goal was *"unlikely."*

- Following President Bush's announcement of a *Vision for Space Exploration* in January 2004, NASA reoriented its goals for the ISS to focus on exploration.

A 2006 NRC report, *NASA's Plans for the International Space Station,* identified several priority areas of research to support NASA's exploration goals, including *"effects of radiation on biological systems, loss of bone and muscle mass during space flight, psychosocial and behavioral risks of long-term space missions, individual variability in mitigating a medical/biological risk, fire safety aboard spacecraft, and multi-phase flow and heat transfer issues in space technology operations."*

In addition, the report recommended that NASA take several other actions in utilizing the ISS to support exploration missions. For example, the NRC recommended that:

- *"NASA should develop an agency-wide, integrated utilization plan for all ISS activities as soon as possible."*
- *"NASA should develop and maintain a set of operations demonstrations that need to be conducted on the ISS to validate operational protocols and procedures for long-duration and long-distance missions such as the ones to Mars."*
- *"NASA should plan options and decision points for obtaining a post-Shuttle logistics capability for . . . demonstrating the technology and operations that will enable exploration missions. NASA should establish priorities and develop back-up plans to enable the post-2010 deployment of large ISS structural components and research facilities required to accomplish exploration mission objectives."*

In 2007, at the House Committee on Science and Technology's hearing on *NASA's Fiscal Year 2008 Budget Request,* NASA provided material for the record noting that NASA's research use of the ISS aligns with the Agency's needs in the following areas:

- Research, Development, Test, and Evaluation of Biomedical Protocols for Human Health and Performance on Long-Duration Space Missions
- Research, Development, Test, and Evaluation of Systems Readiness for Long-Duration Space Missions
- Development, Demonstration, and Validation of Operational Practices and Procedures for Long-Duration Space Missions.

Congressional Policy Direction on ISS Utilization

Congress directed in the *NASA Authorization Act of 2005* (P.L. 109–155) that NASA complete the assembly of the ISS and ensure its utilization for basic and applied research, as well as commercial research, and other benefits to the Nation. As part of this policy direction, NASA is to sustain the necessary scientific expertise to support research in disciplines that require microgravity environments (e.g., molecular crystal growth, animal research, basic fluid physics, combustion research, and cellular research). To ensure that NASA continues to sustain basic research in life and microgravity sciences, the Act directs NASA to allocate at least fifteen percent of ISS research funds to non-exploration research conducted on the ISS, free-flyers and ground. In addition, the Act designates the ISS as a National Laboratory to *"increase the utilization of the ISS by other federal entities and the private sector through partnerships, cost-sharing agreements, and other arrangements that would supplement NASA funding of the ISS."*

Status of NASA Plans for ISS Utilization and Ongoing Utilization Activities

In response to direction in the 2005 *NASA Authorization Act,* NASA submitted a report, the *NASA ISS Research and Utilization Plan.* The nature of that report was high-level, and as a follow-up, NASA submitted three additional documents detailing NASA plans for ISS utilization: 1) *Human Research Program Utilization Plan for the International Space Station,* 2) *ISS Exploration and Non-Exploration Research Project Plan for the NASA ISS Utilization Plan,* 3) *Consolidated Operations and Utilization Plan 2007–2015.* The first report identifies the human health risks to be addressed by the ISS Human Research Program, for which 25 of 32 risks require research on the ISS to mitigate the risk. The second report provides a top-level plan for ISS research to support NASA's exploration objectives (applied) as well as non-exploration (basis) research. The third report details the operational plans for utilizing the ISS, including allocation of resources among partners. An overview summary of these documents states that *"human biomedical research is of the highest priority in order to prepare for longer duration human space exploration missions . . ."*

At a hearing of the House Committee on Science and Technology on NASA's Fiscal Year 2008 Budget Request, the NASA Administrator testified that *"we are still building the Station, and its full capability as a research laboratory is mostly in front of us. But we can't have a research laboratory until we get the power and the water and the air conditioning fully in place. And that is what we are doing right now."* He further stated that *"I believe it [the Station] should be sustained as long as the costs of its operations and maintenance, once built . . . seem to be justified by the research, which is being returned . . ."* The duration of Space Station operations has not yet been determined.

Upon request of the Committee, NASA provided material for the record noting that NASA has conducted 17 NASA Human Research Program investigations (the ISS component of that research was complete) which supported 44 researchers "worldwide." NASA also reported that there were 16 investigations of the Human Research Program being conducted on the ISS in which 49 researchers "worldwide" were involved. NASA's plans were to conduct nine Human Research Program investigations over the next year, which would involve 25 researchers. NASA also conducts exploration and non-exploration research on the ISS, although it is not completely clear how many experiments have been flown or how many will be flown and when.

ISS as a National Laboratory

As directed in the 2005 *NASA Authorization Act,* NASA submitted a report to Congress on an *International Space Station National Laboratory Application Development.* NASA indicates that approximately 50 percent of planned U.S. utilization resources on ISS could be available for non-NASA use through the ISS National Laboratory. In August 2007, NASA solicited proposals for *"Opportunity For The Use Of The International Space Station By U.S. Non-Government Entities For Research And Development And Industrial Processing Purposes."*

ISS National Laboratory Partners and Prospective Partners

In September 2007, NASA and the National Institutes of Health (NIH) signed a Memorandum of Understanding (MOU) for Cooperation on Space-Related Research. The MOU will foster synergies in research being sponsored by both agencies that will help ensure astronaut health, especially on long-duration missions, and yield benefits for medical science on Earth. For example, research on the loss of bone density and muscle mass resulting from the effects of microgravity may improve treatment for bone and muscle diseases. Better understanding of the effects of gravity on astronauts' balance may increase our knowledge of conditions such as vertigo, problems of the inner ear, and dizziness. Research on how microorganisms respond to microgravity may also provide insights into the immune system's response to infectious diseases.

The MOU outlines NIH's particular interest in the use of the ISS for research in the following types of areas:

- *"Basic biological and behavioral mechanisms in the absence of gravity*
- *Human physiology and metabolism*
- *Spatial orientation and cognition*
- *Cell repair processes and tissue regeneration*
- *Pathogen infectivity and host immunity*
- *Medical countermeasures*
- *Health care delivery and health monitoring technologies"*

A copy of the MOU is included as Attachment 2.

In a Fall 2007 issue of *NIH Medline Plus,* Dr. Stephen Katz, National Institute of Arthritis and Musculoskeletal and Skin Diseases, said, *"An enormous amount of time will be required to develop the questions and experimental models for use on the Space Station. . ..."* Members may wish to probe whether or not the Administration's current plans for operating the ISS until 2016 will be sufficient to accommodate the time NIH would need to prepare and carry out research investigations.

NASA is currently working on an MOU with the U.S. Department of Agriculture. Potential UDSA-sponsored research on the ISS could help to advance knowledge in the areas of nutrition and animal and plant biology. Potential goals of the research include outcomes that could provide additional benefits in assuring food safety and the quality of agricultural products.

SPACEHAB, a commercial company that provides space products and services, is also discussing partnership opportunities with NASA as part of the ISS National Laboratory. The company announced in 2007 plans *"to develop a new company division that will focus on manufacturing pharmaceuticals and materials in space for distribution into the commercial marketplace."* Following on this path, SPACEHAB's January 28, 2008 press release announced the company's plans to use the ISS for *"research, development, and industrial processing purposes."* SPACEHAB's past relationship with NASA has been in providing pressurized habitation modules, unpressurized cargo carriers, and related space flight equipment and services to support research and other payloads for launch, operation, and return from NASA space flight and ISS missions. In addition, SPACEHAB has an unfunded Space Act Agreement with NASA to develop (along with several partner companies) a commercial transportation system (COTS) to provide logistical support to the ISS following the retirement of the Shuttle in 2010.

The ISS National Laboratory report refers to *"the availability of cost-effective transportation services"* as the most significant risk for the success of the National Laboratory. The report prepared for Congress did not indicate that NASA planned to provide transportation services to ISS National Laboratory partners. According to the ISS National Laboratory report to Congress, NASA plans to begin managing the operations and utilization of the ISS National Laboratory. NASA is also considering alternative approaches for managing the ISS national lab.

Readiness of the Life and Microgravity Sciences Research Community to Support ISS Research

At a hearing of the Subcommittee on Space and Aeronautics on *"NASA's Space Shuttle and International Space Station Programs: Status and Issues"* in July 2007, Dr. G. Paul Neitzel, a professor of fluid mechanics, testified that *"At its zenith, the budget of the then Office of Biological and Physical Research . . . had grown to approximately $1B and the FY03 OBPR Task Book . . . shows a broad research program containing roughly 1000 tasks, supporting over 1,700 PIs and co-investigators and nearly 3,000 students. . ..."* Following the *Columbia* accident and the President's announcement of a *Vision for Space Exploration,* NASA reduced the size of the life and microgravity sciences program. *"In December 2005, NASA sent letters to hundreds of investigators in the program, informing them of significant cuts in their funding for FY06 and the termination of their grants effective September 30, 2006."* Dr. Neitzel further noted that *"The re-establishment of an external research community will take years, if it can be accomplished at all."*

Existing and Planned Research Facilities for U.S. Use on the ISS

The U.S. laboratory module, Destiny, houses several research facilities. These include the:

- Human Research Facility racks
- Microgravity Science Glovebox

- The Minus Eight-Degree Freezer for ISS that can store and freeze life science and biological samples
- Expedite the Processing of Experiments to Space Station (EXPRESS) racks, which can provide power, data, and fluids and other utilities needed to support research experiments that can attach to the racks.

The following are NASA facilities planned for inclusion on the ISS, and most, if not all, have been manifested on upcoming Shuttle flights to the ISS:

- Fluids and Combustion Facility (includes the Combustion Integrated Rack and the Fluids Integrated Rack)
- Microgravity Science Research Rack
- Space Dynamically Responding Ultrasound Matrix Facility
- Window Observation Research Facility
- EXPRESS Rack 6
- Muscle Atrophy Research Exercise System
- Five External Logistics Carriers (ELCs) each of which can support two payloads that do not require a pressurized environment.
- Several International Standard Payload Racks (ISPR)
- Other research facilities can be accommodated on international modules.

The Alpha Magnetic Spectrometer (AMS), a collaboration between the Department of Energy and international participants, had been planned for flight to the ISS, but is currently not manifested on any of the remaining Shuttle flights.

Use of ISS to Support Math and Science Education and Competitiveness

In exploring the opportunities for using the ISS National Laboratory for potential educational activities, a NASA-led task force produced the *International Space Station National Laboratory Education Concept Development Report.* The task force concluded *"that there is significant interest among other federal agencies in the opportunity to further develop the ISS as an asset for education."*

In 2007, Congress passed the *America COMPETES Act,* which became Public Law 110–69. Section 2006 of the law directs NASA to use the results of the ISS education task force report to *"develop a detailed plan for implementation of one or more education projects that utilize the resources offered by the International Space Station."*

In addition, Section 2006 directs NASA to *"develop a detailed plan for identification and support of research to be conducted aboard the International Space Station, which offers the potential enhancement of United States competitiveness in science, technology, and engineering."* NASA is to work with agencies and organizations that have entered into agreements as partners on the ISS National Laboratory.

Establishing ISS Program Service Life

NASA indicates that while the FY09 budget run out does not presently allocate funds for operating ISS beyond 2016, it is not taking any action to preclude it. Likewise, out year projections do not include costs to retire and de-commission ISS.

Two new issues have bearing on the ISS's life expectancy:

1. Reports of sooner-than-expected wear on components, such as the beta gimbal assembly (BGA) and the Solar Array Rotary Joint (SARJ) could be indications that NASA may need to re-analyze its sparing strategy due to uncertainties about the last two Shuttle logistics flights and resupply options after the Shuttle is retired in 2010.
2. It was recently reported that Russia will ask partners in June to extend the utilization of the ISS until 2020 because a Russian segment would take longer to complete. Russia still does not have a research module on the ISS and the Multi-Purpose Laboratory Module (MLM) would provide the expanded research capability desired. The MLM will be Russia's primary research module as part of the ISS. According to news reports, funding issues had delayed the MLM from an initial 2007 date. A NASA official has told Subcommittee staff that NASA will discuss these issues at a meeting of the partner Space agencies in July of this year.

Attachment 1

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

April 11, 2008

The Honorable Mark Udall
Chairman
Subcommittee on Space and Aeronautics
Committee on Science and Technology
U.S. House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

The National Aeronautics and Space Administration (NASA) proposes the enclosed amendment to the Iran, North Korea, and Syria Nonproliferation Act (50 USC 1701 note). The purpose of the amendment is to permit NASA to continue to procure Russian support for the International Space Station (ISS) until suitable U.S. capabilities are in place. We urge enactment of this important amendment.

The amendment provides a balanced approach, maintaining both U.S. nonproliferation principles and objectives as well as a U.S. presence on ISS. The justification and purpose for this proposed amendment are stated more fully in the enclosed sectional analysis. As an overview, NASA has procured Soyuz services through the fall of 2011, consistent with existing authority under the Act. However, U.S. obligations to provide crew transportation and emergency services to the ISS continue beyond 2011, and Soyuz will be the only viable option for the United States to meet these obligations until the U.S. Orion Crew Exploration Vehicle or U.S. commercial providers can provide such transportation and rescue services. Fabrication of Soyuz vehicles must begin approximately 36 months prior to launch, according to the responsible Russian entities. Thus, unless contractual arrangements for the provision of crew rescue and rotation services beyond 2011 are concluded in 2008, the production of Soyuz vehicles for U.S. crew transportation requirements will be at risk. This, in turn, means that prompt legislative action is needed to provide further relief beyond 2011 and allow for the negotiation of these arrangements.

The Office of Management and Budget advises that there is no objection to the submission of this legislation from the standpoint of the Administration's program.

Sincerely,

Michael D. Griffin
Administrator

2 Enclosures

Amendment to the Iran, North Korea, and Syria Nonproliferation Act

The Iran, North Korea, and Syria Nonproliferation Act (50 USC 1701 note) is amended—

In subsection 7(1)(B) –

(a) after the phrase "except that such term does not mean" insert a ":";
(b) indent the following phrase and insert "(i)" at the beginning;
(c) replace the final period with a "; or"; and
(d) add the following new subsection:

"(ii) payments in cash or in kind made or to be made by the United States Government between January 1, 2012 and reentry into the Earth's atmosphere of the International Space Station at its end of life, for work to be performed or services to be rendered during that period necessary to meet United States obligations under the Agreement Concerning Cooperation on the Civil International Space Station, with annex, signed at Washington on January 29, 1998, and entered into force March 27, 2001, or any protocol, agreement, memorandum of understanding, or contract related thereto, except that this subsection does not allow for payments in cash or in kind to be made by the United States Government for:

(a) any cargo services provided by a Progress vehicle; or
(b) any crew transportation or rescue services provided by a Soyuz vehicle once (1) the Orion Crew Exploration Vehicle reaches Full Operational Capability or (2) a United States commercial provider of crew transportation and rescue services demonstrates the capability to meet International Space Station mission requirements."

Enclosure 1

Amendment to the Iran, North Korea, and Syria Nonproliferation Act

Sectional Analysis

The Administration remains committed to the important objective of persuading the Russian Government and Russian entities to improve their nonproliferation efforts regarding Iran, North Korea, and Syria. Accordingly, the proposed amendment to the Iran, North Korea, and Syria Nonproliferation Act (the Act) would maintain key existing U.S. nonproliferation tools while allowing payments to Russian entities that support U.S. obligations to the International Space Station (ISS) beyond December 31, 2011.

The provision would extend the Act's exception to the prohibition on "extraordinary payments" to the Russian government and Russian entities for goods or services relating to the ISS from January 1, 2012 to the end of the life of the ISS. It would exclude from the exception any payments after December 31, 2011, for cargo services provided by a Progress vehicle. The new provision would also exclude from the exception payments for crew transportation or rescue services provided by a Soyuz vehicle once (1) the U.S. Orion Crew Exploration Vehicle reaches Full Operational Capability or (2) a U.S. commercial provider of crew transportation and rescue services demonstrates the capability to meet ISS mission requirements.

An international partnership governed by an Intergovernmental Agreement (IGA) among the United States, Canada, multiple European States, Japan, and Russia established the ISS. This partnership is a long-standing and interdependent one, with roles and responsibilities outlined in the IGA and subordinate agreements for design, development, and operations of the program. Pursuant to the IGA and subordinate agreements, NASA has an obligation to its non-Russian ISS Partners to provide crew rotation and rescue services during the life of the ISS. Currently, the Russian vehicle Soyuz is the sole provider of rescue services, with the Space Shuttle providing crew transportation. After Shuttle retirement, the partnership will be dependent on Russia to provide both crew transportation and rescue services with Soyuz until the U.S. Orion Crew Exploration Vehicle (CEV) achieves Full Operational Capability (currently projected for 2016) and can provide crew transportation and rescue services or a U.S. commercial provider can demonstrate the capability to provide crew transportation and rescue services to meet ISS mission needs.

NASA has procured Soyuz services through the fall of 2011, consistent with existing authority under the Act. Fabrication of Soyuz vehicles must begin approximately 36 months prior to launch based upon information provided by the Russian entities responsible for manufacturing these vehicles. Thus, unless contractual arrangements for rescue and crew rotation services after 2011 are concluded in 2008, the production of Soyuz vehicles for U.S. crew transfer and rescue will be at risk. This in turn means that prompt legislative action is needed to provide further relief beyond 2011 and allow for the negotiation of these arrangements.

Enclosure 2

Absent the proposed relief, the United States will be unable to meet one of its most critical partner obligations: providing crew transportation and rescue services to European, Japanese and Canadian crews. The United States would not have an American "presence" aboard the ISS, either in terms of astronauts or access to research facilities for the U.S. scientific community, if we could not purchase crew transportation and rescue services from Russia, as no non-Russian crew transfer vehicles will be available until the CEV reaches Full Operational Capability or a U.S. commercial provider demonstrates the capability to meet ISS crew transportation and rescue needs. Given NASA's operational, engineering, safety, and other responsibilities for the ISS, NASA is concerned whether the ISS could remain fully operational for any significant time period absent an American presence.

Moreover, the authority under the present exception to the Act has been used to obtain ancillary goods and services from Russia in addition to crew transport and rescue. For example, although purchased from Russia, the Zarya module is legally a U.S. element under the Space Station agreements, and NASA must purchase unique tools and engineering support, such as sustaining software, from Russia for the continued operation of the module. NASA will have a continuing requirement to procure certain goods and services where Russia offers unique capabilities, such as those related to Russian space suits, software and hardware engineering support, and Extravehicular Activity tools and training, which are required for effective operations onboard the ISS. This amendment will allow NASA to continue to purchase such goods and services that are necessary to meet U.S. responsibilities under the Space Station Agreements.

In addition, this limited relief being requested (*i.e.*, through the life of the ISS) may be necessary even after a U.S. commercial capability is available, because some potential U.S. commercial providers of cargo services and of crew transportation and rescue services have Russian contractors or other relationships with Russian entities that, without this amendment, could trigger the Act's "extraordinary payment" prohibition.

With respect to furthering the United States' nonproliferation objectives and tools, in addition to the positive incentive provided by prudent, closely monitored space cooperation in areas of great benefit to the United States, the proposed amendment would not affect the current nonproliferation framework. The first five sections of the Act establish a requirement to report to Congress on every foreign person that transfers controlled items to, or acquires controlled items from, Iran, Syria, or North Korea and authorizes sanctions against such foreign persons. These key reporting and sanctions provisions would not be affected by the proposed amendment. In addition, the amendment leaves in place the ban on any United States Government agency making extraordinary payments in connection with the ISS or other human space flight to any persons (including entities) subject to sanctions under the Act or the Proliferation of Weapons of Mass Destruction Executive Order (E.O. 12938, as amended by E.O. 13094) or if the U.S. Government agency (in consultation with other interested U.S. Government agencies) anticipates that such payments will be passed on to such persons. Finally, specific proposals for cooperation with Russia would continue to be subject to review under relevant mechanisms such as the Department of State's Circular 175 process for interagency review of international agreements. Likewise, export and import licensing regulations would ensure that U.S. nonproliferation objectives are maintained.

Attachment 2

September 12, 2007

Memorandum of Understanding between the National Institutes of Health and the National Aeronautics and Space Administration for Cooperation in Space-Related Health Research

I. **PURPOSE AND SCOPE**

This Memorandum of Understanding (MOU) sets forth a framework of cooperation between the National Institutes of Health (NIH) and the National Aeronautics and Space Administration (NASA) to encourage:

- Communication and interaction between the NIH and NASA research communities to facilitate space-related research and to integrate results from that research into an improved understanding of human physiology and human health.
- Exchange of ideas, information, and data arising from their respective research efforts.
- Development of biomedical research approaches and clinical technologies for use on Earth and in space.
- Research in Earth- and space-based facilities that could improve human health on Earth and in space.

Of particular interest is the application of the U.S. portion of the International Space Station (ISS) as a National Laboratory, as established by P.L. 109-155. The designation as a National Laboratory underscores the significance and importance that the United States places on the scientific potential of the ISS for research in areas including, but not limited to,

- Basic biological and behavioral mechanisms in the absence of gravity.
- Human physiology and metabolism.
- Spatial orientation and cognition.
- Cell repair processes and tissue regeneration.
- Pathogen infectivity and host immunity.
- Medical countermeasures.
- Health care delivery and health monitoring technologies.

Each agency has existing programs and resources for facilitating health research and technology development. Research facilitated by this MOU will be complementary to studies supported by the NIH, its Institutes and Centers, and NASA, at the agencies' intramural or extramural laboratories.

In pursuing objectives through this MOU, the NIH and NASA shall manage their own activities and use their own resources, including the expenditure of their own funds unless otherwise agreed in specific implementing agreements.

II. **AUTHORITY**

The NIH enters into this MOU in accordance with section 301 of the Public Health Service Act, which authorizes NIH to cooperate with public authorities and scientific institutions.

The NASA enters into this MOU, pursuant to section 203(c) of the National Aeronautics and Space Act of 1958, as amended [42 U.S.C. 2473 (c)].

The NIH and NASA may be individually referred to as a "Party" and collectively referred to as the "Parties." Nothing in this MOU alters the statutory authorities of the NIH or NASA. It is intended to facilitate cooperative efforts in the conduct of research and development of technologies in the area of space-related health research. It does not supersede or void existing agreements between NASA and the NIH or any of its Institutes or Centers.

III. BACKGROUND

The programmatic strengths of the NIH and NASA offer opportunities for synergy that can accelerate basic knowledge and technology development that can be applied to humans in space and on Earth. For example, NASA enables research in reduced gravity by facilitating access to the unique environment of space and has created systems that are analogous to the space environment. NASA also supports technologies that are not yet available to Earth-based researchers that could contribute greatly to biomedical advances. Likewise, the NIH, with its 27 Institutes and Centers, is capable of reaching a broad range of basic and clinical biomedical researchers whose involvement in space-related projects would create an intellectual environment where unanticipated breakthroughs could occur.

In a report accompanying the National Aeronautics and Space Administration Authorization Act of 2005 (P.L. 109-155), the Senate Committee on Commerce, Science, and Transportation repeatedly emphasized that a primary justification for support of the ISS is its scientific and research potential (Senate Report 109-108). Recognizing that the ISS will be capable of hosting a wide range of scientific research that can only be undertaken in a microgravity environment, the authors of P.L. 109-155 specifically noted that the NASA portfolio should include microgravity research that is not related directly to its human exploration efforts (e.g., growth of molecular crystals, development of cell-based technologies).

When complete, the ISS will provide a unique life sciences laboratory and will be able to facilitate testing of new biosensors and telemedicine technologies. It also may promote development of international research collaborations that would improve the lives of people around the world or accelerate fundamental discoveries. The U.S. segment of the ISS will have laboratory space, data processing capabilities, and crew time for experiments conducted on the ISS once it is fully operational in 2011. Because commitment of ISS resources is likely to be made on a first come, first serve basis, now is an appropriate time for researchers to begin proposing studies, conducting preliminary experiments on Earth, and arranging with NASA to have their hypotheses tested on the ISS.

IV. RESPONSIBILITIES

This MOU is intended to provide an enabling mechanism for coordination and cooperation whenever appropriate and mutually beneficial, subject to program priorities and availability of funds and personnel.

Within the context of the Purpose and Scope above, the NIH agrees to use reasonable efforts to:

- Publicize, to the intramural and extramural communities, the availability of the ISS as a research environment that can accommodate a variety of experimental approaches and can address a vast range of research questions. In the course of its communications with the scientific community, NIH will note that, with respect to the placement of any article on the ISS, liability is governed by Article 16 of the 1998 ISS Intergovernmental Agreement requiring cross waivers of liability, as implemented by 14 CFR Part 1266. Separate launch services or payload integration agreements, as appropriate, may be required prior to flight.
- Give careful consideration through the standard review process to well-developed, investigator-initiated extramural applications and potential intramural activities related to space-related health research that are developed in response to the publicity noted above.

Within the context of the Purpose and Scope above, NASA agrees to use reasonable efforts to:

- Advise investigators on implementation of NIH-funded projects that would use the ISS.

Within the context of the Purpose and Scope above, the NIH and NASA agree to use reasonable efforts to:

- Encourage space-related health research through the exchange of expertise, scientific and technical information, data, and publications.
- Provide technical expertise for performance, planning, review, or consultation in areas of mutual interest, subject to program priorities and availability of funds and personnel.
- Facilitate and enhance research and development activities by either agency.
- Coordinate publicity of mutually reinforcing activities, publications, and research results.
- Include representatives from each agency in workshops, working groups, seminars, and other related activities.

V. RESPONSIBLE OFFICERS/AGENCY CONTACTS

For the National Institutes of Health:

Anita M. Linde
Director, Office of Science Policy and Planning
National Institute of Arthritis and Musculoskeletal and Skin Diseases
Building 31, Room 4C13
National Institutes of Health
Bethesda, MD 20892-2350
Phone: 301-496-8271
Fax: 301-480-0183
lindea@mail.nih.gov

For the National Aeronautics and Space Administration:

Mark Uhran
Assistant Associate Administrator
International Space Station
Space Operations Mission Directorate, Suite 7P39
National Aeronautics and Space Administration
Washington, DC 20546-0001
Phone: 202-358-2233
Fax: 202-358-2848
mark.l.uhran@nasa.gov

VI. FINANCIAL OBLIGATIONS

This MOU does not constitute any obligations of funds by either party. There will be no transfer of funds or other financial obligations between NASA and NIH under this Agreement. Each Party will fund its own participation. All activities under or pursuant to this agreement are subject to the availability of appropriated funds, and no provision herein shall be interpreted to require obligations or payment of funds in violation of the Anti-Deficiency Act, 31 U.S.C. § 1341.

VII. DATA RIGHTS

The Parties agree that, to the extent permitted by law, the information and data exchanged in furtherance of the activities under this MOU will be exchanged without use and disclosure restrictions unless required by national security regulations or otherwise agreed to by the Parties for specifically identified information or data (e.g., information or data specifically marked with a restrictive notice).

VIII. **AMENDMENT AND TERMINATION**

The MOU may be amended at any time by the mutual written consent of the Agencies. On an annual basis, the Parties will conduct a review of this MOU to evaluate progress and achievement of mutual goals and objectives consistent with the purpose and scope.

Either Party may unilaterally terminate this MOU by providing 90 calendar days written notice to the other Party.

IX. **TERM OF AGREEMENT**

This MOU will be effective upon the date of the last signature below, and shall remain in effect for 5 years. At the conclusion of 5 years, the parties will consider the development of a new agreement.

X. **ACCEPTANCE AND APPROVAL OF AUTHORIZING OFFICIALS**

Agreed to by:

NATIONAL INSTITUTES OF HEALTH

Elias A. Zerhouni, M.D. Date
Director

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Michael Griffin, Ph.D. Date
Administrator

Chairman UDALL. This hearing will come to order. Good morning to all of you. I want to welcome today's witnesses to our hearing. We welcome your participation and look forward very much to your testimony.

Today's hearing continues the Subcommittee's oversight of NASA's major programs by focusing on the International Space Station (ISS) Program. While it is a program that has had a long and at times controversial and frustrating development path, I am impressed with the progress that has been made in assembling and operating this incredibly complex international space science and technology facility. The NASA witness, Mr. William Gerstenmaier, will describe some of the recent accomplishments of the ISS Program in his testimony, and he and his team and all the international partners, too, can take justifiable pride in what they are achieving.

An important component of that success is the way the ISS is truly becoming the *International* Space Station with American, Japanese, European, Canadian, and Russian astronauts, engineers, and program managers working together to overcome challenges on a continuing basis.

Yet, if we are to justify the significant resources that have been expended on the ISS Program, we need to be confident that it is going to be used in as productive a manner as possible once it is assembled.

To that end, I am encouraged by news of emerging research and commercial collaborations with NASA, and I am looking forward to hearing from our witnesses from the research and commercial sectors about their plans for utilizing the Station. Equally important, their views on what it will take to make the ISS a productive venue for research and commercial activities.

I also want to hear NASA tell us what it intends to do to make the ISS a productive facility, not just for research and commercial activities but also to carry out the ISS research and technology activities that NASA has said will be necessary to prepare for future exploration.

In this hearing instead of dwelling on past problems, I want to focus on where we go from here.

However, as NASA talks about providing research opportunities on the Station, we cannot forget that the funding cuts NASA has made to its microgravity research programs in recent years, whether willingly or not, have largely decimated the research community.

Thus, I think the onus has to be on NASA to prove that it means what it says by taking meaningful steps both to make the Station a productive venue for research and to start to rebuild the research community.

Yet, it won't be possible to have a productive Station unless the facility can be sustained after the Shuttle is retired.

I am going to want to hear from NASA about how it plans to ensure the availability and productivity of the ISS after the Shuttle is retired, what it considers the major risks ahead, and how it plans to manage those risks.

It is no secret that we are currently living with the adverse impacts of the Administration's shortsighted decision four years ago to accept a four-year gap in U.S. crew launch capabilities after the

Shuttle is retired. I hope we learn from that experience and not let the future of the Station to be determined by equally shortsighted measures.

If we are to receive a meaningful return on the Nation's investment in the ISS, we need to ensure that the Station's post-Shuttle logistics re-supply needs are adequately funded.

It is also clear that it is time for the Administration to commit to flying the two contingency Shuttle flights that will deliver critical spares and logistics to the Station before the Shuttle is retired.

Based on all the information provided to the Committee to date, it is clear that those flights are not optional if NASA is to minimize the risks facing the ISS after 2010.

And finally, we need to ensure that any decision on the service life of this international facility is based on sound policy, considerations, and thorough consultations with our international partners and not simply be a date based on the current Administration's desire to make it conform to their own under-funded budget plan for NASA.

Well, we have a great number of issues to consider today. As I have said, we have a very good panel of witnesses to help us address them.

Again, I want to welcome you, and we will look forward to your testimony.

[The prepared statement of Chairman Udall follows:]

PREPARED STATEMENT OF CHAIRMAN MARK UDALL

Good morning. I'd like to welcome our witnesses to today's hearing. We welcome your participation and look forward to your testimony.

Today's hearing continues the Subcommittee's oversight of NASA's major programs by focusing on the International Space Station program.

While it is a program that has had a long, and at times controversial and frustrating development path, I am impressed with the progress that has been made in assembling and operating this incredibly complex international space-based science and technology facility.

The NASA witness, Mr. William Gerstenmaier, will describe some of the recent accomplishments of the ISS program in his testimony, and he and his team—and all of the international partners too—can take justifiable pride in what they are achieving.

An important component of that success is the way that the ISS is truly becoming the *International* Space Station, with American, Japanese, European, Canadian, and Russian astronauts, engineers, and program managers working together to overcome challenges on a continuing basis.

Yet, if we are to justify the significant resources that have been expended on the ISS program, we need to be confident that it is going to be used in as productive a manner as possible once it is assembled.

To that end, I am encouraged by news of emerging research and commercial collaborations with NASA, and I am looking forward to hearing from our witnesses from the research and commercial sectors about their plans for utilizing the Station. . .

And equally importantly, their views on what it will take to make the ISS a productive venue for research and commercial activities.

I also want to hear NASA tell us what *it* intends to do to make the ISS a productive facility—not just for research and commercial activities, but also to carry out the ISS research and technology activities that NASA has said will be needed to prepare for future exploration.

In this hearing, instead of dwelling on past problems, I want to focus on where we go from here.

However, as NASA talks about providing research opportunities on the ISS, we cannot forget that the funding cuts NASA has made to its microgravity research programs in recent years—whether willingly or not—have largely decimated that research community.

Thus, I think the onus has to be on NASA to prove that it means what it says by taking meaningful steps both to make the ISS a productive venue for research and to start to rebuild that research community.

Yet, it won't be possible to have a productive ISS unless the facility can be sustained after the Shuttle is retired.

I am going to want to hear from NASA about how it plans to ensure the viability and productivity of the ISS after the Shuttle is retired, what it considers the major risks ahead, and how it plans to manage those risks.

It is no secret that we are currently living with the adverse impacts of the Administration's shortsighted decision four years ago to accept a four-year gap in U.S. crew launch capabilities after the Shuttle is retired.

I hope we learn from that experience and not let the future of the ISS be determined by equally shortsighted measures.

If we are to realize a meaningful return on the Nation's investment in the ISS, we need to ensure that the ISS's post-Shuttle logistics resupply needs are adequately funded.

It is also clear that it is time for the Administration to commit to flying the two "contingency" Shuttle flights that will deliver critical spares and logistics to the Station before the Shuttle is retired.

Based on all of the information provided to the Committee to date, it is clear those flights are not optional if NASA is to minimize the risks facing the ISS after 2010.

And finally, we need to ensure that any decision on the service life of this international facility is based on sound policy considerations and thorough consultations with our international partners—and not simply be a date based on the current Administration's desire to make it conform to their own underfunded budget plan for NASA.

Well, we have a great number of issues to consider today, and we have a very good panel of witnesses to help us address them.

I again want to welcome them, and we look forward to your testimony.

Chairman UDALL. The Chair now is greatly privileged to recognize my good friend, Congressman Hall, for an opening statement.

Mr. HALL. Thank you, Mr. Chairman. I thank you, again, for my first neighbor when I came up here 28 years ago with Mr. Udall. I learned more from him than I had the past 50 years politically. And I thank you, Mr. Chairman, for calling this morning's very timely hearing on the International Space Station.

I want to begin by thanking the witnesses, because I know about your busy schedules, and I know a lot of you have traveled considerable distance, and I want to assure all of you that your wisdom and expertise are greatly valued by, I value them greatly, as do other Members of this committee, because we, you are knowledgeable about what we are discussing, and we write laws based on the good information that we get from good folks like you that give us your time.

And I would ask you, Mr. Pickens, are you related to Boone Pickens? He is one of the finest guys in the whole world. He just absolutely leads the energy chase and is generous with universities. Golly, he is going to solicit Nature's Aid in the greatest way. He is really a great guy, and I am—and how is he related to you?

Mr. PICKENS. He is my father.

Mr. HALL. Your father? Golly, I wish he was my father.

Anyway, Mr. Chairman, the International Space Station is well on its way to completion, and if NASA successfully flies out its remaining schedule of flights over the next two years, it will be capable of conducting a wide array of world-class science.

The United States and its international partners have invested tens of billions of dollars to assemble the most complex and largest laboratory and living facility ever to fly in space. The fruits of this investment are only now capable of really being realized.

But having said that, a number of critical questions and challenges remain to be answered, both with respect to completing assembly of Station and once accomplished, using the Station as a one-of-a-kind laboratory to conduct research in a microgravity environment.

Issues that bear discussion include the status of the two contingency flights. Is NASA committed to flying them or not? Will the United States be able to reliably and safely move crew and cargo to and from Station during the five-year gap between retirement of Shuttle and advent of the Orion Ares Launch System?

Now, and how safe is Soyuz in light of the most recent pair of re-entries that did not perform as expected? I hope our NASA witnesses, Mr. Gerstenmaier, will be able to spend a couple of minutes in his opening testimony talking about Soyuz performance problems and potential solutions.

I am also concerned about NASA's plans to fully exploit the Station's research and testing capabilities and how it intends to maximize its utility as a national research laboratory.

Several of the witnesses will offer helpful insights and suggestions stemming from their experiences. By raising these questions I don't mean to appear critical of NASA's management of ISS. In fact, I would applaud Mr. Gerstenmaier and the men and women of NASA and their contractor teams for making the difficult task of building the Station look relatively routine. I can only imagine the amount of detailed planning, design, and consultation, as well as negotiating with our international partners that went into this effort.

It has always been one of NASA's great strengths and perhaps one of its biggest public relations challenges to make the highly-dangerous and complex task of space flight look benign, easy, or of no significance.

I want to again thank our witnesses for joining us this morning, and I certainly look forward to your testimony.

Mr. Chairman, I yield back.

[The prepared statement of Mr. Hall follows:]

PREPARED STATEMENT OF REPRESENTATIVE RALPH M. HALL

Thank you, Mr. Chairman, for calling this morning's timely hearing on the status of the International Space Station. I want to begin by thanking our witnesses for taking time out of their busy schedules to be here. Some of you have traveled considerable distance, and I want to assure all of you that your wisdom and expertise are greatly valued by me and other Members of the Committee.

Mr. Chairman, the International Space Station is well on its way to completion and, if NASA successfully flies out its remaining schedule of flights over the next two years, it will be capable of conducting a wide array of world class science. The United States and its international partners have invested tens of billions of dollars to assemble the most complex and largest laboratory and living facility ever to fly in space. The fruits of this investment are only now capable of being realized.

But having said that, a number of critical questions and challenges remain to be answered, both with respect to completing assembly of station, and once accomplished, using the station as a one-of-a-kind laboratory to conduct research in a microgravity environment. Issues that bear discussion include the status of the two contingency flights; is NASA committed to flying them or not? Will the United States be able to reliably and safely move crew and cargo to and from station during the five-year gap between retirement of Shuttle and advent of the Orion/Ares launch system? How safe is Soyuz in light of the most recent pair of re-entries that did not perform as expected? I hope our NASA witness, Mr. Gerstenmaier, will be able to spend a couple of minutes in his opening testimony talking about Soyuz performance problems and potential solutions.

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By raising these questions, I don't mean to appear critical of NASA's management of ISS. In fact, I want to applaud Mr. Gerstenmaier and the men and women of NASA, and their contractor teams, for making the difficult task of building the station look relatively routine. I can only imagine the amount of detailed planning, design, and consultation, as well as negotiating with our international partners, that went into this effort. It has always been one of NASA's greatest strengths, and perhaps one of its biggest public relations challenges, to make the highly dangerous and complex task of space flight look benign.

I want to again thank our witnesses for joining us this morning, and I look forward to hearing their testimony. Thank you.

Chairman UDALL. Thank you, Mr. Hall. If there are Members who wish to submit additional opening statements, your statements will be added to the record. Without objection, so ordered.

At this time I would like to introduce our first panel of witnesses. I am going to start from my left, and we will introduce each one of you, and then we will return and start with the panel.

Dr. Edward Knipling is the Administrator for the Agricultural Research Service at the U.S. Department of Agriculture. Next to him, Dr. Louis Stodieck, who is a constituent of mine. He is the Director of the BioServe Space Technologies at the University of Colorado at Boulder. To his left, Dr. Cheryl Nickerson is an Associate Professor at the Biodesign Institute in the Center for Infectious Diseases and Vaccinology at Arizona State University. I would note I grew up in Tucson so I tend to be a little bit more of a fan of the University of Arizona, but we will leave that where it may be, Dr. Nickerson. And finally we have Mr. Thomas Pickens, III, who is the President and CEO of SPACEHAB, Incorporated, and who shares kinship now with Dr. Hall because you both have a father in common. You have, Dr. Hall is an honorable, he is everybody's father, including mine.

I would add before we turn back to the witnesses, it is an honor for me. I don't know that I have had a chance to Chair a committee hearing in the presence of Judge Hall, but he has been a mentor to me, and he chaired this committee, and I am truly honored.

Mr. ROHRABACHER. Mr. Chairman, I would like to also note that it is an honor for me to be here with a man who knew Sam Houston as well.

Chairman UDALL. We will discuss later whether that commentary will be in the record or not based on Judge Hall's perspective.

And again, the witnesses know that spoken testimony is limited to five minutes each, after which Members of the Subcommittee will have five minutes each to ask questions.

Dr. Knipling, the floor is yours.

Panel 1:

STATEMENT OF DR. EDWARD B. KNIPLING, ADMINISTRATOR, AGRICULTURAL RESEARCH SERVICE, U.S. DEPARTMENT OF AGRICULTURE

Dr. KNIPLING. Well, thank you, Mr. Chairman, and Members of the Subcommittee. My name is Edward Knipling. I serve as the Administrator of the Agriculture Research Service, also known as ARS. ARS is the research arm of USDA, the intramural, in-house research arm of USDA, and we operate a network of 100 federal agricultural science laboratories across the Nation in all aspects of agricultural science.

And thank you for the opportunity to appear before this subcommittee today to present testimony about ARS's collaboration with NASA on research relevant to agriculture and the Space Program.

ARS and NASA have a long history of working together. The ARS Beltsville Agricultural Research Center and the Goddard Space Flight Center in Maryland, we are next-door neighbors. We worked together for many years, particularly with respect to the Earth Observation Program and various aspects of remote sensing of the environment.

Among our successes in that area are predictions of animal disease outbreaks in Africa based upon global weather and vegetation patterns that affect insect vector populations, detection of drought indicators, remote measurements of crop yields, detection and risk assessment of plant pests and invasive species, and development of data for application of precision farming using GPS technology. The role of ARS scientists in these collaborations has been to provide the knowledge and interpretation of plant, animal, and environmental indicators recorded in the imagery and other data collected by NASA's satellites and other aerial platform sensors, and in turn, how to effectively design and use those systems for meaningful environmental and biological assessments.

These research activities have been conducted under the framework of an existing Memorandum of Understanding between USDA and NASA and various predecessor agreements, and today I will speak of a planned new Memorandum of Understanding involving research collaboration in the agricultural life sciences that will take advantage of the microgravity environment of the International Space Station.

And Mr. Chairman, I will address four questions about this new collaboration between ARS and NASA that are of particular interest to this subcommittee. One of these is what achievements are expected under this new collaboration? Well, we anticipate this research will lead to new understandings of biological cellular mechanisms and creative new ways to improve American agriculture, protect the environment, and contribute to human health. These will be based upon principles related to the early development of cells and how that development is influenced by zero or reduced gravity compared to the Earth's gravitational field.

Certainly access to the facilities and the environment of the International Space Station will provide ARS with new abilities to test biological processes in microgravity. Topics of immediate interest are development plant and animal cells and culture and improved understanding of the capacity of such cells to express desired traits or to develop in specialized ways. Selection of cell lines under microgravity may provide germplasm capable of improving plant resistance to pathogens, improved growth characteristics, and generation of functional replacement organs.

Question number two. How will ARS and NASA proceed on these collaborations? Our ARS program managers and scientists have met with NASA program managers and scientists to define areas of mutual interest. They have determined that for work on the International Space Station, the ARS focus will be on the science of cells, principally the affects of microgravity on basic biological mechanisms, genetic regulation in plants and animal cells, pathogenesis in both plants and animal cells, development of cells cultured to understand organ function and development, and selection of plant cells for desirable growth characteristics.

We expect to apply the findings and results of research in these areas to improving animal and plant productivity. We anticipate that our first collaborative research on the Space Station will be to understand the effect of microgravity on the differentiation of animal germ cells. Our goal is to develop and validate the technology to produce and replicate undifferentiated cells that can be, in turn, used to study gene expression, cellular differentiation, and to improve genetic enhancement technologies.

What is the role of agriculture in space research? Well, we envision the tools of space research provided by NASA collaboration as a powerful means to better understand and deal with the responsibilities and challenges we face in agriculture as well as exploiting new opportunities to help advance to agricultural life scientists and potential new applications. And certainly our experiences with the development of remote sensing applications have proven this to be possible.

The ARS research mission and our own goals themselves will not change, but we will benefit from the NASA collaboration and unique approaches to help reach our goals. The new MOU that I spoke about will specify that each agency, ARS and NASA, will, shall provide their own resources, including expenditure of funds, to support their, our respective complementary part of the collaborative research.

Question four. How will ARS develop a research plan for work on the International Space Station? Well, planning for this work has already begun at the national or program level. Our respective program managers have worked together to assure that the goals to be met will be relevant to the problems of agriculture and to establish a formal relationship through the MOU. And at the investigator level, science level, NASA, ARS, and cooperating private sector and university scientists have met and explored the possibilities for specific experiments to be conducted.

Initially ARS investigators are interested in determining if fertilized cow eggs do not differentiate under microgravity but continue to replicate. And additional experiments will be designed for a particular set of cell lines from swine embryos that have been shown to give rise to liver cells, and these cells may have potential use in artificial liver devices.

Many questions about the regulation of their differentiation and replication in culture remain unanswered. And the research planning has focused on the design of experiments to answer such questions.

In addition to the potential value of all of these experiments for advancing animal and plant agriculture, they are expected to serve as models for beneficial applications of cell culture technologies for human health as well.

Mr. Chairman and Members of the Subcommittee, this completes my testimony. I will be pleased to address any questions that you have at a later time.

[The prepared statement of Dr. Knipling follows:]

PREPARED STATEMENT OF EDWARD B. KNIPLING

Mr. Chairman and Members of the Subcommittee, I am Edward B. Knipling, Administrator of the Agricultural Research Service (ARS). ARS is the principal intramural science research agency of the United States Department of Agriculture (USDA). ARS operates a network of more than 100 federal research laboratories across the Nation on all aspects of agricultural science.

Thank you for the opportunity to appear before the Subcommittee today to present testimony about ARS' collaboration with the National Aeronautics and Space Administration (NASA) on research relevant to agriculture and the space program.

ARS and NASA have a long history of working together. The ARS Beltsville Agricultural Research Center and the Goddard Space Flight Center are next-door neighbors in Maryland. ARS scientists at Beltsville and other ARS locations have worked with the NASA scientists in the Earth Observation program at Goddard and elsewhere to apply a wide range of remote sensing methods to environmental and agricultural problems.

Among our successes are predictions of animal disease (Rift Valley Fever) outbreaks based on global weather patterns, detection of drought indicators, remote measurement of crop yields, detection and risk assessment of plant pests and invasive species, and development of data for application of precision farming. The roles of ARS scientists in such collaborations have been to provide knowledge and interpretation of plant, animal, and environmental indicators recorded in the imagery and data collected by NASA's satellite and other aerial platform sensors, as well as how to effectively design and use these systems for meaningful environmental and biological assessments.

These research activities have been conducted under the framework of an existing Memorandum of Understanding (MOU) and predecessor agreements between USDA and NASA. Today I will speak of a planned new Memorandum of Understanding involving research collaborations in the agricultural life sciences that will take advantage of the microgravity environment of the International Space Station (ISS). Mr. Chairman, I will address four issues about this new collaboration between ARS and NASA that are of particular interest to this subcommittee.

Achievements Expected Under the New Collaboration

We anticipate that this research will lead to new understandings of biological cellular mechanisms and creative new ways to improve American agriculture, protect the environment, and contribute to human health. These will be based on principles related to the early development of cells and how that development is influenced by zero or reduced gravity compared to the earth's gravity environment.

Access to the facilities and environment of the ISS will provide ARS with new abilities to test biological processes in microgravity. Topics of immediate interest are development of plant and animal cells in culture and improved understanding of the capacity of such cells to express desired traits or to develop in specialized ways. Selection of cell lines under microgravity may provide germplasm capable of improving plant resistance to pathogens, improved growth characteristics, and generation of functional replacement organs.

How ARS and NASA Will Proceed on Significant Collaborations

ARS program managers and scientists have met with NASA program managers and scientists to define the areas of mutual interest. They have determined that for work on the ISS the ARS focus will be on the science of cells, principally the effects of microgravity on:

- basic biological mechanisms,
- genetic regulation in plants and animals cells,
- pathogenesis in both plants and animal cells,
- development of cells cultured to understand organ function and development, and
- selection of plant cells for desirable growth characteristics.

We expect to apply the findings and results of research in these areas to improving animal and plant productivity. We anticipate that our first collaborative research on the ISS will be to understand the effect of microgravity on the differentiation of animal germ cells. Our goal is to be able to produce undifferentiated cells that can be used to study gene expression, cellular differentiation, and to improve genetic enhancement technologies.

The Role of Agriculture in Space Research

We envision the tools of space research provided by NASA collaboration as a powerful means to better understand and deal with the responsibilities and challenges we face in agriculture as well as exploiting new opportunities. Our experiences with the development of remote sensing applications have proven this to be true. We expect that the microgravity environment on the ISS will provide the same kinds of benefits to help advance our agricultural life sciences programs and potential new applications. The ARS research mission and goals will not change but we will benefit from NASA collaboration and unique approaches to help reach those goals. The new MOU will specify that each agency, ARS and NASA, shall provide their own resources, including expenditure of funding, to support their respective complementary part of the collaborative research.

How ARS Will Develop a Research Plan for Work on the ISS

Planning for this research on the ISS has begun. ARS has been involved at two levels: at the national planning level and at the investigator level. At the national level, ARS program managers have worked with NASA program managers to assure that the goals to be met would be relevant to problems of agriculture and to establish a formal relationship through a MOU. At the investigator level, NASA and ARS scientists have met and explored the possibilities for specific experiments to be conducted at the ISS. In particular ARS investigators are interested the development and differentiation of a particular set of cell lines that came from swine embryos and have been shown to give rise to liver cells. These cells may even be able to be used in artificial liver devices. Many questions about the regulation of their differentiation in culture remain unanswered. Research planning has focused on the design of experiment to ask questions about the role of gravity in cell culture differentiation.

Mr. Chairman, this completes my testimony. I will be pleased to address any questions you and Subcommittee Members may have.

Chairman UDALL. Thank you, Dr. Knipling.

Dr. Stodieck.

STATEMENT OF DR. LOUIS S. STODIECK, DIRECTOR, BIOSERVE SPACE TECHNOLOGIES; ASSOCIATE RESEARCH PROFESSOR, AEROSPACE ENGINEERING SCIENCES, UNIVERSITY OF COLORADO AT BOULDER

Dr. STODIECK. Chairman Udall and Members of the Subcommittee, thank you for inviting me to testify before you today. The International Space Station represents an incredible human achievement for which our nation and our international partners can be very proud. It represents the best of what people can do working together with commitment and resolve. I for one am very grateful to the engineers and all who have built this magnificent facility.

With the focus on assembly of the ISS set to end in only two and one-half years, research utilization, the original purpose of the ISS, can finally be brought to the forefront of our discussions and planning. The ISS has tremendous potential to advance our nation's interests in science, technology, and commerce. I imagine some of the witnesses here today will testify to this potential, and you will find other illustrations of this in my written statement.

These examples are but the tip of the proverbial iceberg. The ability to use the lens of microgravity to understand and exploit gravity as a physical force is unique to the ISS. If fully utilized, I expect that the ISS is going to greatly advance scientific knowledge and have important economic impacts in many fields of study.

The *NASA Authorization Act of 2005,* designated the U.S. segment of the ISS as a national laboratory. This designation was a result of Congress recognizing that limiting ISS utilization to only NASA's exploration research needs would do a disservice to the taxpaying public and the many ISS stakeholders. This designation clearly opens the door to re-establishing the ISS as an important, productive R&D facility.

However, this step by itself is insufficient to insure that the ISS National Lab will be successful. In my view there are three actions that need to be taken.

The first is Congress or NASA should establish an independent management organization to provide leadership of the ISS National Lab R&D activities. This organization should be chartered to develop and manage a rich portfolio of non-exploration research on the ISS. The expeditious way to do this might be for NASA to identify one or more qualified organizations to provide this leadership and form a partnership with them through the use of a space act agreement.

Resulting ISS National Lab management organization would reach out to scientists and commercial users across disciplines and across institutions, identify the best research ideas to bring forward. The organization would also serve as the interface to NASA and assure, and assume the responsibility for getting the research integrated and operated on the ISS.

The second action that should be taken is Congress should provide modest funding to encourage and support non-NASA agencies, U.S. industry, universities, and other organizations to utilize the ISS. Under the ISS National Lab model, the research sponsor would be expected to cover the cost of the science. And it should. However, conducting research on the ISS requires something like five to ten times the funding than that needed for comparable ground-based research. This is because research on the ISS carries additional costs associated with all the requirements to fly with the procurement of specialized hardware and with securing transportation to and from low-Earth orbit.

If ISS National Lab users are required to cover these full costs, then I fear it will have the unfortunate affect of precluding a number of excellent ideas from going forward. Funding provided to the ISS National Lab management organization to cover these extra costs would encourage increased demand for ISS utilization and help achieve a high level of productivity and ultimately success.

The third action is for Congress or NASA to ensure that research sponsors have regular, reliable, and frequent transportation access to and from the ISS. The Space Shuttle is currently the only vehicle with any significant capacity for bringing research samples and equipment back to Earth. Retirement of the Space Shuttle in 2010, will exactly coincide with when this capability will be most needed for the ISS National Lab to become productive.

The best option for both up and down transportation will be for one or more U.S. commercial providers to be successful at developing new launch vehicles and ISS docking spacecraft and for these capabilities to be pressed into service. As NASA works to procure services for logistics re-supply to the ISS, planning should also include the needs of the ISS National Lab users. Productive ISS National Lab will require something like 20 to 25 percent of the transportation capacity both up and down with shipments spread across multiple flights each year.

The ISS National Lab has enormous potential to advance the interests of the Nation in commerce, science, medicine, technology, and education. If the steps I have just outlined are taken, I believe ISS National Lab will be productive, and significant breakthroughs can be expected.

Thank you for your time, and I look forward to answering any questions you may have.

[The prepared statement of Dr. Stodieck follows:]

PREPARED STATEMENT OF LOUIS S. STODIECK

Chairman Udall, Ranking Member Feeney and Members of the Subcommittee, thank you for inviting me to testify on a subject that I feel is very important to our nation. As you will see, I believe there is tremendous potential for the International Space Station (ISS), as a National Laboratory, to be utilized for high-value research and development in low-Earth orbit. I also hope to convince you that more must be done now to position the ISS National Laboratory to succeed.

My name is Louis Stodieck and I am a Research Professor in the department of Aerospace Engineering Sciences at the University of Colorado at Boulder. In addition to my academic role at CU–Boulder, I am privileged to serve as the Director of *BioServe Space Technologies,* a space life sciences research center. BioServe was founded in November 1987 through a NASA grant to the University. Through its 20-year history, BioServe's mission has essentially remained unchanged: we work in partnership with industry, academia and government to conduct space life sciences research that primarily focuses on commercial applications that could benefit the public. BioServe has served the biotechnology, pharmaceutical, agribusiness and biomedical industry sectors with most Center projects focusing on the effects of microgravity, often referred to as weightlessness.

Starting with our first flight in 1991 on STS–37, the Center has flown 40 payloads on 29 missions. Our experiments have launched on the Space Shuttle, Progress and Soyuz vehicles and were operated in orbit on the Space Shuttle, the Russian Mir Space Station and, more recently, the International Space Station. A wide range of experiments have been carried out across the full spectrum of space life sciences applications that have evaluated molecular processes, cell and tissue biology and the development and adaptation of various plants and organisms. BioServe's commercial partners have included large Fortune 500 companies such as Amgen, Bristol-Myers Squibb, Procter and Gamble and Weyerhaeuser along with numerous start-up and established smaller life sciences companies.

It is through the above activities that I feel I am qualified to present to you today the reasons why the Nation should capitalize on the ISS and utilize its capabilities to the greatest possible extent.

Potential for R&D on the International Space Station

The International Space Station (ISS) represents an incredible human achievement for which our nation and our International Partners can be very proud. The launch of the first ISS element took place just under 10 years ago in 1998. Today, the ISS is a remarkable orbiting laboratory with unequaled capabilities. It represents the culmination of the dedication and commitment of thousands of people who have worked tirelessly on the design, fabrication and on-orbit assembly of this massive undertaking. The ISS also represents an unparalleled opportunity in human history: The ability to use the "lens" of microgravity to understand and exploit gravity as a physical force. The ISS offers a superb vantage point from which to observe the Earth as well as providing access to the space environment, attributes that can both be exploited for research. The ISS is rapidly growing in capability and even now can support a wide array of research and development activities that simply cannot be done on Earth.

During the last 10 years, the focus for the ISS Program has necessarily been on assembly. NASA's ISS Payload's Office at the Johnson Space Center has done an excellent job of supporting research utilization, but in reality such utilization has had to take a back seat to ISS assembly and maintenance. The focus on assembly has meant that comparatively little transportation volume, mass, power and, probably most important of all—crew time—have been available to utilize the ISS to any significant extent. As a result, many of the ISS racks and equipment are currently sitting idle awaiting the day when ISS utilization can be ramped up. So, when can ISS utilization be ramped up, and what will it take to do so?

Based on the current schedule, the ISS project is now only two and one-half years away from completion. At that point, the ISS can be officially and substantially opened for business. A significant part of that business, in my mind, ought to be scientific and commercial research and development. It will indeed be unfortunate if the ISS remains substantially under-utilized once it is completed in 2010. I hope instead that with proper planning and strategic investment now, the ISS will be able to live up to its fullest potential as a unique laboratory the like of which has never before been available and possibly never again will be in our lifetime. It is probably not possible to predict when the ISS will reach the end of its lifetime and be de-commissioned, and it seems quite premature to discuss this when the lab is not yet completed and anything close to full utilization remains unrealized. However, the operational lifetime of the ISS is currently certified only through 2016. Even if this date is extended, it should be clear to all of us that the ISS will be available to serve the interests of the U.S., our International Partners and, more broadly, humanity for a finite period of time. Once the Space Shuttle is retired, our ability to service and replace major components of the ISS will be severely constrained. This ultimately could limit or reduce the amount of science that is conducted in this laboratory. Compare this situation with that of the Hubble Space Telescope. Just imagine how the lifetime of the Hubble Space Telescope would have been shortened and consider the amount of science lost without Space Shuttle servicing missions. The period of actual use of the ISS after assembly complete may be only five to 10 years and may be determined more by an inability to maintain safe operations than by U.S. policy. Thus, it will be very important to derive the most benefits possible from this incredible, one-of-a-kind laboratory as early as possible and for as long as possible.

Currently, NASA remains the predominant user of the ISS. Research is being performed to better understand the negative effects of long-duration space flight on the human body and to develop countermeasures and technologies to mitigate these effects. Non-exploration utilization research on the ISS has been conducted but only on a limited basis due to resource constraints and NASA's focus on the Exploration Vision. If the ISS is going to live up to its full potential, then clearly the productivity of the station must significantly increase, especially for non-exploration research.

Before discussing the future of ISS utilization, I believe it is important to revisit the potential that ISS represents and why planning and further investment should be considered to jump start the great body of work to be done there.

Value of ISS as a National Lab

It is easiest for me to speak from the experience and flight research projects that my Center has directly sponsored or supported. Of course there are numerous articles and studies that have identified and vetted the best R&D applications for the ISS across a host of scientific disciplines. The examples below are based in the life sciences, which is the focus of our Center and my area of expertise.

Despite significant funding challenges over the last few years following the termination of NASA's Space Product Development program, the program within NASA under which BioServe was funded, BioServe has strived to remain productive in space flight research endeavors. We have done so for the simple reason that we believe strongly in the potential of the ISS to benefit the general public, commerce, scientific knowledge, technology development and education. Since December of

2006, space flight hardware designed and developed by BioServe has supported 17 different commercial, international, NASA and K–12 research projects. These research experiments have flown on five different Shuttle missions, launched and landed on the Russian Soyuz spacecraft, and spanned three ISS increments. In addition, BioServe has had operating research hardware on-board the ISS since December of 2002.

Over the years BioServe has worked with several different commercial companies in support of collaborative research with commercial applications. Some of these companies are mentioned above but the most recent support of commercial research involved experiments conducted in collaboration with Amgen and SPACEHAB.

Amgen, one of the world's largest biotechnology companies, has collaborated with BioServe in the area of disuse bone and muscle loss since 1995. During this time BioServe conducted ground- and space-based studies both to verify the models utilized in these studies as well as to determine the effectiveness of two Amgen developed investigational compounds designed to reduce or prevent significant bone and muscle loss associated with certain types of disease and disuse conditions. This work culminated in two successful space flight experiments, one conducted on-board STS–108 and the other on-board STS–118. For each experiment, in addition to the primary research that was conducted, Amgen agreed BioServe could arrange a tissue-sharing program in which unused tissues from the space experiments were given to over 20 separate investigators each researching the effects of space flight and microgravity exposure on different physiological systems. In essence with careful planning productivity was greatly enhanced despite limited resources. Although these two space flight experiments were Shuttle missions, it is believed that significant additional information could be learned through longer duration studies on-board ISS.

The research projects with Amgen show the potential for alignment between industry and NASA goals and needs in the broader context of the ISS National Lab. For example, the research investigation of a bone therapeutic on STS–108 was part of a much larger traditional development program being conducted by Amgen. Today, that development program has led to a therapeutic called Denosumab which is in Phase III clinical trials. In addition to helping patients with osteoporosis, bone metastasis, and other serious bone loss conditions, this drug could become a highly effective countermeasure for future flight crews exposed to long-duration skeletal unloading. In the context of the ISS National Lab, this project shows the potential for industry-sponsored research to benefit the company, NASA's exploration vision and the general public.

As part of a Space Act Agreement that is being completed between NASA and BioServe to support ISS National Lab commercial path-finder research, BioServe recently collaborated with SPACEHAB, Inc. to launch a series of commercially applicable experiments in the area of vaccine development for certain infectious diseases. The first of these payloads launched in March on-board STS–123 and the second is scheduled to launch in May on-board STS–124. The results, while still preliminary, are very encouraging. SPACEHAB, which is represented here today, can speak more to this promising work.

Additionally, BioServe supported four NASA peer-reviewed life science researchers on-board STS–123. The Microbial Drug Resistance and Virulence or MDRV payload was sponsored by NASA's Exploration Systems Mission Directorate under the non-exploration research program. As the payload name implies, the research conducted by these investigators focused on the effects of space flight on virulence in pathogenic microbes, specifically bacteria, and antifungal resistance in a yeast model organism. This research has tremendous space- and Earth-based applications. Again, one of the investigators from this mission is here today and can speak to the value of this important work.

BioServe has a long history of providing training and educational opportunities to graduate, undergraduate and K–12 students. The Center has trained and educated over 115 graduate students since its inception. BioServe students are highly sought by NASA and industry once they graduate due to the unique education in bioastronautics and hands-on training received within the Aerospace Engineering Sciences department and at the Center. This important benefit of the ISS National Lab simply cannot be overstated. With the sharp cuts by NASA in the physical and life sciences, universities and colleges have lost critical support for students to keep them engaged in these important fields. More importantly, academic institutions have lost the single largest set of opportunities for students to be involved with the human space program. Without this connection, I fear that fewer and fewer students will pursue lines of study and choose careers associated with NASA's ambitious *Vision for Exploration.* The ISS National Lab has the potential to restore some of these lost opportunities.

In late 2006 BioServe started a formal K–12 education program called CSI. CSI brings actual space flight experiments into the K–12 classroom. Through its education partners, curriculum supplements are developed for each CSI experiment. These materials are delivered to participating classroom teachers via the Internet. Once the experiment is activated on-orbit, images and data of the experiment are down-linked to BioServe and then up-linked to the educational web site. Students are able to conduct their own "ground controls" in the classroom and compare their results on a near-real time basis to the space experiment. These experiments have examined seed germination, growth of metallic salts in silicate solutions, multi-generational organism growth in space and plant development. The CSI–01 and CSI–02 projects have reached over 10,000 students. This program is an excellent example of utilizing a national asset, the ISS, to inspire K–12 students in science, technology, engineering and math. It utilizes a unique element, the ISS, to promote inquiry of gravity's effects and influence on our every day lives. In turn, this type of activity creates a very real connection between students and parents and the tremendous accomplishments of NASA and the ISS.

This brief description of work we have recently been conducting provides what I believe is only a very small glimpse into what could be possible on the ISS National Lab if research utilization were significantly stepped up. There is great potential to use ISS to advance applications in biotechnology, life sciences, fluid physics, fundamental physics, combustion, energy, Earth sciences, materials and biomedicine. Of course, there are critics of the ISS who disagree with this statement as would be expected when competing interests come into play. I would argue, however, that the work done to date on the Shuttle and on the ISS has shown the potential of the ISS National Laboratory to produce a rich return for taxpayers and that far greater benefits and discoveries await us. In any event, strict scientific return on investment should not be the sole measure of the worth of taking the ISS National Lab to the next level. Like it or not, the investment to build and assemble ISS in orbit has been made. We should now recognize the historically unique capability of this tremendous facility and exploit that capability to the maximum extent possible while we can.

Status of ISS National Lab Utilization

It is difficult to assess the current status of ISS utilization without first considering how we arrived where we are today. It is well known that NASA policy concerning utilization of the ISS changed dramatically in January 2004 with the release of the new Vision for U.S. Space Exploration. The new vision for NASA clearly enumerated that the NASA Administrator should:

- "Complete assembly of the International Space Station, including the U.S. components that support the U.S. space exploration goals and those provided by foreign partners, planned for the end of this decade;"
- "Focus U.S. research and use of the International Space Station on supporting space exploration goals, with emphasis on understanding how the space environment affects astronaut health and capabilities and developing countermeasures."

Two significant decisions by NASA leadership pertinent to the future of the ISS followed from the new Vision for Exploration policy:

1. NASA's life and physical science programs were drastically cut with many lines of research being eliminated altogether. Even life sciences research that was seen as supportive of the *Vision for Space Exploration* but was more fundamental in nature or involved pre-clinical animal models, was effectively canceled. For many scientists within NASA and at universities across the country, these decisions translated to the termination of grants and forced the redirection of research programs, even whole careers. Hundreds of college undergraduate and graduate students were discouraged from engaging in physical and space life sciences research. The development of much of the life and physical sciences equipment that was being built to support robust research programs on the ISS was canceled.
2. As part of the realignment of NASA programs to the Vision for Exploration, in 2006, NASA terminated the Space Product Development program, which at the time supported 11 Research Partnership Centers around the country, including ours. Many of these centers were engaged in commercial research and development activities that planned to utilize the ISS.

These changes, along with others, certainly had the desired effect to reprogram significant funding and define budgets to carry out the *Vision for Space Exploration* and help focus NASA squarely on the development of replacement vehicles to the Space Shuttle and the development of plans and hardware systems to return to the Moon.

Of course these decisions also placed in serious doubt the future of the ISS as a world-class, productive research laboratory in space, as had been originally envisioned. The momentum that had been built up by the collective efforts of thousands of people was depleted by these decisions in what seemed a very short period of time. There are in fact few organizations remaining today with the knowledge and expertise to conduct ISS utilization. Even now, these organizations are at risk of disappearing altogether and would take years to recreate.

The *NASA Authorization Act of 2005* designated the U.S. segment of the International Space Station as a National Laboratory. This designation was made as a result of strong leadership within Congress who recognized that limiting ISS utilization to only exploration research would do a disservice to the taxpaying public and the myriad of ISS stakeholders who should expect a reasonable return from the ISS in the form of scientific advances, new technologies, economic development, inspiration of education in technical fields and overall societal enrichment. This designation clearly opened the door to re-establishing the ISS as an important and productive R&D facility.

The designation of the ISS as a National Lab represents an important step in the right direction. However, this step by itself is insufficient to ensure that ISS will be productive in supporting high-value R&D activities. In my view, there are three actions that need to be taken for the ISS National Lab to become successful.

1. Establish an independent management organization to provide leadership and oversight of the ISS National Lab R&D activities.
2. Provide modest funding to encourage and support non-NASA agencies, U.S. industry, universities, colleges and other organizations to utilize the ISS.
3. Ensure regular, reliable and frequent transportation access to and from the ISS.

Please allow me to expand on each of these steps.

ISS National Lab Management Organization

The ISS National Lab designation from the 2005 Authorization Act establishes the potential for the ISS to be used for non-exploration research but does not establish a path by which this is to happen. In essence, this designation establishes the national lab facility without specifically identifying the people who would manage it. Imagine if Brookhaven National Lab, with its incredible facilities, were operated and maintained but no organization existed to serve the extramural research scientists and communities who might want to use the facilities. The productivity of Brookhaven's facilities would drop off precipitously.

The NASA Report to Congress regarding a Plan for the ISS National Laboratory in 2007 partially addressed the question of management. In the report, NASA acknowledged the issue and indicated that various management structures had been considered to create a possible future ISS National Lab management organization. The report went on to recommend a two-phase approach to implementation. Phase I, which is currently being followed, utilizes the expertise of a small project office at NASA headquarters under the direction of the Associate Administrator for Space Operations. In this phase, NASA is focused on identifying end-users of the ISS National Lab and securing agreements intended to provide access to NASA expertise and eventual access to ISS for R&D activities. Phase II would occur depending on whether demand for access to the ISS National Lab evolved to a scale that would warrant such an organization. In this event, *"NASA could establish an institute, or other cost-effective entity, to manage opportunities for non-government organizations that are pursing applications unrelated to the NASA mission."*

I am very encouraged by the steps that NASA has so far taken in creating a small project office at headquarters and by the accomplishments of this office. Clearly, our Center is a beneficiary of the work of this office through the Space Act Agreement about to be completed. However, demand for the use of the ISS is already high and continuing to grow. This can be evidenced, in part, by the increasing number of agreements being formed with NASA by various organizations including, commercial, academic and government, all of which are interested in utilizing the ISS. Many of the witnesses here today are testifying about these interests. I would argue that now is the time to move into the second phase of the ISS National Lab management strategy identified in NASA's report. An effective management organization put into place now should have a strong initial focus on expanding the user base by providing outreach to scientists, engineers and leaders of R&D organizations.

This would continue to build demand for ISS utilization, which would lay the foundation for a high level of productivity of the ISS National Lab soon after completion of the ISS facility in 2010.

How can an organization capable of leading ISS National Lab utilization be created in a short time frame? One approach could be pursued by the ISS National Lab office at NASA headquarters. Specifically, this office could seek interested parties, identify one or more qualified organizations and then proceed to execute a Space Act Agreement that would establish a public-private partnership to oversee ISS National Lab utilization on behalf of multiple users. I have recently become aware of one such organization that allows me to believe that this approach would be possible. The Biotechnology Space Research Alliance (BSRA) is a self-organized partnership between university, industry, foundation and economic development organizations. The purpose of BSRA is to facilitate access to the ISS National Lab and create benefits for the biotechnology industry sector in Southern California. This represents a possible model of how an ISS National Lab management organization might be structured. It should also be pointed out that BSRA could grow to support other industry sectors and expand to meet the needs of other regions across the Nation.

The ISS National Lab management organization should be chartered to develop and manage a rich portfolio of non-exploration research activities on the ISS. To be clear, this organization would not be intended to replace the office at NASA headquarters but rather to greatly augment its efforts. This organization also would not replace any of the responsibilities of NASA's Payloads Office, which serves to integrate requirements for flight research across all users of the ISS including exploration and non-exploration research, but rather work hand-in-hand with this group.

An effective ISS research management organization would have a number of key responsibilities in supporting the ISS National Lab:

1. Perform outreach to scientists across multiple disciplines such as physics, materials science, life science, biomedicine, chemistry, Earth science, etc. The organization would educate scientists and others on the known effects of gravity, the space environment and other space attributes and how conducting studies on the ISS might benefit their research. The ISS would essentially be marketed to prospective university, government and commercial users. The goal would be to identify researchers whose work could benefit the most from utilizing the ISS and develop a substantial portfolio of prospective R&D projects.
2. Develop a selection process to prioritize and support the best research from a regularly updated list of candidates. The goal would be to serve as a fair broker in selecting research, particularly when flight resources are constrained, based on criteria that would be established by the organization when it is formed.
3. Work to seamlessly integrate and fly research as a turn-key operation. The goal would be to take responsibility for the onerous process of flying research so that the scientists can focus solely on their science.
4. Work closely with the ISS Payloads Office to streamline the process of integrating and certifying research for flight. The goal would be to shorten the payload processing timeline as much as possible so as to maximize the productivity of the ISS National Lab.
5. Maintain a database with key specifications for all space flight research hardware that might be used on the ISS. In some cases, the organization might maintain an inventory of flight hardware and make this hardware available, as needed. The goal would be to match the best available hardware with a particular research project to avoid duplicate hardware development.
6. Assist NASA to archive results from work performed on the ISS and effectively communicate these results to the public.

ISS National Lab Utilization Costs

Performing research in orbit is more expensive than comparable ground-based research. Conducting a research investigation on the ISS could include 1) the cost of the science itself (research team, materials, analyses, etc.), 2) the cost for development of new hardware necessary to meet the science objectives, 3) the costs for payload integration, operations, preparation and flight certification, 4) the costs of transportation to and from the Space Station and, 5) use of the ISS and associated resources (power, crew time, volume, etc.).

Within the concept of ISS as a National Lab, it is appropriate that the research sponsor or beneficiary would cover the cost of the research itself. This expectation would apply whether the work was being sponsored by a commercial, academic or government organization. In short, whoever brings research ideas forward and expects to benefit from those ideas should cover the full costs for executing the research.

On the other end of the spectrum, it is currently NASA's policy to cover the costs associated with Space Shuttle transportation and the use of the ISS utilization resources. Compared with the costs being borne by NASA to launch the Shuttle, and assemble and operate the ISS, costs for transporting research and use of ISS resources for utilization are certainly marginal. Assuming that the costs for use of ISS resources continue to be covered by NASA for the foreseeable future, the obvious question is what happens to the transportation costs after the ISS is complete and the Space Shuttle is retired in 2010? Without doubt, this question poses a significant risk to ISS R&D productivity post-assembly complete. Transportation costs for ISS National Lab research communities after 2010 need to be understood as soon as possible so they can be taken into account in laying a plan for productive ISS utilization. I'll address more on the subject of transportation shortly.

Cost categories 2 and 3 present a different type of challenge. The costs of developing new hardware and meeting all of the NASA requirements associated with safety, integration, operations and flight certification can be significant. These costs are not ones that are normally associated with terrestrial research and, as such, even with the transportation cost excepted, the cost for conducting a research investigation on the ISS may be anywhere from two- to tenfold higher than a comparable ground investigation. These costs could impose a high barrier to research utilization of the ISS. Passing these costs to the end user will discourage high-risk, high-payoff research on the ISS. One obvious solution might be to provide modest funding to the ISS National Lab management organization so the organization can assume the responsibility for performing and meeting all NASA payload integration, operations and flight requirements. If research is selected for flight through an appropriate prioritization and vetting process, then the ISS National Lab organization could assume the responsibility and costs for its execution in orbit. This approach would have the important advantage that neither the research sponsor nor the science team will need to learn the daunting process for integrating and certifying an investigation for flight. At the same time, more high-risk, high-payoff experiments will be possible.

ISS National Lab Utilization Transportation

After the Space Shuttle is retired in 2010, the options for transporting research between Earth and the ISS become limited. At this point, the U.S. Space Shuttle, the Russian Soyuz and Progress vehicles and now the European Space Agency's Autonomous Transfer Vehicle are the only means for transporting research equipment, supplies and samples. By 2009–2010, the H–II Transfer Vehicle (HTV) being developed by JAXA should have a similar capability to transport cargo to the ISS. Of these, only the Space Shuttle has significant capacity for transport back to Earth and yet it will be retired exactly at the time that research on the ISS should be significantly stepped up. Without a solution to this dilemma, ISS National Lab utilization will be crippled. The only research that will be practically possible, other than exploration research involving the station crews as test subjects, will be research where data are generated on-orbit and samples and payload equipment are considered disposable and incinerated in the atmosphere after use. While this approach might work for some investigations, the technology necessary to do this on a large scale on the ISS has not been developed nor are there any plans to do so.

NASA should be credited for pursuing commercial options for ISS resupply. The Commercial Orbital Transportation Services or COTS providers may help to solve the transportation problem for the ISS National Lab. The release by NASA only recently of the request for proposals for Cargo Resupply Services (CRS) represents a critical step forward and suggests a certain level of confidence that one or more COTS providers will step up and be able to meet the cargo resupply and sample return needs of NASA and the ISS. To be clear, the solicitation appears to only cover NASA's needs for logistics and science materials and equipment. The solicitation does not cover ISS National Lab research users. Instead, NASA's expectation is that prospective ISS National Lab users will independently negotiate transportation to meet their needs.

There are two concerns with NASA's approach to the CRS procurement from the perspective of ISS National Lab users.

First, in planning for success with the ISS National Lab, there will be many different users needing to make transportation arrangements. Clearly, having multiple organizations, such as individual companies, agencies, government labs, even individual scientists, all approaching the successful COTS provider for a ride will create some degree of chaos. More importantly, it is not clear how coordination between ISS National Lab users and NASA (logistics resupply and exploration science) will be done. It is my opinion that the ISS National Lab will be most productive if research material can be transported both up and down on a schedule of 4–5 times per year or more. This schedule will provide the greatest flexibility to meet the requirements of multiple end users. ISS National Lab users should be included on every NASA procured shipment. This will require careful coordination between the ISS National Lab management organization and NASA. For now while the Cargo Resupply Services are being procured, NASA needs to plan to include perhaps 20–25 percent of the volume on each supply mission for the ISS National Lab work.

Second, the cost of this component of the research, as mentioned above, could be the most severe challenge of all. Without knowing the charges for transportation that the selected Cargo Resupply Services providers will decide is needed to allow them to recoup their investment, it is difficult to know how to predict this critical cost component. However, as a point of reference, a reasonable approximation that has been previously used is $20,000 to launch and return a kilogram of mass. Of course the actual charge could be different, either higher or lower. Based on this value, one modest sized experiment, comparable to what is currently flown in the Shuttle mid-deck, would cost over $600,000 to transport to and from the ISS. Add the cost of integration, operations and safety certification (category 3 discussed above) and an experiment may cost ~$1,000,000. Add the cost of any modest new hardware development, if suitable existing hardware cannot be found, and the cost for a single experiment may reach as high as $2,000,000, a cost prohibitive to most research sponsors.

Conducting research on the ISS National Lab is going to require 5–10 times the investment for comparable research on the ground. The transportation element is a significant portion of this cost. As previously stated, if this cost must be fully borne by the ISS National Lab users, then there will be a very high barrier that many end users may choose not to cross. This will have the unfortunate effect of precluding a number of excellent ideas and projects from going forward under the ISS National Lab. Keep in mind that some of the best and most successful ideas originate with entrepreneurial individuals or start-up companies, which may have little investment capital on hand.

The issue of transportation and cost go hand in hand. One solution might be for the ISS National Lab management organization, if it were to be established, to be given sufficient funding outside of NASA to negotiate transportation contracts with the COTS providers on behalf of all ISS National Lab users. This would need to be done working with NASA to ensure sufficient capacity could be made available on each delivery mission to the ISS for ISS National Lab users.

The greatest risk to the ISS National Lab failing to deliver on its research potential, in my opinion, is that the COTS providers may not succeed in developing an ISS re-supply capability soon enough or perhaps at all. Even though NASA is investing $500M into this program, considerably more investment capital is required from each of the COTS companies for these new rocket and spacecraft systems to be developed and tested and to meet NASA's safety requirements to dock with the ISS. Having a successful commercial transportation provider is strategically and technically important to the U.S. Without a U.S. provider, we will be purchasing extensive services from the Russians (Progress and Soyuz vehicles) and there will still be insufficient return mass capability to meet anyone's needs. All ISS research, including that of NASA and the ISS National Lab, will be crippled. While there is no simple solution to this issue, it is one that NASA should carefully consider, perhaps with the development of a contingency plan to assist any selected Commercial Resupply Services providers, if they encounter major technical difficulties.

Summary of Key Points and Recommendations

- The ISS National Lab has *tremendous* potential to advance the interests of the Nation in commerce, science, medicine, technology and education.
- Not enough is being done to ensure that the ISS National Lab will succeed in what should be the most productive time for the highly capable ISS facility after assembly is complete. Given the finite period of time that it can be safely assumed to be operational, perhaps only 5–10 years, it will be very important to accommodate as many of the best research and development ideas as possible.
- Transportation of research utilization equipment and materials to and from the ISS with a frequency of at least 4–5 times per year is critical. With the

Shuttle retiring in 2010, the only other viable option will be for one or more COTS providers to be successful at developing new launch vehicles and docking-capable spacecraft. NASA is pursuing this solution with the recently released solicitation for Cargo Resupply Services.

- Recommendations
    a. NASA should proceed to identify and select an ISS National Lab management organization as soon as possible. (Described in NASA's Plan for the ISS National Laboratory.) Time is of the essence when considering what must be done to set the stage for full ISS National Lab utilization after 2010. Use of a Space Act Agreement to form a public-private partnership could allow this to be done relatively quickly.
    b. Once it is formed, the ISS National Lab management organization should be given adequate resources to identify, manage and support a rich portfolio of utilization projects. The organization should not cover science costs, as those will be the responsibility of the research sponsor, but should be structured to cover some or all of the additional costs (hardware, integration, operations, transportation, etc.) not normally associated with terrestrial research. This approach could change over time as demand for the ISS increases where more and more of the full costs are covered by the end users.
    c. NASA should plan to fully accommodate ISS National Lab transportation needs in their effort to secure Cargo Resupply Services. At the least, this should include setting aside 20–25 percent of the up and down volume and mass on any given ISS resupply vehicle, even if that means that the number of total commercial launches per year must be increased.

BIOGRAPHY FOR LOUIS S. STODIECK

Louis S. Stodieck, Ph.D. is the Director of BioServe Space Technologies and Associate Research Professor in Aerospace Engineering Sciences at the University of Colorado, Boulder. Dr. Stodieck earned his doctorate in Aerospace Engineering from the University of Colorado, Boulder in 1985. His research focus was biomedical engineering. He trained for two years as a postdoctoral Medical Research Council Fellow in the Department of Physiology at the University of British Columbia. He returned to the University of Colorado in 1987 to take a position as Associate Director for Technical Affairs for BioServe Space Technologies, a newly-formed NASA-sponsored Commercial Space Center. The Center's mission was to engage the private sector in conducting space life sciences research and development. Dr. Stodieck became Director of BioServe in 1999 where he currently leads an organization of approximately 25 faculty, staff and students. During his tenure at BioServe, Dr. Stodieck has overseen extensive ground-based research and over 40 space-based research payloads flown on the Space Shuttle, Mir Space Station and International Space Station. As a result of Dr. Stodieck's strong leadership BioServe is widely recognized for its successful partnerships with large and small biotechnology, pharmaceutical, biomedical and agricultural companies and for its highly successful, cost effective and innovative commercial space flight research program. Based in the College of Engineering and Applied Sciences, BioServe is also well regarded for providing high quality and unique hands-on educational opportunities for the next generation of scientists and engineers involved in space exploration. Dr. Stodieck's current research focuses on the development of countermeasures to the deleterious effects of space flight on human health especially in regard to space flight-induced bone and muscle loss. He has authored or co-authored 24 peer reviewed journal publications and over 40 conference papers in the fields of biomedical engineering and space life sciences research and hardware development.

Chairman UDALL. Thank you, Dr. Stodieck.
Dr. Nickerson.

STATEMENT OF DR. CHERYL A. NICKERSON, ASSOCIATE PROFESSOR OF LIFE SCIENCES, SCHOOL OF LIFE SCIENCES, CENTER FOR INFECTIOUS DISEASES AND VACCINOLOGY, THE BIODESIGN INSTITUTE, ARIZONA STATE UNIVERSITY

Dr. NICKERSON. Mr. Chairman and Members of the Committee, thank you for inviting me to appear today before you to testify. My name is Cheryl Nickerson. I am an Associate Professor in the Center for Infectious Diseases and Vaccinology at the Biodesign Institute at Arizona State University. I have been the principal investigator on multiple NASA-funded life science experiments. I serve as a consultant to the NASA Life Sciences Program at the Johnson Space Center, and I was honored to have been selected as a NASA astronaut candidate finalist in 2003.

In your invitation letter today you posed a series of questions to me regarding the utilization prospects by ISS research that I would like to now address in sequence.

First, what had been the nature of my space-based research, and what had been my findings to date? My research focuses on understanding the molecular mechanisms of infectious disease and specifically on the affect of space flight on the molecular mechanisms of infectious disease, with an important emphasis on the microbial pathogen response.

Infectious disease is responsible for 35 percent of all deaths globally, and it is the world's largest killer of children and young adults. The economic impact on the U.S. alone from infectious disease exceeds $120 billion annually, and of course, future threats loom on the horizon for us globally as well, including new and re-emerging infectious diseases for which we do not have sufficient treatments, antibiotic resistance strains, and always the potential for the intentional misuse of microbial pathogens as agents of bioterrorism. Clearly then new treatment and prevention paradigms are desperately needed.

My space flight research is focused on the bacterial pathogen Salmonella, which is a global threat to public health and it counts for approximately 30 percent of all deaths from food-borne illness in the United States. From NASA's perspective Salmonella is considered a potential source of infection during space flight that could incapacitate crew members during a mission. However, there are currently no human vaccines to prevent Salmonella food-borne illness.

I applaud NASA's foresight in funding our space flight research in the field of infectious diseases, as well as the awesome engineers for building this wonderful ISS craft. The connection between space flight and infectious diseases was not immediately clear 10 years ago when NASA originally funded our research. Based on our early findings using ground base space flight analogs, NASA awarded us a grant to investigate the effect of true space flight on Salmonella disease-causing ability, which we call virulence, and gene expression results. This experiment flew on STS–115 in September of '06, and the results were remarkable. They showed that space flight increased the virulence of this important pathogen and globally altered its gene expression profiles by changing 167 genes.

Now, the interesting part about that is it not only increased its disease-causing potential and changed all these expression of genes, but it did so in unique ways that are not observed using traditional experimental approaches in the laboratory. So what we have done is we have been able to discover new ways that this important human pathogen causes disease in the host.

We also discovered a key master regulatory mechanism that controls the vast majority of the Salmonella's responses to the space flight environment. This molecular target, along with others that we identified in my laboratory, holds real potential to be translated into new therapeutics and new vaccines to treat and prevent human enteric food-borne illness caused by Salmonella.

Our findings were published in the proceedings of the National Academy of Sciences. The success of our flight experiment on STS–115 inspired a follow-up experiment on STS–123, which just flew in March, 2008, and the results from that are equally exciting, and we are looking forward to publishing those within the next one to two months.

An important part of our space flight work is helping us to understand, therefore, how microbial pathogens cause infectious disease here on Earth, and likewise, then using space flight as a novel, enabling research platform to translate those innovations into infectious disease control here for the general public on Earth. Shortly we expect NASA and the public to receive a direct benefit from their investment in our work.

Second, what is my perspective on the future potential for the use of microgravity environment as a research tool? It is simple. The microgravity of space flight offers a unique environment for ground-breaking biotechnology and biomedical advances and discoveries to globally advance human health. Not just in infectious diseases but in some of the major health illnesses here that we worry about globally. Cancer, aging, bone and muscle wasting diseases, and tissue engineering. And it will have a long-lasting impact on our nation's scientific capability, economy, and the quality of our lives.

Many breakthroughs in life sciences research have come from studying living systems in extreme environments. The environment of space flight offers insight into fundamental cellular and molecular response mechanisms that are directly relevant to human health and disease and which cannot be observed using traditional experimental approaches in the lab.

Third, and my final question. What are any potential applications of the basic research I have conducted to date or intend to pursue? The investment that NASA has made in our research for innovations in infectious disease treatment and control will provide long-lasting return in the protection of humans as they explore space and for the general public here on Earth.

An example of the potential boom from space flight experiments is my laboratory's discovery that gene regulatory proteins participate in the space flight response of microbial pathogens. Gene regulatory proteins affect every property of a cell, including its ability to cause disease. My lab is currently studying how this regulatory and these regulatory pathways work in Salmonella and other important human pathogens and how they can be manipulated to control microbial virulence and subsequently, how those findings can be translated to the design of new drugs and new vaccines with clinical applications.

One key to our nation's economic success has been its ability to consistently provide unique answers to the world's problems. We have the opportunity here and now to advance in a field where the U.S. is a world leader. I firmly believe that space exploration and development will be one of the defining activities of our nation that will lead the world in this new millennium.

And I thank you.

[The prepared statement of Dr. Nickerson follows:]

PREPARED STATEMENT OF CHERYL A. NICKERSON

Mr. Chairman, Members of the Committee, thank you for inviting me to appear before you today to testify. My name is Cheryl Nickerson, and I am an Associate Professor in the Center for Infectious Diseases and Vaccinology at the Biodesign Institute at Arizona State University. My research focuses on understanding the molecular mechanisms and processes of infectious disease, with an important emphasis on investigating the unique effect of space flight on microbial pathogen responses. NASA's support of my research has resulted in multiple space flight experiments, which have provided novel insight into how microbial pathogens cause infection both during flight and on Earth, and hold promise for new drug and vaccine development to combat infectious disease.

Through awards such as the Presidential Early Career Award for Scientists and Engineers, and independent research funding from grants totaling over three million dollars, NASA has consistently recognized my laboratory's contributions to the United States Space Program into infectious disease risks for the crew during space flight and the general public here on Earth. I also serve as a scientific consultant for NASA at the Johnson Space Center in support of their efforts to determine and mitigate microbial risks to the crew during flight, and was honored to be selected as a NASA Astronaut candidate finalist for the Astronaut class of 2004. That being said, the views expressed in today's testimony are my own, but I believe they reflect community concerns.

In your invitation letter asking me to testify before you today you asked a series of questions regarding the utilization prospects of ISS research that I would like to address now in sequence.

1. What has been the nature of your space-based research, and what have been your findings to date?

I would like to begin by applauding NASA's foresight in funding our space flight research in the field of infectious disease. We were initially funded by NASA's Office of Biological and Physical Research and are currently funded by both the Advanced Capabilities Division and the Human Research Program in the Explorations Systems Mission Directorate. The connection between space flight and its influence on infectious disease was not immediately clear 10 years ago when NASA initially funded our research. As a result, NASA's support of my research through multiple space flight experiments has allowed us to provide novel insight into the molecular mechanisms that microbial pathogens use to cause infectious disease both during flight and on Earth, and has exciting implications for translation into human health benefits, including the development of new drugs and vaccines for treatment and prevention.

While the eradication or control of many microbial diseases has dramatically improved the health outlook of our society, infectious diseases are still a leading cause of human death and illness worldwide. Infectious disease causes 35 percent of deaths worldwide, and is the world's biggest killer of children and young adults. Within the United States, infectious disease has a tremendous social, economic, and security impact. Total cost for infectious disease in the U.S. exceeds $120 billion annually due to direct medical and lost productivity costs. Moreover, the future is threatened by new and re-emerging infectious diseases, an alarming increase in antibiotic resistance, and the use of microbial agents as a bioterrorist threat. Thus, research platforms that offer new insight into how pathogens cause infection and disease are desperately needed and will lead to novel strategies for treatment and prevention.

To enhance our understanding of how pathogens cause disease in the infected host, my laboratory uses innovative approaches to investigate the molecular mechanisms of infectious disease. It was this search for novel approaches that drove our initial investigations with NASA technology. As flight experiments are a rare opportunity, our early experimental efforts concentrated on the use of a unique bioreactor, called the Rotating Wall Vessel (RWV), designed at the NASA Johnson Space Center in Houston as a ground-based space flight analogue. The RWV bioreactor allows scientists to culture cells (microbial or mammalian) in the laboratory under conditions that mimic several aspects of space flight and can be used to induce many of the biological changes that occur during space flight. In addition, by using mathematical modeling, we found that this analogue, and true space flight, produce an environment that is relevant to conditions encountered by the pathogen during infection in the human host—thus enhancing the relevance of our findings for the development of new strategies to combat infectious disease on Earth.

We chose the model bacterial pathogen *Salmonella typhimurium* for both our space flight analogue and space flight studies, as it is the best characterized pathogen and poses a risk to both the crew during flight and the general public on Earth. *Salmonella* is the most readily and fully understood pathogen and belongs to a large group of bacteria whose natural habitat is the intestinal tract of humans and animals. This group includes most of the bacteria that cause intestinal and diarrheal disease, considered to be one of the greatest health problems globally. Indeed, *Salmonella* infection is one of the most common food-borne infections worldwide. In the United States an estimated 1.41 million cases occur, resulting in 168,000 visits to physicians, 15,000 hospitalizations and 580 deaths annually. *Salmonella* accounts for approximately 30 percent of deaths caused by food-borne infections in the United States, and is even more detrimental in the developing world. The total cost associated with *Salmonella* infections in the U.S. is estimated at three billion dollars annually. Moreover, in 1984, *Salmonella* was used in a bioterrorism attack by a religious cult in Oregon to cause a community-wide outbreak of food-borne illness in an attempt to influence the outcome of a local election. The organism is also an excellent choice for NASA as it is considered a potential threat to crew health as a food contaminant. There are currently no human vaccines to prevent *Salmonella* food-borne illness.

Using the RWV ground-based technology, we conducted preliminary studies showing that *Salmonella* responded to this environment by globally altering its gene expression, stress resistance, and disease causing (virulence) profiles, thereby improving our chance of success and need for a space flight experiment. Subsequent analysis of the genes that were expressed after growth in this analogue suggested that the environment induced unique molecular mechanisms in the microbe to cause disease. Our information from these early experiments provided NASA with new insight toward understanding the risk of infection during flight. In addition, the unique molecular mechanisms that were identified held the potential to be used to develop new therapeutics and vaccines for the general public on Earth.

NASA and the scientific community continued their support of our ground-based findings by awarding us a grant to investigate the effect of true space flight on *Salmonella* virulence and gene expression responses. This was an exciting opportunity for us, as while the RWV bioreactor can simulate some aspects of the space flight environment, it cannot duplicate all of the physical parameters that organisms encounter during space flight or their biological responses. In September 2006, our first space flight experiment flew aboard STS–115, and we investigated the comprehensive changes in *Salmonella* when exposed to the truly unique environment of microgravity. The results from this experiment were remarkable and showed that during space flight, *Salmonella* altered its virulence and gene expression responses in unique ways that are not observed using traditional experimental approaches. These findings immediately advanced our knowledge of microbial responses to space flight and disease causing mechanisms used by this important human pathogen. Our first technical report from this space flight experiment was recently published in the *Proceedings of the National Academy of Sciences,* and our results demonstrated changes in *Salmonella* disease causing potential (virulence) during flight as compared to identical samples that were grown on the ground. Specifically, our findings demonstrated that space flight increased the virulence of *Salmonella,* and the pathogen was able to cause disease at lower doses. In addition, we identified 167 genes in *Salmonella* that changed expression in response to space flight. The identity of these genes allowed us to discover a key "master switch" regulatory mechanism that controls *Salmonella* responses to space flight environments. This molecular target, and others that we identified, hold potential to be translated into new therapeutic and vaccine approaches to treat and prevent human enteric salmonellosis.

This experiment was a "first of its kind" in space flight biological study. It was the first study ever to investigate the effect of space flight on the disease-causing potential (virulence) of a pathogen, and the first ever to obtain the entire gene expression response profiles of a bacterium to space flight. In fact, very few studies contain data that document gene expression changes during space flight. It is also critical to mention that an important part of our space flight work is directly related to helping us understand how microbial pathogens cause infectious disease here on Earth. This is possible because the unique environment of space flight encountered by microorganisms (including pathogens) are also relevant to conditions that these cells encounter here on Earth during the normal course of their life cycles, including certain niches within the infected host, such as parts of the human intestine. Thus, an exciting part of this work is the opportunity to use space flight and the ISS as a novel enabling research platform for innovations in infectious disease control here on Earth—including novel insight into how pathogens cause disease and for the development of new therapeutics and vaccines for treatment and prevention.

The success of our flight experiment aboard STS–115 inspired a follow-up experiment aboard STS–123, which just flew in March 2008. While the data is still being analyzed, our preliminary findings are leading toward translational applications of our original data for the development of novel strategies to treat and prevent infection and disease during flight and here on Earth. Shortly, we expect NASA and the public to receive a direct benefit from their investment.

The ISS holds tremendous potential to provide novel insight into human health and disease mechanisms that can lead to ground-breaking new treatments to combat infectious disease and improve the quality of life.

2. What is your perspective on the future potential for use of the microgravity environment as a research tool?

The microgravity of space flight offers a unique environment for ground-breaking biotechnology and biomedical innovations and discoveries to globally advance human health in the following areas:

– Infectious disease
– Immunology
– Cancer
– Aging
– Bone and muscle wasting diseases
– Development of biopharmaceuticals
– Tissue engineering

It is not surprising that biological systems respond in novel ways to the space flight environment. Many breakthroughs in life sciences research have come from studying living systems in unique and extreme environments. It is from studying the response of biological systems under these environments that we have not only gained new fundamental insight into how they function and adapt to extreme conditions, but have also translated these findings into beneficial biotechnology and biomedical advances to improve our quality of life. Space flight is simply the next logical progression and extreme environment to study that holds tremendous potential to provide the next ground-breaking advances in public health.

The ISS provides a unique environment where researchers can explore fundamental questions about human health—like how the body heals itself and develops disease. Specifically, the ISS offers an orbiting laboratory to use microgravity as a tool to bring a new technological approach to understanding living systems and discover basic mechanisms we haven't seen before. That is because organisms and cells respond in unique ways to space flight and exhibit characteristics relevant to human health and disease that they do not when cultured using traditional conditions on Earth. Accordingly, cellular and molecular mechanisms that underlie disease can be studied, offering new opportunities to see how cells operate in these conditions, and giving new fundamental insight into the disease process. Many of these findings may translate directly to the clinical setting for novel ways to diagnose, treat and prevent disease here on Earth. This type of research creates exciting new opportunities for the utilization of ISS to advance the frontiers of knowledge and act as a commercial platform for breakthrough biomedical and biotechnological discoveries. I believe it is important to take advantage of this unique research facility to develop new advances in biotech and biomedicine that will globally advance human health and benefit the United States in the international economy.

Thus, it is anticipated that ISS life sciences research will lead to ground-breaking discoveries and innovations in human health, biotech and biomedical innovations, and will have a lasting impact on our nation's scientific capability, economy, and quality of our lives.

3. What are any potential applications of the basic research you have conducted to date or intend to pursue?

The investment that NASA has made in our research for innovations in infectious disease treatment and control will provide long lasting return in the protection of humans as they explore space and for the general public here on Earth. Regarding protection of the crew, the negative impacts of infectious disease range from impeded crew performance to potentially life threatening scenarios. As humans travel further away from our home planet, the risk to crew health and mission success becomes even greater. As we gain greater knowledge of the risks of microbial infection, prudent preventative operational activities, therapeutics, and other countermeasures can be implemented to mitigate the risk to the crew and mission success.

Perhaps the greatest application from this research will not apply directly to space flight, but rather to improving the quality of life on Earth through the development of novel strategies to combat infection and disease. Internationally, we face many challenges to our health by microbial threats. Antibiotic resistant strains are on the rise, regional diseases are expanding to new locations, the threat of bioterrorism looms, and a multitude of diseases have insufficient treatments. New treatment paradigms and testing methods are desperately needed. The knowledge from space flight experiments is providing novel insight into how microbes cause disease in the human body and is providing new targets for therapeutic and vaccine development. The goal is to identify target mechanisms in space and then investigate these mechanisms on Earth. By understanding more fully how these organisms function and react to novel stimuli, we can develop new methods to treat and prevent the spread of infectious agents.

In addition, the knowledge gained from space flight research can advance and accelerate therapeutic development and implementation of new strategies for translation of this research into health benefits for the developing world. The costs of therapeutics and vaccine development can be prohibitively high. Bringing a new drug to market can cost in excess of one billion dollars over a decade before it reaches the patient. If the knowledge gained from space flight studies provides even an incremental decrease in these costs and timelines (which studies strongly suggest is the case), then this research is of tremendous importance.

An example of a potential boon from space flight experiments is our laboratory's discovery that gene regulatory proteins participate in the space flight mechanistic response of microbial pathogens. Gene regulatory proteins affect every property of a cell including its ability to cause disease. Our laboratory is currently focusing on how this regulatory pathway works in *Salmonella* and how it can be manipulated to control that organism's virulence in flight and here on Earth. Once understood, we will use that knowledge to see which other microorganisms can be controlled in a similar fashion. A detailed understanding of how these gene regulatory proteins are controlled may offer new opportunities to design efficacious drugs and vaccines that would target this class of protein.

It is also relevant to note that there are exciting efforts underway to develop a nationwide Biotechnology Space Research Alliance (BSRA) Consortium that partners a world-class team of industry, university, and economic development organizations across the country to partner with NASA to utilize the ISS for breakthrough biomedical and biotechnology discoveries. It is anticipated that the discoveries made on ISS will engender scientific knowledge, technological capability, and commerce on Earth as a gateway to 21st Century exploration and development of space.

One key to our nation's economic success has been its ability to provide unique answers to the world's problems. We have the opportunity to advance in a field where the United States is a world leader. I believe space exploration and development will be one of the defining activities for our nation that will lead the world in this new millennium.

BIOGRAPHY FOR CHERYL A. NICKERSON

Dr. Nickerson is an Associate Professor at The Biodesign Institute in the Center for Infectious Diseases and Vaccinology at Arizona State University. She obtained a B.S. in Biology at Tulane University/Newcomb College (1983), a M.S. degree in Genetics from the University of Missouri (1988), and a Ph.D. in Microbiology from Louisiana State University (1994). Her postdoctoral internship in microbial pathogenesis and infectious disease research was done at Washington University in St. Louis, MO, in the laboratory of Dr. Roy Curtiss III. In 1998, Dr. Nickerson joined the Tulane University School of Medicine as an Assistant Professor in the Department of Microbiology and Immunology, where in 2003 she received tenure and appointment to Associate Professor. While at Tulane, she also served as the Director for the Tulane Center of Excellence in Bioengineering, and as Co-Director of the Tulane Environmental Astrobiology Center. In January 2006, Dr. Nickerson joined the Biodesign Institute at Arizona State University as an Associate Professor in the Center for Infectious Diseases and Vaccinology.

Dr. Nickerson's research interests are focused on understanding how microbial pathogens cause infection and disease in humans, both on Earth and in space flight. By combining cell biology and microbiology with engineering and mathematics, she has been at the forefront of space biosciences and the emerging field called cellular biomechanics, making several fundamental discoveries in these fields. Her research has contributed important new insight into how mechanical forces like microgravity and fluid shear affect the function and behavior of living cells, and ultimately, play an important role in infectious disease. The results of Dr. Nickerson's NASA-funded work have been published in high-quality, peer-reviewed journals, including *Proceedings of the National Academy of Sciences, Infection and Immunity,* and *Applied and Environmental Microbiology.* She is recognized internationally for her work and has won several prestigious awards including the Presidential Early Career Award for Scientists and Engineers from NASA—presented by President George W. Bush at the White House (2001); the Charles C. Randall Award for Outstanding Young Faculty Member from the American Society for Microbiology (2000); Woman of the Year, New Orleans, LA, presented by New Orleans City Business (2002); Outstanding Newcomb College Alumnae (2004), and selection by NASA as an Astronaut Candidate Finalist (2003). She also serves as a Scientific Consultant for the NASA Life Sciences Division at the Johnson Space Center in Houston, TX. Experimental payloads from Dr. Nickerson's laboratory have flown on-board NASA Space Shuttle missions STS–112, STS–115, STS–123, and the International Space Station.

A landmark experiment from Dr. Nickerson's lab recently flew on Shuttle mission STS–115, and was the first study to examine the effect of space flight on the virulence (disease-causing potential) of a microbial pathogen, and the first to obtain the entire gene expression response of a bacterium to space flight. The results from this experiment were remarkable and showed that during space flight, the bacterial pathogen *Salmonella* increased its virulence and altered its gene expression responses in unique ways that are not observed using traditional experimental approaches. The results from this work have provided novel insight into the molecular mechanisms that microbial pathogens use to cause infectious disease both during flight and on Earth, and has exciting implications for translation into human health benefits, including the development of new drugs and vaccines for treatment and prevention.

Chairman UDALL. Thank you, Dr. Nickerson.

Mr. Pickens.

STATEMENT OF MR. THOMAS BOONE PICKENS, III, CHAIRMAN AND CHIEF EXECUTIVE OFFICER, SPACEHAB, INC.

Mr. PICKENS. Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to make my first appearance before you today as the Chairman and CEO of SPACEHAB to discuss the significance of NASA's International Space Station Program, not just as it applies to commercial aerospace company, but also for its tremendous potential to benefit mankind. I represent the commercial perspective of microgravity and its value.

First question was how does your company arrive at the decision to pursue vaccine development under microgravity conditions and other opportunities? SPACEHAB has long known the value of the microgravity as our commercial modules and carriers have been the primary payload on 23 Space Shuttle missions in both the Space Station here and International Space Station. We have flown over 1,500 experiments to space, and much knowledge was discovered.

However, after reviewing these experiments I found that we have only begun the discovery processes. While experiments were sent to space, the ISS was under construction, and the environment was not ideal for these sometimes very sensitive samples.

But today the International Space Station is nearly complete, and the ISS has been designated a national laboratory available for commercial endeavors, setting the stage for a new age in microgravity experimentation that shows strong indications of great value both in commercial investment returns and in saving and enhancing our lives here on Earth.

To take advantage of these unparalleled space-based resources, SPACEHAB has initiated a new division. SPACEHAB's Microgravity Processing division is uniquely qualified to identify commercial microgravity processing opportunities through our history of supporting microgravity research activities and our wide range of partnerships with agencies and industry leaders.

This division focuses on commercial R&D initiatives that are aligned with the national lab capabilities, transportation opportunities, and market demand.

To assist SPACEHAB in identifying these high-value opportunities for commercialization, we formed a team of our nation's leading microgravity researchers. SPACEHAB Science Advisory Council is comprised of experts in microgravity life sciences, biotechnology, and material sciences, and most of these distinguished individuals have extensive experience with microgravity.

The first step in this process is to gain access to the ISS through a Space Act Agreement, and the next step is to establish the appropriate public and private partnerships required to execute an ISS National Lab project.

As an example, SPACEHAB has established a public partnership with the Department of Veterans Affairs, which will allow joint efforts in various biotechnology research and product development in the national lab, leading to commercial healthcare solutions.

Second question. Are there other applications of the microgravity environment that you intend to pursue? And I will go through those. The space environment has been, has shown to induce key changes in microbial cells to, and are directly relevant to infectious disease. The targets identified from each of these microgravity-induced alterations represents an opportunity to develop new and improved therapeutics, including vaccines, as well as biological and pharmaceutical agents aimed specifically at eradicating the pathogen. Furthermore, these different targeted approaches each represent potential product lines of development within the microgravity environment.

SPACEHAB has determined that one of the most valuable short-term microgravity opportunities is in the development of advanced vaccines that have the potential to be worth billions of dollars while saving thousands and perhaps millions of lives.

No single medical advance has had a greater historical impact on human health than vaccines. Today vaccines continue to be developed, providing hope to eradicate many diseases that continue to kill millions every year as pandemic influenza, AIDS, cancer, and instruments of bioterror.

An experiment that flew in the ISS in 2006, concluded that bacteria grown in microgravity are much stronger than those grown on Earth. This is a very important discovery as it signaled to scientists that microgravity properly controlled could be used to design vaccines much quicker and with much greater precision than before possible.

As a result of these and other conclusions, SPACEHAB has taken these composite findings to the next level in sponsoring a microgravity vaccine development model that was sent to space on the Space Shuttle during mission STS–123. The vaccine model is scheduled to return on the STS–124 mission in May to confirm the initial results. Once complete, this new space-based model has the potential to significantly increase our ability to develop vaccines for various types of infectious diseases.

Protein crystal growths, we call those PCGs, the cells of the human body are the mini factories that enable life. What divide all those factories to perform their specific functions are the proteins that are synthesized within these cells. The body utilizes approximately 400,000 of these proteins, and when certain protein/cell functions become abnormal, a wide variety of diseases and conditions may present themselves. Drugs can be developed to alter the effects of these problem proteins, but drug development is very difficult to accomplish on Earth and for some of those more serious diseases, microgravity is thought to hold the only solution for saving millions of lives on Earth.

Diabetes, Parkinson's, Alzheimer's, Cystic Fibrosis are only just a few of the diseases the microgravity is thought to hold the potential to provide significant advancements in developing a drug treatment.

A technique has been developed on Earth to discover drug therapies that involves growing a very pure crystal that is used to obtain an image of the atomic structure of a protein. Once the crystal is obtained, a very high powered X-ray or X-ray crystallography, reads the structure of the protein and from this, a drug can be developed. It was discovered that when crystals were grown in microgravity, the results are often times a larger and better quality crystal that can be more easily and accurately characterized, making it more possible to develop a drug treatment that can treat these diseases.

The PCGs have flown more than any other experiment with an estimated investment of over $400 million by NASA. SPACEHAB has identified 1,250 Membrane Proteins and 425 Aqueous Proteins that are ready for microgravity crystallization. The company expect to send the first samples to the ISS for processing in the third quarter of 2008. Upon return from space, these crystals will be X-rayed and the data sold to drug development companies. Alternatively, the company may choose to add more value to the discovery by pursuing its own drug development program.

Since the inception of the ISS, hundreds of experiments have been conducted giving rise to additional opportunities to provide Earth-based benefit. As NASA's mission priorities focus on exploration beyond low-Earth orbit, the designation of the ISS as a national lab enables non-government entities to partner with NASA to further the benefit of space-based research and development. SPACEHAB intends to conduct its national lab activities to move technology forward, provide economic growth, stimulate the minds of our future engineers and scientists, and to ultimately improve the quality of life here on Earth.

The third question that I had was are the current, what are the current perspectives in the financial community with respect to underwriting R&D efforts that require the microgravity environment of space? We are currently funding our micro-G efforts with internal cash and financial assistance from the State of Florida and its Space Florida Authority. The fact that the ISS was designated as a national laboratory last year went a long, long way to produce a—to putting an environment together to attract capital.

Ultimately, the investment community needs to see commercial product come back from micro-G in products sold, in profits made. We feel confident that we can attract capital from corporate and institutional investors as needed to provide an acceptable return.

In closing, I would like to add the International Space Station is unarguably the greatest achievement man has ever accomplished. The ISS is the pyramids of our generations in the aqueducts of our nation. The taxpayers of this country have spent over $100 billion in its design and construction, and it is a magnificent achievement that has included 19 countries in this effort.

I want to take this moment to recognize the engineers, the technicians, and politicians that have accomplished this great feat, and I want to close by reminding you that this is the time to take advantage of what we have built.

Mr. Chairman and Members of the Subcommittee, I want to extend my sincere appreciation for having me here today.

[The prepared statement of Mr. Pickens follows:]

PREPARED STATEMENT OF THOMAS BOONE PICKENS, III

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to make my first appearance before you today as the Chairman and CEO of SPACEHAB, Inc. to discuss the significance of NASA's International Space Station Program—not just as it applies to a commercial aerospace company—but also for its tremendous potential to benefit mankind.

SPACEHAB, Inc. (NASDAQ: SPAB), was incorporated in 1984 and made its initial public offering in 1995. The Company flew its first module on a Space Shuttle mission in 1993. To date, SPACEHAB modules and carriers, which fly in NASA's Space Shuttle cargo bay, have been the primary payload on 23 Space Shuttle missions, including research missions on-board the fleet of orbiters, resupply missions to both the Russian space station Mir, and the International Space Station (ISS). The modules doubled the amount of working and living space available to the astronaut crews. Over the course of our pressurized module program, SPACEHAB has been involved in the analytical and physical integration and operation of hundreds of microgravity research and science payloads.

SPACEHAB has long known the value of microgravity; however there has never been the environment to commercially exploit these opportunities as the priorities of the international space partners have been the construction of the ISS while performing rudimentary experiments in microgravity. Additionally, until this year, the ISS has simply not been in the state of completion that would have been able to sustain repeated processing of microgravity products. And, until the *NASA Authorization Act of 2005,* NASA has never considered commercial ventures to profit from ISS produced products. Now that the International Space Station is nearly complete, and the ISS has been designated as a National Laboratory available for commercial endeavors, the next obvious direction for SPACEHAB is to utilize its experience in microgravity and commercial practices in forming a partnership with NASA to demonstrate the efficacy of the commercial space industry. This goal is achieved by the enhancement of life on Earth through the advancement of a wide range of microgravity technologies from a "demonstrated" state to a production state.

To take advantage of these unparalleled space based resources SPACEHAB has initiated a new division. SPACEHAB's Microgravity Processing division is uniquely qualified to identify commercial microgravity processing opportunities through our history of supporting microgravity research activities and our wide range of partnerships with agency and industry leaders. Additionally, SPACEHAB's Microgravity Processing division is ideally positioned to implement these commercial microgravity opportunities through the company's core capability of planning, integrating, operating payloads and its proven experience in commercial business practices. This division focuses on commercial R&D activities that are aligned with the National Lab capabilities, transportation opportunities and market demand.

SPACEHAB's Microgravity Processing division serves to advance both the business and technical state-of-the-art. With the designation of the ISS as a National

Lab, SPACEHAB is establishing a broad portfolio of commercialization initiatives that will advance the state of the commercial space business sector to a level only previously theorized by commercial space advocates. By migrating microgravity processing initiatives from demonstration and validation to commercial production initiatives, substantial progress is made in sample throughput by adding to existing microgravity processing hardware the advanced automation systems necessary for higher volumes.

To assist SPACEHAB in identifying those high-value opportunities for commercialization, a team of our nation's leading microgravity researchers has been formed. This Science Advisory Council, chaired by SPACEHAB's MGP Program Manager, is comprised of experts in microgravity life sciences, biotechnology and material sciences. The majority of the council members are affiliated with educational institutions and will also provide significant guidance and contribution to SPACEHAB-developed educational programs used to motivate the next generation of science and engineering professionals. Members of this council include:

Science Advisory Council	
Member	**Affiliation**
Jeanne Becker, Ph.D.	National Space Biomedical Research Institute
Tim Hammond, MB, BS	Duke University
Neal Pellis, Ph.D.	NASA- Johnson Space Center
Louis Stodiek, Ph.D.	BioServe, University of Colorado
Wagner Vendrame, Ph.D.	University of Florida
Xing Wang, Ph.D.	Alfred University

Once a commercial opportunity has been identified, SPACEHAB will develop a unique business plan to ensure the viability of the proposed opportunity. Each business will utilize a systematic process to assure all technical and financial aspects of each opportunity are aligned with the goals and objectives of the National Lab and have a high probability of success.

The first step in this process is to establish the appropriate public and private partnerships required to execute an ISS National Lab project. As an example, SPACEHAB has established a public partnership with the Department of Veterans Affairs which will allow joint efforts in various biotechnology research and product development on the National Lab leading to commercial health care solutions. Additionally, SPACEHAB is establishing partnerships with private commercial companies to better ensure its success for the development of commercial products utilizing the National Lab. SPACEHAB has established a commercial partnership with Dynamac, the operator of the Space Life Sciences Laboratory (SLSL) at the Kennedy Space Center (KSC). For 37 years, Dynamac has been providing advanced science research and technology services related to physical, chemical, and life science research initiatives. Beginning in 1995, as the prime Life Sciences Services Contractor (LSSC) for NASA–KSC, Dynamac scientists have helped process more than 180 Shuttle and ISS flight experiments. In addition to supporting Principle Investigators (PIs) world wide, Dynamac scientists have designed, constructed, and processed over 10 flight experiments as the primary PIs. This partnership arrangement utilizes their commercial "work-for-others" allocation in their SLSL contract allowing them to support industry initiatives in microgravity research. Utilization of their skills and this state of the art facility accommodates payload preparation, in-flight data collection, payload control, and supports post flight sample recovery and evaluation. The data network system installed in the SLSL, and managed by Dynamac, allows payload monitoring and control capability to both on-site and at off-site SPACEHAB facilities.

SPACEHAB has developed a broad portfolio of opportunities in the biotech and material science markets. We are working diligently to match these opportunities with flight opportunities and funding profiles. The overall objective is to have a dynamic matrix that can quickly match opportunities with flight availability, market demand and available resources. Some near-term targets include:

Infectious Disease

The space environment has been shown to induce key changes in microbial cells that are directly relevant to infectious disease, including alterations of microbial growth rates, antibiotic resistance, microbial pathogenicity (that is, the ability of the organism to invade human tissue and cause disease), organism virulence, and genetic changes within the organism. The targets identified from each of these microgravity-induced alterations represent an opportunity to develop new and improved therapeutics, including vaccines, as well as biological and pharmaceutical agents aimed specifically at eradicating the pathogen. Furthermore, these different targeted approaches each represent potential product lines of development within the microgravity environment.

Understanding virulence factors is key to developing a vaccine. Virulence refers to the degree of pathogenicity of a microbe, or in other words, the relative ability of a microbe to cause disease. Virulence factors must be identified, and either purified for use as a vaccine, or the virulence factor can be deleted from the bacterium, yielding an attenuated strain to use as a vaccine. Hence, vaccines may consist of dead or inactivated organisms, or purified products derived from them. As the development of antibiotic resistance continues to erode one of the greatest advances in modern health care, it is crucial to identify bacterial targets that can form the basis of novel anti-infective therapies, including vaccines.

SPACEHAB has determined that one of the most valuable short-term microgravity opportunities is the development of advanced vaccines that have the potential to be worth billions of dollars and also represents one of the quickest paths to success.

No single medical advance has had a greater impact on human health than vaccines. Before vaccines, Americans could expect that every year measles would infect four million children and kill 3,000; diphtheria would kill 15,000 people, mostly teenagers; rubella (German measles) would cause 20,000 babies to be born blind, deaf, or mentally retarded; pertussis would kill 8,000 children, most of whom were less than one year old; and polio would paralyze 15,000 children and kill 1,000. Smallpox, a disease estimated to have killed 500 million people, was eradicated by vaccines. Today, vaccines continue to be developed providing hope to eradicate many diseases that continue to kill millions every year such as pandemic influenza, staphylococcus, AIDS, instruments of bioterror, and various types of cancers.

The frustration encountered by the biotech vaccine industry lays in the cost of the discovering the exact strain of bacteria needed to invigorate the immune system while causing no harm to the animal—including humans. On Earth this is a very arduous process typically taking many years with a low probability of success. However, an experiment that flew to the ISS in 2006 concluded that bacteria grown in microgravity are much stronger than those grown on Earth. This was a very important discovery as it signaled to scientists that microgravity, properly controlled, could be used to design vaccines much quicker and with much greater precision than ever before possible. Many other vaccine experiments have since been sent with similar findings. As a result, SPACEHAB is taking these composite findings to the next level and sponsoring a microgravity vaccine development model that was sent to space on the Space Shuttle during mission STS–123. The vaccine model is scheduled to return on the STS–124 mission in May to confirm the initial results. The selected vaccine that SPACEHAB has chosen is to combat the complex *Salmonella* bacteria that makes millions sick every year, kills thousands, and costs many millions of dollars in financial damages. SPACEHAB has teamed with the Department of Veterans Affairs in collaboration with investigators from the National Space Biomedical Research Institute at Baylor College of Medicine, Duke University Medical Center, University of Colorado at Boulder, and the Max Planck Institute for Infection Biology. Results of this infectious disease model will be made public in the coming months. Once complete this new space based model has the potential to significantly increase our ability to develop vaccines for various types of infectious disease.

Proteins

The cells of the human body are the mini “factories” that enable life. What drive all of those factories to perform their specific functions are the proteins that are synthesized within those cells. The body utilizes approximately 400,000 of these proteins and when certain protein/cell functions become abnormal, a wide variety of diseases and conditions may present themselves. Drugs can be developed to alter the effects of these problem proteins, but drug development is very difficult to accomplish on Earth and for some of the more serious diseases, microgravity is thought to hold the only solution for saving millions of lives on Earth. The following is a list of those diseases that microgravity is thought to hold the potential to provide significant advancements in developing a drug treatment:

- Diabetes
- Parkinson’s
- Alzheimer’s

- Lou Gehrig's disease
- Pancreas Cancer
- Cystic Fibrosis
- Hemophilia

Protein Crystal Growth (PCG)

A technique has been developed on Earth to discover drug therapies that involves growing a very pure crystal that is used to obtain an image of the atomic structure of a protein. Once the crystal is obtained, a very high powered x-ray (x-ray crystallography) reads the structure of the protein and from this, a drug can be developed. This crystallography technique is routinely performed on Earth however it has been found that gravity has a limiting effect on the growth and quality of the crystals. It was discovered that when crystals are grown in microgravity, the result is often times a larger and better quality crystal that can be more easily and accurately characterized making it more possible to develop a drug treatment that can treat these diseases.

The PCG's have flown more than any other experiment with an estimated investment of over $400 million to date. SPACEHAB has identified 1,250 Membrane Proteins and 425 Aqueous Proteins that are ready for microgravity crystallization. The Company expects to send the first samples to the ISS for processing in the third quarter of 2008. Upon return from space, these crystals will be x-rayed and the data sold to drug development companies. Alternatively, the Company may choose to add more value to the discovery by pursuing its own drug development program.

Of the human body's approximately 400,000 proteins, nearly 30% are considered membrane proteins and are, in fact, the types of proteins involved in some of the higher mortality diseases thereby commanding significant governmental and corporate research funding. While 30 percent represents well over 100,000 proteins, unfortunately only about 100 membrane protein structures have been identified due to the extreme difficulty of growing membrane protein crystals of sufficient quality for crystallography. To show the importance of membrane proteins and despite low number identified, nearly 50 percent of the commercially available drugs target membrane proteins. Given the improvements in crystallography and drug design over the past 10 years, Vergara, notes that the "production of well diffracting crystals of biological macromolecules remains a major impediment."

Previous space flight activities indicated that growing protein crystals in the microgravity environment experienced in spacecraft offers significantly increased quality of protein crystals. These better diffracting crystals create the opportunity to increase the number of protein structures identified that can be used for new drug development efforts.

As SPACEHAB's microgravity processing initiative gains momentum, our business model is to reinvest in our own future. SPACEHAB will continuously evaluate past microgravity research and emerging discovery opportunities to drive our next generation microgravity processing programs. This exploratory activity will be self-funded and will set as a goal the continued demonstration to the American public the value of the International Space Station.

From improved firefighting equipment derived from NASA's advances in extra-vehicular mobility units (EMUs) to satellite tracking of forest fires by NASA's Earth Observing System, the value of NASA's research and development activities has been manifested countless times here on Earth. Since the inception of the ISS, hundreds of experiments have been conducted giving rise to additional opportunities to provide Earth based benefit. As NASA's mission priorities focus on exploration beyond Low-Earth Orbit (LEO), the designation of the ISS as a National Lab enables non-government entities to partner with NASA to further the benefit of space based research and development. SPACEHAB intends to conduct National Lab activities on a broad portfolio of technologies in the life sciences, biotechnology and material sciences arenas to move technology forward, provide economic growth, stimulate the minds of our future engineers and scientists, and to ultimately improve the quality to life here on Earth. The SPACEHAB microgravity processing effort directly benefits the public in multiple ways.

Through the establishment of our microgravity processing division and initial on-orbit processing opportunities, SPACEHAB will raise significant capital and re-invest this capital in established biotech companies, universities, research centers, as well as our own MGP division resulting in direct growth to local economies at our sites in Texas and Florida. Furthermore, as we incrementally increase the scale of our microgravity processing capabilities, we create job opportunities within the aerospace industry in support of the on-orbit facilities (i.e., rack facilities, etc.) development and operations, the necessary ground infrastructure to support microgravity processing preparation and flight operations, and non-traditional jobs in support of product post processing and distribution. We are actively planning the creation of new companies that are established as a result of the products developed from our space based processing; these new companies contribute positively to economic growth through additional job creation and capital investment.

An integral component of the planned activities for utilization of ISS as a National Laboratory is the development of education and outreach initiatives for the advancement of 6–12 science, technology, engineering and mathematics (STEM). An education task force convened by NASA has defined a role for private sector participation in this important goal, and has extended this objective to also include activities ranging to university, graduate and post-doctoral studies. R&D activities in microgravity provide much opportunity in support of educational initiatives. SPACEHAB has a rich history in this area, specifically in the successful Space Technology and Research Students (STARS) program, which provided hands-on, interactive scientific learning for students from grammar through high school aboard the Space Shuttle missions, including STS–107. Students from six countries participated in the STS–107 mission and were directly involved in the experimental concept, design, management, set-up and data assessment of research conducted in microgravity. More than 40 countries expressed interest in participating during the development of the STARS program. This activity partnered with BioServe Space Technologies, and utilized the Isothermal Containment Module (ICM) for the experimental studies. BioServe has continued educational payload design—the Commercial Generic Bioprocessing Apparatus Insert–02 (CGB–02) was successfully deployed on STS–116 and provided data and imagery, via cameras installed within the hardware, which were down-linked directly into classrooms across the world via the World Wide Web. The CSI–02 is an educational payload designed specifically to heighten the enthusiasm of students in STEM and to provide opportunities for these students to participate in near-real time research on ISS. Moreover, these activities also raise national and international awareness of cutting edge science and technology, and opportunities for product development in microgravity. Partnerships to utilize ISS for educational endeavors can be modeled after the STARS program for 6–12, with additional outreach to the broader educator community to include teachers and scientists in both academia and industry, and can be further extended to educational program administrators for design of next-generation programs in STEM disciplines. The development of training, internship and shadowing programs designed to raise awareness of the commercial sector as it pertains to microgravity R&D would also be an important outcome of these educational initiatives.

In conjunction with the establishment of our MGP business unit, SPACEHAB has undertaken the development of our microgravity processing technology roadmap. With 23 successful SPACEHAB missions containing numerous microgravity payloads, our engineers are experienced in end-to-end microgravity payload processing including analytical integration, comprehensive payload functional and interface testing, physical integration, and payload flight operations. Leveraging this unique experience in the development of our technology roadmap, our efforts are focused on innovative concepts that move the state-of-the-art in microgravity from small scale locker processing to large scale rack processing on-orbit, on automation techniques that reduce the required on-orbit crew time requirements, and to develop new techniques for on-orbit data processing where results can be down-linked thereby reducing the down-mass requirements.

Mr. Chairman and Members of the Subcommittee, I want to extend my sincere appreciation for allowing me this forum to discuss a topic as critical to our future as the International Space Station Program—as well as your continued support which is vital for its success going forward. I would be pleased to respond to any questions you may have.

BIOGRAPHY FOR THOMAS BOONE PICKENS, III

Mr. Tom B. Pickens, III is presently the Chief Executive Officer of SPACEHAB, Incorporated, a Texas-based aerospace company, which has been pioneering in providing commercial space services for nearly 25 years. Mr. Pickens is also the Managing Partner of Texas Nanotech Ventures, Inc., a leader in the global nanotechnology industry; and, the Managing Partner and Founder of Tactic Advisors, Inc., a company specializing in corporate turnarounds that have aggregated to more than $20 billion in value. Concurrently, Mr. Pickens is President of T.B. Pickens & Co., which has acted as both advisor and principal of corporate acquisitions now totaling more than $10 billion.

Mr. Pickens' financial and corporate streamlining experience began in the Wall Street arena where he worked extensively in hedge fund management and due diligence implementation. His unprecedented experience with all facets of corporate turnaround and restructuring including startup, growth, and value creation has gained him the esteemed reputation of being one of the leading authorities in corporate transactional matters. Mr. Pickens has been a member of SPACEHAB's Board of Directors since 2003 and became the President and Chief Executive Officer in January 2007.

Other notable contributions include acting as Founder and President of Beta Computer Systems; Managing Partner, Grace Pickens Acquisition Partners, LT; Managing Partner, Sumter Partners L.P.; Chairman and CEO of Catalyst Energy Corporation (NYSE); Chairman, United Thermal Corporation (NYSE); President, Golden Bear Corporation; President, Slate Creek Corporation; President, Eury Dam Corporation; Chairman, Century Power Corporation; President, Vidalia Hydroelectric Corporation; Managing Partner, Pickens Capital Income Fund, L.P.; Chairman, The Code Corporation; and President, U.S. Utilities, Inc. Mr. Pickens has also served in the capacity representing the Office of the Chairman, Mirant Equity Committee (NYSE) and Director, Optifab, Inc. (NASDAQ). He is currently Director, Trenwick America Corporation, and Director of Advocate MD.

Mr. Pickens graduated from Southern Methodist University with a Bachelor of Arts in Economics.

DISCUSSION

Chairman UDALL. Thank you, Mr. Pickens.

At this point let us jump right into our first round of questions. The Chair recognizes himself for five minutes.

I would like to direct a question to every member of the panel, and I would give each one of you about a minute or so to respond.

ISS PRODUCTIVITY AND UTILIZATION

In your opinion what needs to be done to ensure that the ISS will be a productive research facility, and Dr. Stodieck, I might also ask you if you would speak to when you mentioned modest funding, what that might entail. But we will start with Dr. Knipling.

Dr. KNIPLING. Well, my sense it is already very successful as one witness, Mr. Pickens, indicated. It is a tremendous success. Certainly, yes, we garner the results of some of these initial experiments. I think that is really going to provide testimony for the opportunity, and that in turn will drive our future strategies for expanding and enhancing that work. That is my sense of how this work will unfold.

Dr. STODIECK. Thank you. Modest funding. You know, it depends, of course, on ultimately what it is going to cost for transportation, and that is a fairly uncertain term at this point, but just doing some estimates based on what I suspect this will get, I would say if you funded an organization somewhere between $50 million and $150 million, maybe ramping up to that point, that you would have a substantial ability to attract and raise the productivity of the space station, something on that order.

Chairman UDALL. Thank you. Dr. Nickerson.

Dr. NICKERSON. From a scientific perspective, in order to truly tap into the fundamental and the enormous potential of the ISS as I mentioned in my previous testimony to lead to global advances in human health, two things from my perspective.

Consistent funding and access. The consistency in that funding word is very important, because science doesn't stop after one experiment. Good science leads to more questions than it answers, and so once you find something truly remarkable in flight and that potential for novel discovery, just as we found in STS–115, we were fortunate enough to have the follow-up flight on STS–123. But that consistency has to continue.

So consistency for funding and access.

Chairman UDALL. Mr. Pickens.

Mr. PICKENS. I think that it is a little more complex from my standpoint, because I am from the commercial side. I have seen where they have put experiments in space. They have done kind of fits and starts of it in terms of funding, timing, but they are in the middle of a construction program, and I kind of, you know, put the analogy is that you are trying to do open-heart surgery on the back of a bulldozer in the middle of a construction site at a skyscraper.

You know, they were building a space station in space, and they were putting and wedging the science in whenever they had the opportunity, and that is very, very hard to do science that way. When you talk to the scientists, they need to have consistency where they are bringing back samples, they are fixing them, they are going back again, over and over and over.

Now is the time, because we have completed the station or we are near completion of the station. Now is the time that we should get in there and do that. We should do it exactly like Louis says. We should fund something. We should remain, if there is somebody who is independent to make sure that these initiatives are held forth, there is $100 billion asset up there. The taxpayers expect a return, and they are entitled to a return. And they need to be given that opportunity and that science needs to be taken care of.

From a commercial standpoint I will take the low-hanging fruit of those efforts, and I will take, and whenever they are discovered to a point where they are commercial, and I will move them on through to the marketplace.

Chairman UDALL. I could follow on, what are your next steps in preparing for the utilization of station?

Mr. PICKENS. We are already moving, I mean, STS–123, 124, we are headed out for the, you know, duration of the Space Shuttle missions. We are concerned after that, because we don't have as easy access to space. It is nearing the completion of the manifest of the Shuttle. It is very, very tight to wedge our way in there. We are doing that successfully thus far, but we are very concerned about it, and we need that desperately because by the time we finish, we need to not have some gap in there, not to overemphasize the gap, but we don't want a gap sitting there on the science either. We still have to make a return as soon as possible to the American people and by getting on these Space Shuttle flights and sending up what we are sending up that goes a long way, and I commend NASA for allowing us to go on the Shuttle to date.

And I hope for more of that.

Chairman UDALL. You are ready to go, you have got the capital lined up, you are confident what you need is——

Mr. PICKENS. Yes, sir. I am sending samples to space as we speak.

Chairman UDALL. Thank you very much. I am going to recognize Judge Hall for five minutes. Look forward to hearing his questions.

Mr. HALL. I thank you, Mr. Chairman.

And I guess I will use part of my time in thanking this very capable group of witnesses here. I have really got something from every one of you. And I thank, Mr. Rohrabacher for being here. I especially ask him, you can tell by my raspy voice that I have been a victim of the influenza, and Dr. Nickerson, if you will do some more work on that, we will all be——

Dr. NICKERSON. I will get right on that.

Mr. HALL. And everybody around me would appreciate it.

I want to say of course I enjoyed Dr. Knipling's work, and to Dr. Stodieck, I liked your use of all agency's cost covered and comparisons with other research, and NASA and Congress admonished to have access to ISS and planning together and producing together. Very good instructions.

And Dr. Nickerson, our nation badly needs good news from space, not just tickertape, something over the television or just huge appropriations and exciting and delicate yes and still fragile missions. We need studies of cures from space, and you certainly reflect your intention is such, and I know I appreciate that and this group does.

DIFFERENCES BETWEEN GOVERNMENT AND SPACEHAB ACTIVITIES

And to Tom Pickens, accelerating the need for microgravity and the many experiments of space and the comparisons were very helpful. And your salute to the Space Station by it being at a class of all strategies is very, and the suggestion also to be as sensible as possible as they can be with the funds.

And along that line let me ask you, Mr. Pickens, do you see any distinction between the types of activity SPACEHAB seeks to conduct versus those that would be of interest to university and government researchers? Or commercial activities in competition with other university government research for ISS resources.

I would like to hear your comments on that if we have time left. I would like to hear each of you.

Mr. PICKENS. I always look when doing due diligence on, you know, opportunities in the marketplace, I like to see paradigms that were successful in the past, and I think a paradigm, you could take most of them, but let us just take the railroads.

You know, the United States Government built the railroads and then they proved out the technology and then today, you know, the, you know, all that evidence of success is certainly there. We built the International Space Station. We have built the access to space. What we haven't done and what is necessary here is that the government is the only one that is going to take these kind of risks, because commercial enterprise is not. They are not going to be sending up a whole lot of real basic science that we really haven't gone to the steps necessary in order to discover.

Again, we weren't given, the science community was not given and nor should really, I mean, the amount of time that they were given was generous by NASA. They were building a skyscraper in space, and to be putting science in there was generous of them to do that. But now we are at the stage to where we need to go and promote that and move forward with it, and government needs to go with the university level like Louis suggests and do a lot of basic science work. When it gets to the point to where it is commercial, people like me and myself, we will see that. We will identify that, and then we will move forward with how you end up taking that to a commercial setting.

So I think that there is a differentiation between the commercial interests and from the more basic science university interest, and I think they should be treated differently as well, sir.

Dr. NICKERSON. Thank you for the opportunity to answer that question. From researchers and scientific individuals' perspective and maybe I was fortunate to have been trained in a very multidisciplinary background which thinks outside of the box, but I have been trained, and I have always believed in a diversified research portfolio that is funded on multiple fronts, both by a government, traditional federal funding agencies, but also by corporate and private funding as well.

In that capacity, therefore, a lot of times some of your higher-risk research which has real tremendous potential to lead to major advances in public health, but it is higher risk, and sometimes some of the traditional funding venues in terms of our federal funding agencies like in NIH, tend to steer away from that a little bit and go for a more safer paradigm in terms of funding.

And sometimes those risks don't pay off, but holy cow, sometimes they do. And we have got to make that translational leap of not phenomenology. This isn't would be, could be, wishing kind of stuff. This is going to happen. It already is happening, and it will continue to happen. And for us to continue to maintain our nation's leap in technological and biomedical innovations to translate in terms of these types of advances, in terms of my end of public health, we have got to be able to successfully balance these types of funding and get away from them being normally separate but merge them together.

So absolutely. All three of those types of funding levels can exist together nicely and do.

Mr. HALL. My time is up, and I hope Dr. Stodieck and Dr. Knipling will answer my questions in some other people's five minutes here in a little bit.

But I would say to you, Mr. Pickens, that your comparison of railroads to space really goes from the bottom to the top, and it is a good comparison. You know, I vote for Amtrak and all that, and the dang thing goes to New York about 35 times a day and goes to Philadelphia about 40 times, 38 times a day, but, hell, they don't even whistle going through my district a lot of times, but I vote for railroads because we relied on rail during national emergency and war times and things like that. Thanks for that good comparison.

I yield back my time.

Chairman UDALL. Everybody here understands why Judge Hall is known as a statesman, although in some quarters, well, statesmen are dead politicians. We are glad to have a living statesman here among us today, and infrastructure is so important to our——

Mr. HALL. Maybe you will give me another five minutes.

Chairman UDALL. That is going too far.

The Chair recognizes the great Member, the Chairman of the Energy and Environment Subcommittee from Texas, Mr. Lampson. He is also known, although there would be others that might want to wrestle him for the title, as the man from NASA. He looks after NASA with the passion and consistency. Mr. Lampson, five minutes.

Mr. LAMPSON. Thank you, Mr. Chairman, and I have to agree with some of the words that have been said. This is something that can drive a great deal of the enthusiasm of this country when we make our commitment to it and consider the return that we are going to, that we have always gotten from our investment in space and in science.

I have had a number of conversations of late with Mr. Pickens, and one of the things that has impressed me specifically that you said was about how we seem to have gotten away from our concentration on science and relied more on the idea of if we build a craft, we can figure out what we do with it. We sort of get the cart before the horse. Really and truly our use of space should be about what we can learn from it, what we can get from the science. And then whatever craft we have to put together, then so be it. We go and do it.

And I know that you have done some specific work, Mr. Pickens, and I will pick on you because you do have SPACEHAB, which is in the 22nd Congressional District of Texas, and we are proud of the work that you do there and——

Mr. PICKENS. We are proud to be there.

Mr. LAMPSON.—the many employees that you have there. But let me start with you and ask you to continue your comment that you made a minute ago about due diligence. You have done something I think that is out of the ordinary with regard to how you looked at what potential there was for commercial activity.

COMMERCIAL ACTIVITY AT THE ISS

Can you discuss that a little bit? What did you do that may have been different in your findings as related to the potential for scientific research at the International Space Station?

Mr. PICKENS. As CEO of SPACEHAB, there, I am in a very unique situation. I am on a platform where I can access all of the thousands of people, billions of dollars, research, white papers, scientists, all those people will always end up responding to me. I have access to those people, they are excited about having the discussion with somebody, especially in the commercial sector, and as a CEO of SPACEHAB, I think I am the only guy that has the kind of access and that kind of position probably oddly enough in this country and maybe even in the world.

Most of the other aerospace engineering companies are aerospace engineering companies. SPACEHAB sent 1,500 experiments to space over a 23-year period of time. We had intimate knowledge of how to do that, and I use that platform and trained in New York, I consider myself quite a professional in due diligence, and I don't stop until I hear glass break as my granddad used to say.

And I just keep going and going and going, and these guys, some of them on this panel right here, they are sick of me, and that is usually when I start to slow down is about the time they do get sick of me.

But I have found that there is a lot of value up there. There is billions of dollars worth of value in terms of commercial value. In this, you know, environment that we are in that seems so appropriate where we should also be cognizant as commercial enterprise leaders of commercial companies, we also need to take care of things like environment and people and whatnot. It is just such a great added benefit to also be able to have the opportunity to save millions of lives with what we see as opportunities in microgravity.

This thing is for real. I think just in summary to you, Congressman, is this is for real. This is the real deal, is that there is a huge amount of value in microgravity. It wasn't given all the attention that it was, that we would have hoped, but we were, again, constructing a skyscraper in space.

So I think that, you know, what needs to happen now is that I think Louis is very, is being very conservative in terms of the amount of investment that should go up there. We end up in our barter arrangement that we ended up by taking and transferring the Columbus Module, which is the ESA Module, the European Space Agency Module, and the Kibox Module, with the Japanese Space Agency Module. We get half of their space because we transported that on our Space Shuttle. That is the deal. It was a barter agreement.

We have so much laboratory space up there it is unbelievable. With ours, with theirs there is lots of space available. I would like to see billions of dollars go into the basic science of this, and I think that it deserves it, and with aging of America and with health being such a big issue right now, there isn't any excuse not to. We should fund NASA more. We should give them more money, and we should put them on that focus to go get that done and exploit that $100 billion asset up there.

UNCERTAINTY PERTAINING TO LONG-TERM RESEARCH

Mr. LAMPSON. I have got less than a minute left, so let me just ask whoever would like to start on this question of the panel. What impact does, I am concerned that we are not going to fully use the ISS, especially after we retire the Shuttle. What impact does the uncertain status of the ISS past 2016, have on potential users being able to plan long-term research using the Station?

Dr. NICKERSON. Well, I think there are two questions there, but first I would focus on what we can get done before 2016, which if we get the kind of appropriations and funding in here we need to, we can learn an enormous amount up until that point in time. So let us not underestimate the tremendous impact that that can make up until then.

After that point in time it is going to depend on access and access to space through other venues and how we can continue to use the microgravity environment after that. But up to that point in time I am more focused on what we can do on a consistent basis to maximize that space and utilize our potential to lead to these new technology advances.

Mr. LAMPSON. If it, Mr. Chairman, can anyone else comment before I yield my time back?

Dr. STODIECK. And I just want to add that I think, you know, in fact, that 2016, is frankly much too close a horizon for us to be planning it. It seems ridiculous to even be thinking about the decommissioning of Space Station before it has even been completed.

But in reality, of course, that is what you are really asking, and I think that we need to already begin the planning, and I think, of course, appropriations looks at, you know, five-year timeframes. It is not too soon to really be thinking about extending the service life of the Space Station, and I think we need to go out to at least 2020, and frankly, I think, you know, when we start to get the kind of productivity and the results that I expect to see, then I think there will be a lot of interest and extended beyond that.

But I think we need to recognize that without the Space Shuttle that the, you know, the clock really starts ticking for Space Station because it will become more and more difficult to maintain it and service it. So starting that productivity as soon as possible and using it for as long as we can.

Mr. LAMPSON. Thanks. Dr. Knipling, anything?

Dr. KNIPLING. I believe my comments will reinforce what has been said. I think much can be accomplished in the near term to validate these concepts that we have talked about. And we are very confident that they will be validated one way or the other. We can adapt to what we learned, but I think that the promise of what we learn will actually provide testimony for further extension in the further of the Space Station in one way or another.

Mr. LAMPSON. Thank you all. Thank you, Mr. Chairman.

Chairman UDALL. Thank the gentleman.

The Chair recognizes the gentleman from California, Mr. Rohrabacher, who is one of the most dedicated and consistent supporters of this, and he always has his back peering over the horizon and bringing some really creative thinking to NASA and how we promote our space program both in the private and public sectors.

Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you. Let me note that I have supported Space Station. I see the Space Station as a success in the sense that we have learned how to build structures in space. Humankind is to advance, if we are going to conquer this frontier, we have learned how to cooperate with other countries in achieving that.

I am not sure even from the testimony today, however, that the accomplishments that are being talked about have been accomplished in terms of medical research. All along we were told that there would be these great accomplishments. It has been a long time.

Frankly, they have not been validated yet. I have heard a lot of rhetoric today, but I have been listening to that rhetoric for 20 years. I am satisfied with the fact that we now have the capabilities of building structures in space. I would hope they are not just pyramids. I hope this isn't just a pyramid that will be historic, a historic structure. I hope that there is something that comes out of it in terms of a cure for a disease. Believe me, I have been listening to that for 10 years. I haven't seen it yet.

ISS LAB COMPATABILITY

Your comment, Mr. Pickens, about that there is plenty of lab space up there and value to be made from that. I appreciated that. Are these, is the research facility that is in the Space Station, the various labs that you have talked about, are they outfitted for the type of research that is necessary to validate the things that we have heard today?

Mr. PICKENS. The way they have it set up is is that other than the fact that the Columbus Module has an X-ray crystallography machine that they have sent up with that so you don't, you can actually do the defracture from the crystals off the protein crystal growth from that piece of equipment. Basically what they did is they set up these things that they call express racks, which are really data feeds, power feeds. They are just set up for you, and what they do is they take it out of whatever the visiting, you know, vehicle is, and then they put it in, and they slide it in there, and they flip on a button, and then from that they control everything from the ground operations.

And, yes, it is all there. I mean, they put that very modularly in place, and they have done that. So, yes.

Mr. ROHRABACHER. Is that the same answer I am getting from the other panelists, too? Is—are these labs properly outfitted?

Dr. Nickerson, you have been very optimistic about these great achievements that are about to happen. Are we outfitted up there to make sure that we can actually achieve those things?

Dr. NICKERSON. There were, of course, a number of cuts that were made to important research infrastructure that was supposed to be installed on ISS, the centrifuge, things like that. It would be very nice if those things could be up there.

Mr. ROHRABACHER. Could you give me a couple of examples of that?

Dr. NICKERSON. In terms of how they could be used?

Mr. ROHRABACHER. No. In terms of what needs to be replaced so we can start thinking about financing it.

Dr. NICKERSON. So it would be nice to have the centrifuge facility up there.

Mr. ROHRABACHER. A what now?

Dr. NICKERSON. Centrifuge.

Mr. ROHRABACHER. Centrifuge. Okay.

Dr. NICKERSON. It would be nice to have some very nice imaging capabilities on-board in terms of abilities to image very small cells like microscopic imaging. It would be very nice to have that up there so we can see in real time exactly how these cells are manifesting their changes.

Mr. ROHRABACHER. Are there any plans to put microscopic imaging, I know about the centrifuge.

Dr. NICKERSON. There were, but those plans were scrapped, and it was being, those plans were in place, but I know those funds were cut. For a long time I know with the MELFI there was a question, and we need to be able to have for long-term work on ISS, you know, capabilities to store at minus 80, and I know after much time the MELFI, I think, is finally fully operational up there in terms of the freezer capabilities.

But when we are going to be on terms of long-term research on ISS, we need those kinds of capabilities, some samples we want to store, some we want to keep viable. And when we store them, we need to make sure that they are stored viably, and their integrity is preserved.

Mr. ROHRABACHER. Okay. So we need storage and something to do microscopic imaging, and I know that the centrifuge debate was a big debate early on.

Dr. NICKERSON. Right.

Mr. ROHRABACHER. And an imager, it is not just a small investment——

Dr. NICKERSON. Right.

Mr. ROHRABACHER.—there. It is huge. But——

Dr. NICKERSON. That is one reason, though, that leads to, and your question was well founded, is that you have heard about this rhetoric for a long period of time. It is going to lead to these advances, it is going to lead to these advances, but in all honesty, the reason you haven't seen that is some of those capabilities are now being able to be put in place and be done. And with our study it was a biological first. It was the first time that space flight had ever been looked at as ability to affect disease-causing potential. It was the first time that a pathogen had ever been looked at in terms of a complete molecular global profiling and look at changing its virulence.

So those kinds of things, you know, until you can translate that, and we just, by the way, repeated that so we do have biological validation on the STS–123.

Mr. ROHRABACHER. Oh. As I say, I think we learned a lot on how to build structures.

Dr. NICKERSON. Right.

Mr. ROHRABACHER. I think that in and of itself is for humankind and how to cooperate internationally——

Dr. NICKERSON. But to have those additional capabilities would be helpful.

Mr. ROHRABACHER. That is good. But I would sure hope that we see some of the things that you have been talking about. I have heard this before, and I hope it is validated like we say, and if we, Mr. Chairman, if we need a couple of things to add to the Space Station to see that it actually accomplishes the $100 billion that we have spent, if we are talking about tens of millions of dollars to get some of these things up there—thank you very much.

Chairman UDALL. I thank the gentleman from California for his insightful questions and commentary.

Unfortunately, we need to move to the second panel. I know everybody on the dais here could spend another hour directing questions to the panel, and we hope to bring you back. We also will direct some additional questions to you all for the record.

I did want to take an additional moment, Dr. Nickerson had mentioned that in the town of Alamosa, which is in the St. Louis valley, South Central portion of our state, important agricultural area. It is also an area in which we are planning to develop a lot of alternative energy technologies. They had to shut down their water supply system recently. You may have read the story. It made the national news because of Salmonella somehow infiltrating the system, and it, over 300 people were taken ill in a town of about 15,000 people.

So your work is an area in which there may be real applicability. So I look forward to watching and learning from what you discover about Salmonella.

Dr. NICKERSON. Thank you. I look forward to giving you updates.

Chairman UDALL. At this time we will excuse the panel. Again, thank you for being here and providing us with such informative testimony.

We will ask the second panel to take their seats as quickly as we can, and we will move to the second round.

Let us move to our second panel of witnesses. I would like to introduce each of them in turn.

Dr. William Gerstenmaier, who is the Associate Administrator of the Space Operations Mission Directorate at NASA. Next to Mr. Gerstenmaier is Cristina Chaplain, who has been a visitor to our committee before, and she is the Director of Acquisition and Sourcing Management at the GAO, has a great rooting in NASA and many aspects of the NASA world. And then finally we have Dr. Jeffrey Sutton, who is the President and Director of the National Space Biomedical Research Institute. Welcome to the three of you.

As you know, our spoken testimony is limited to five minutes, after which Members of the Subcommittee will have five minutes each to ask questions.

We will start with Mr. Gerstenmaier and his five minutes. Welcome.

Panel 2:

STATEMENT OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR FOR SPACE OPERATIONS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Mr. GERSTENMAIER. Thank you. I have addressed your questions specifically in my written testimony, and I won't spend much time with my verbal discussion.

I would just say there is a couple of areas I think are really important to stress here, and first of all, they were discussed earlier a little bit. The international achievement of the Space Station is really unprecedented in my mind. The fact that we are actually operating internationally today with the laboratories on-board Space Station is a huge testimony to this team that has worked internationally to continue to build Space Station and has guided it to this point.

And we have also done a lot of engineering evaluations and tests and evaluation of Space Station. It fits well as we move into exploration of the components, the hardware, the systems, the engineering analysis that we are working and developing on Space Station today that we used to assemble it. Those are directly applicable to what we are going to be doing as we go to the Moon and Mars, running pumps for long time, doing fluid circulation, operating computers, working internationally, all those things have direct application to what we are going to do as we go, move beyond low-Earth orbit and move to the Moon and Mars. And that is a first step in the engineering sense.

I would also say Space Station provides a commercial opportunity as Mr. Pickens talked about a little bit earlier. It clearly does for transportation. As we look to transportation in the future as the Shuttle retires, we are looking to commercial transportation for Space Station. We have recently put out a request for a proposal to commercial industry to provide transportation for Space Station. We think that provides a tremendous opportunity for the commercial sector to step up and provide transportation of the materials needed for the research, for the investigations, as well as for the basic supplies of Space Station.

We recently had the Automated Transfer Vehicle from the European Space Agency dock to Space Station. That shows that we are able to do the rendezvous docking. We are able to take a brand new spacecraft, take it through developmental test program, and actually dock it to Space Station so that gives credibility and shows proof to the commercial sector that this can be done and is very achievable and they are ready to move forward.

We have also looked at a new thing, a new way of acquiring hardware on Space Station. We are using a Sabatier reaction, which takes waste carbon dioxide and waste hydrogen, combines those, makes water, and generates methane that gets dumped overboard. We will save about 2,000 pounds of water with that system. We acquired that commercially for the first time. We didn't pay the typical development way we do. It is not a cost-plus contract. It is a fixed-price contract, and we get paid for the water or the contractor gets paid for the water that is generated. So they take the risk, and NASA is not involved in the development. We are not attending their design reviews. They show us the hardware is safe to fly in orbit. If it generates water, they receive revenue from that. If it doesn't generate water, they have lost their investment. So it is a new creative way of utilizing the commercial sector to provide services that we need. And that is another evidence of what the Station can do.

And lastly, the previous panel talked a lot about the research avenues. There was a lot of discussion on the biological aspects. I think there is a lot of other areas of Space Station that can be used. There is a combustion research rack that is going up, there is material science activities, there is fluid physics, and low temperature physics.

The unique thing about Space Station is it gives us a different lens to look at all these phenomena, be it biological, physical, or materials processes. It gives us a chance to learn about things that we experience here on the Earth in a different way. Some of the Apollo astronauts talked about that we went to the Moon to learn about the Earth. I think in the same sense we are going to Space Station and with the different lens of microgravity, we are going to learn more about processes on the Earth and directly impact what is going on in the very physical sense.

[The prepared statement of Mr. Gerstenmaier follows:]

PREPARED STATEMENT OF WILLIAM H. GERSTENMAIER

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

International Space Station—Experience in Exploration

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

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

International Collaboration

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

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

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

Research and Technology Development

The ISS is NASA's only long-duration flight analog for future human lunar missions and Mars transit. It provides an invaluable laboratory for research with direct application to the exploration requirements that address human risks associated with missions to the Moon and beyond. It is the only space-based multinational research and technology testbed available to identify and quantify risks to human health and performance, identify and validate potential risk mitigation techniques, and develop countermeasures for future human exploration.

The ISS research portfolio includes human research and countermeasure development for exploration. The ISS crew is conducting human medical research to develop knowledge in the areas of clinical medicine, human physiology, cardiovascular research, bone and muscle health, neurovestibular medicine, diagnostic instruments and sensors, advanced ultrasound, exercise and pharmacological countermeasures, food and nutrition, immunology and infection, exercise systems, and human behavior and performance.

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

Crew Operations

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

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

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

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

Spacecraft Systems Operations

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

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

- The ISS environmental control and life support systems include water electrolysis for oxygen generation and carbon dioxide removal.
- The thermal control systems include heat rejection and management using multi-layer insulation, heat exchangers, strip heaters and radiators.
- The electrical power system includes energy collected by solar arrays and stored in nickel hydrogen batteries.
- The command and data systems include computer systems using standard 1553B data buses and networks using the 802.4 Ethernet protocol.
- The U.S. Control Moment Gyroscopes (CMGs) and Russian motion control systems provide guidance and propulsion.

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

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

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

Crew-System Interfaces

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

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

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

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

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

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

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

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

National Laboratory Opportunities

While the ISS continues to meet NASA's mission objective to prepare for the next steps in human space exploration, it will also offer extraordinary opportunities for advancing science and technology to other U.S. Government agencies, non-profit research foundations, and private firms. The National Institutes of Health entered into an MOU with NASA in October of 2007 and plans to issue a formal research announcement in 2008 for use of the ISS in the post-assembly period. The U.S. Department of Agriculture, Agricultural Research Service, is evaluating a similar arrangement and may enter into an MOU in the near future for plant- and animal-related research. In the private sector, two Space Act Agreements are currently under development for pursuing proprietary research in biotechnologies, and another agreement is pending with the University of Colorado's Bioserve Center for ISS-based research.

International Space Station Assembly and Resupply Operations

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

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

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

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

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

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

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

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

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

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

Conclusion

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

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

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

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

Chairman UDALL. Thank you.

Ms. Chaplain.

STATEMENT OF MS. CRISTINA T. CHAPLAIN, DIRECTOR, ACQUISITION AND SOURCING MANAGEMENT, U.S. GOVERNMENT ACCOUNTABILITY OFFICE

Ms. CHAPLAIN. Thank you for asking me to discuss our work on challenges related to completing and sustaining the International Space Station. This program has clearly achieved significant successes in engineering, technology development, as well as in building effective international partnerships. The logistical and technical problems that have been overcome in just the last year are a testament to the program's agility and ingenuity under extreme pressures.

However, the ISS has also struggled with significant cost growth, scheduled delays, redesigns, as well as changes in requirements and content. Such challenges, in fact, have forced cutbacks and planned capabilities and scientific research.

A recent change with wide-ranging impacts on the program is, of course, the decision to retire the Space Shuttle in 2010. This was considered necessary to enable NASA to develop new launch and transportation vehicles needed to support the President's vision for space. But it leaves NASA with little flexibility in the Shuttle schedule more at risk for not completing the Station as planned, more at risk for not being able to effectively support the Station, and more dependent on other countries.

The schedule for completing the Station, for example, is only slightly less demanding than it was prior to the *Columbia* disaster when the agency launched a Shuttle every other month with a larger fleet. Though there is some reserve, the schedule leaves little room for the kinds of weather-related technical and logistical problems that have delayed flights in the past.

NASA remains confident that the current manifest can be accomplished within the given time, and there are tradeoffs NASA can make in terms of what it can take up to the Station should unanticipated delays occur. However, failure to complete assembly as currently planned could further reduce the Station's ability to fulfill its research objectives and short the Station of critical spare parts that only the Shuttle can deliver.

In the event that NASA completes assembly of the Station on schedule and pre-positions an adequate number of spares, the agency still faces a host of challenges in sustaining the station until its retirement.

Simply put, there is no other vehicle available with the capacity of the Shuttle to deliver supplies. Instead, the program will rely on vehicles developed by its international partners, the commercial sector, and NASA under the Ares and Orion Programs.

While it seems that NASA has an array of options, there are substantial limitations. One, only the Russian vehicles have proven capability, though the recent operational tests of the European vehicle is a good indication that this will not continue to be the case.

Two, all vehicles currently or nearly available have mass capacities far below the Shuttles.

Three, only the Soyuz vehicle can carry crew.

Four, neither the European, Japanese, or Russian progress vehicle can take experiments or other materials back down to Earth. They are expendable vehicles.

Five, more capability is planned for the COTS vehicles, but their schedules are considered by many to be highly optimistic and schedule slips have already occurred.

Six, NASA's Orion vehicle is not expected to come on line until 2015, and we have found that it is not certain that this date will be met due to inherent technical complexities and production challenges.

Within this context it is our understanding that NASA would like to rely solely on commercial vehicles to take cargo to the Station beginning in 2013. The aim is to fully incentivize the commercial industry to develop capabilities that are needed to support the Vision in the long-term. There is merit to this objective as commercial suppliers are being counted on to reduce the costs of access to space and to introduce new concepts and capabilities needed to sustain our country's technical edge.

But there are also risks with this approach, particularly if the commercial efforts are unsuccessful and more established vehicles cannot be brought back into production quickly. NASA is well aware of the predicament it faces both in completing and sustaining the Station, and it has weighted options and tradeoffs. It is important in going forward that flexibility continue to be maintained as events impacting schedule occur and that contingencies be well thought out and planned so that results can be maximized.

Mr. Chairman, this concludes my statement, and I am happy to answer any questions you have.

[The prepared statement of Ms. Chaplain follows:]

PREPARED STATEMENT OF CRISTINA T. CHAPLAIN

NASA: Challenges in Completing and Sustaining the International Space Station

Mr. Chairman and Members of the Committee:

I am pleased to be here to discuss challenges that the National Aeronautics and Space Administration (NASA) faces in completing and sustaining the International Space Station (ISS). After delays and redesigns, efforts are under way for a long-envisioned expansion of the station so it can support a larger crew and more scientific research. NASA officials estimate the entire cost to complete the station will total $31 billion, and another $11 billion will be needed to sustain it through its planned decommissioning in fiscal year 2016.

The Space Shuttle has been and is critical to completion of the space station and re-supplying the station. The Shuttle remains the only vehicle capable of transporting large segments of the station into orbit for assembly. NASA plans to complete ISS assembly duties and retire the Shuttle fleet in 2010 in order to pursue a new generation of space flight vehicles for exploration. To that end, NASA has begun the process of making key decisions on suppliers that will no longer be needed. NASA officials told us that in many cases, restarting suppliers after these decisions are made would be cost prohibitive and time consuming. However, a new NASA vehicle will not be available until 2015 at the earliest, when the Crew Launch Vehicle (Aces 1) and Crew Exploration Vehicle (Orion) are expected to fly. To fill the gap following retirement of the Shuttle and provide crew rotation and logistical support, NASA plans to rely on a variety of spacecraft developed by the commercial sector and other countries.

In July 2007, we testified on a number of challenges NASA was facing with regard to completing the ISS within the time constraints created by the Shuttle's retirement. Those challenges are still relevant. In light of these issues, we examined the risks and challenges NASA faces in (1) completing assembly of the ISS by 2010, and (2) providing logistics and maintenance support to the ISS after 2010.

In short, our work continued to find that NASA's plans to complete assembly of the International Space Station prior to the scheduled retirement of the Space Shuttle at end of fiscal year 2010 require much to happen and very little to go wrong. While NASA believes the schedule is still achievable, the flight rate that NASA is projecting is only slightly less aggressive than it was prior to the *Columbia* disaster[1] when, from 1992 to 2003, the agency launched a Shuttle every other month. At that time, NASA used four vehicles to maintain its flight schedule. To complete the station by 2010, NASA will need to maintain a similar flight rate with fewer Shuttles and with a Shuttle fleet that is aging and continuing to face fuel sensor challenges. NASA remains confident that the current manifest can be accomplished within the given time, and in fact, it has several months of reserve time in its manifest. However, agency officials readily admit that the schedule is aggressive. If delays continue, NASA may need to reduce the number of flights to the station, which could prevent delivery of items currently scheduled for assembly and the pre-positioning of critical spares. Further, while NASA still expects to be able to increase crew capacity from three to six persons, changes it may need to make to the space station's configuration could limit the extent of scientific research that can be conducted onboard the ISS or quality of life for the crew.

After assembly is completed and the Shuttle is retired, NASA's ability to rotate crew and supply the ISS will be impaired because of the absence of a vehicle capable of carrying the 114,199 pounds (or 51.8 metric tons) of additional supplies needed to sustain the station until its planned retirement in fiscal year 2016. NASA plans to rely on Russian, European and Japanese vehicles to service the station. Even with these vehicles, this shortfall remains. While the Russian vehicles are already in service, the European vehicle just completed its first operational test flight, and development efforts are still under way on the Japanese vehicle. In addition, these vehicles were designed to augment the capabilities of the Shuttle, not replace them. Both the European and Japanese vehicles were designed to deliver supplies to the station but their capacities are not equal to the Shuttle's 37,864 pounds of capacity. Furthermore, aside from a single Russian vehicle that can bring back 132 pounds of cargo and rotate crew, no vehicle can return cargo from the International Space Station after the Shuttle is retired. NASA plans to rely on commercially developed vehicles to address some of these shortfalls and has pledged approximately $500 million for their development. NASA expects one of these vehicles will be ready for cargo use in 2010 and crew use in 2012. However, no vehicle has successfully been launched into orbit and their development schedules may leave little room for the unexpected. If these vehicles cannot be delivered according to NASA's current expectations, NASA will have to rely on Russian vehicles to maintain U.S. crew on the International Space Station until the new generation of U.S. spacecraft becomes available.

To conduct our work, we reviewed documents and testimonies by NASA officials relating to the challenges associated with ISS completion, the delivery schedule for ISS assembly and replacement units, and the Space Shuttle manifest. We reviewed key ISS budget and strategic maintenance plans, the ISS Independent Safety Task Force Report, and previous GAO reports relating to the ISS. We visited and interviewed officials responsible for ISS operations at NASA Headquarters, Washington, D.C., and the Johnson Space Center in Houston, Texas. At NASA Headquarters, we met with officials from the Exploration Systems Mission Directorate and the Space Operations Mission Directorate, including representatives from the International Space Station and Space Shuttle programs. We met with ISS and Space Shuttle officials at the Johnson Space Center. We also talked to a commercial developer of space vehicles and met with representatives of foreign space efforts. Complete details of our scope and methodology can be found in Appendix I. We conducted this performance audit from July 2007 to April 2008, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The International Space Station program began in 1993 with several partner countries: Canada, the 11 member nations of the European Space Agency (ESA),

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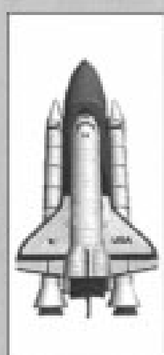
[1] In 2003, the Space Shuttle *Columbia* broke up as it returned to Earth after 16 days in orbit. After the accident of *Columbia,* the Shuttle fleet was grounded for approximately two and one-half years. During that the time, U.S. crew and supplies were launched in the Russian Soyuz and Progress.

Japan, and Russia. The ISS has served and is intended to expand its service as a laboratory for exploring basic questions in a variety of fields, including commercial, scientific, and engineering research. The first assembly flight of the station, in which the Space Shuttle Endeavor attached the U.S. laboratory module to the Russian laboratory module, occurred in early December of 1998. However, since the program's inception, NASA has struggled with cost growth, schedule delays and redesigns of the station. As we reported in the past, these challenges were largely due to poorly defined requirements, changes in program content and inadequate program oversight. Due to these challenges, the configuration of the station has devolved over time. In the spring of 2001, NASA announced that it would make major changes in the final configuration of the ISS to address cost overruns. In 2003, the National Academies reported that this reconfiguration greatly affected the overall ability of the ISS to support science. NASA estimates that assembly and operating costs of the ISS will be between $2.1 billion to $2.4 billion annually for FY 2009–FY 2012. The ISS as of February 19, 2008, is approximately 65 percent complete.

The Shuttle program and the ISS program are inherently intertwined. The Shuttle has unique capabilities in that it can lift and return more cargo to and from orbit than any other current or planned space vehicle. Figure 1 shows the capabilities of the Shuttle in various configurations. Most segments of ISS cannot be delivered by any other vehicle. For example, the *Columbia* disaster in 2003 put ISS assembly on hiatus as NASA ceased Shuttle launches for two and one-half years while it investigated the safety of the fleet. During this period, the Russian Soyuz became the means of transportation for crew members traveling to and returning from the ISS.

Figure 1: Cargo Capabilities of the Shuttle

The shuttle's different capabilities



Mixed Flight Capability: 16,480 lbs./7,475 mass kg.
Consisting of internal cargo (8,818 lbs./4,000 kg.), external (2,205 lbs./1,000 kg.), water (882 lbs./400 kg.), nitrogen (55 lbs./25 kg.), oxygen (110 lbs./50 kg.) and propellants which are fuel and oxidizer (4,409 lbs./2,000 kg.). The majority of internal cargo is packaged in cargo transfer bags and then flown in either a rack or middeck locker.

External Capability: 14,716 lbs./6,675 mass kg.
Consisting of internal cargo (441 lbs./200 kg.), external (8,818 lbs./4,000 kg.), water (882 lbs./400 kg.), nitrogen (55 lbs./25 kg.), oxygen (110 lbs./50 kg.) and propellant (4,409 lbs./2,000 kg.). Two Express Logistics Carriers (ELC) can be loaded on the Shuttle payload bay. The ELC's can be left on the ISS for stowage of science payloads and maintenance of spares—each holding up to 10 orbital replacement units (ORU), and each has the ability to deliver up to two science payloads.

Assembly Capability: 37,864 lbs./17,175 mass kg.
Consisting of internal cargo (441 lbs./200 kg.), external (31,967 lbs./14,500 kg.), water (882 lbs./400 kg.), nitrogen (55 lbs./25 kg.), oxygen (110 lbs./50 kg.) and propellant (4,409 lbs./2,000 kg.). The assembly configuration enables the delivery of assembly hardware, such as the ESA's Columbus module.

Source: GAO analysis of NASA data.

In a major space policy address on January 14, 2004, President Bush announced his *"Vision for U.S. Space Exploration"* (Vision) and directed NASA to focus its future human space exploration activities on a return to the Moon as prelude to future human missions to Mars and beyond. As part of the Vision, NASA is developing new crew and cargo vehicles, with the first crew vehicle currently scheduled to be available in 2015. The President also directed NASA to retire the Space Shuttle after completion of the ISS, which is planned for the end of the decade. Based on that directive, NASA officials told us that they developed a manifest consisting of 17 Shuttle launches to support ISS assembly and supply between 2005 and 2010.[2] Nine of these have taken place. In response to the President's Vision, NASA formally set September 30, 2010, as the date that the Shuttle program will cease because agency officials believe that continuing the program beyond that date will

[2] The manifest includes 18 total flights, but one of the launches is reserved for repairs to the Hubble Space Telescope.

slow development of the agency's new vehicles—specifically, the agency budget cannot support both programs at costs of $2.5 billion to $4 billion above current budget. As shown in Table 1, the Shuttle program costs NASA several billion dollars annually and projected funding is phased out in fiscal year 2011. NASA officials stated that the majority of Shuttle program cost is fixed at roughly $3 billion a year whether it flies or not. NASA officials stated that the average cost per flight is $150 million to $200 million.[3]

Table 1: Space Shuttle Program Costs

Dollars in millions

Funding Year	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
space shuttle program	3,315.3	3,266.7	2,981.7	2,983.7	95.7	—	—

Source: President's FY 2009 Budget Request.

The 2005 *NASA Authorization Act* designated the U.S. segment of the ISS as a national laboratory and directed NASA to develop a plan to increase the utilization of the ISS by other federal entities and the private sector. In response, NASA has been pursuing relationships with these entities. NASA expects that as the Nation's newest national laboratory, the ISS will strengthen NASA's relationships with other federal entities and private sector leaders in the pursuit of national priorities for the advancement of science, technology, engineering, and mathematics. The ISS National Laboratory is also intended to open new paths for the exploration and economic development of space.

The Retirement of the Shuttle Poses Challenges to NASA's Ability to Complete the International Space Station

It will be a challenge for NASA to complete the space station by 2010 given the compressed nature of the schedule, maintenance and safety concerns, as well as events beyond its control such as weather. Any of these factors can cause delays that may require NASA to re-evaluate and reconstitute the assembly sequence. NASA remains confident that the current manifest can be accomplished within the given time and there are tradeoffs NASA can make in terms of what it can take up to support and sustain the station should unanticipated delays occur. However, failure to complete assembly as currently planned would further reduce the station's ability to fulfill its research objectives and short the station of critical spare parts that only the Shuttle can currently deliver.

Shuttle Flight Schedule Is Aggressive

In our July 2007 testimony, we reported that NASA planned to launch a Shuttle once every 2.7 months. The plan for launches remains aggressive, partly because NASA plans on completing the ISS with the last assembly mission in April 2010, with two contingency flights in February and July 2010 to deliver key replacement units. The five months between the last assembly launch and Shuttle retirement in September 2010 act as a schedule reserve, which can be used to address delays. There are eight Shuttle flights left to complete the station and two contingency flights left to deliver key components necessary to sustain the ISS after the retirement of the Shuttle. There is an average of two and one-half months between each Shuttle launch.[4] Table 2 shows the current Shuttle manifest.

[3] This cost is based on hardware, such as the booster rocket, used for the Shuttles.
[4] This includes one mission to repair the Hubble Space Telescope and two contingency flights.

Table 2: Remaining Flights of the Space Shuttles

Space shuttles	Expected launch dates
Discovery	May 31, 2008
Atlantis[a]	August 28, 2008
Endeavor	October 16, 2008
Discovery	December 4, 2008
Endeavor	March 2009
Discovery	April 2009
Endeavor	August 2009
Discovery	October 2009
Endeavor[b]	February 2010
Discovery	April 2010
Endeavor[b]	July 2010

Source: GAO analysis of NASA's shuttle manifest.

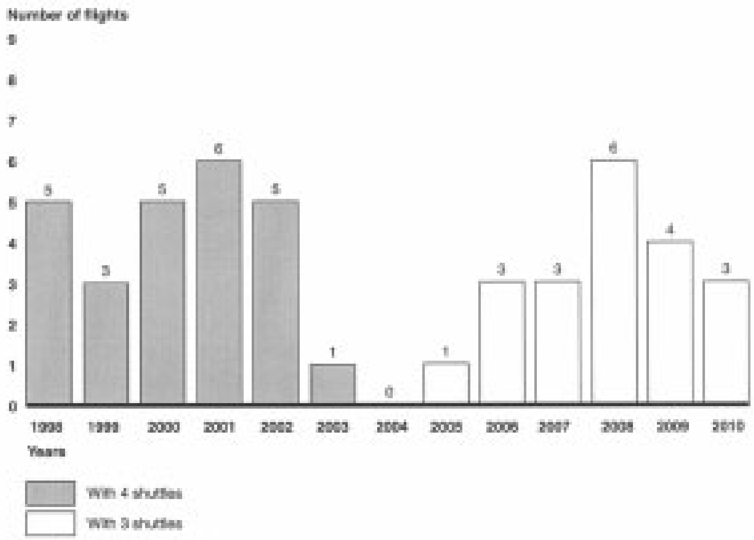
[a]Mission to repair the Hubble Space Telescope

[b]Contingency flights

NASA has launched Shuttles at this rate in the past. In fact, the agency launched a Shuttle, on average, every two months from 1992 through the *Columbia* disaster in 2003. However, at that time the agency was launching a fleet of four Shuttles.[5] The Shuttles require maintenance and refurbishing that can last four to five months before they can be re-launched. Launching at such a rate means that the rotation schedule can handle few significant delays, such as those previously experienced due to weather and fuel sensor difficulties. Lastly, NASA officials said that Shuttle Atlantis, which was to go out of service after the Hubble mission, will return to servicing the ISS for two more flights, which NASA believes will add more schedule flexibility.

[5] The remaining three Shuttles are the Atlantis, Discovery, and Endeavor.

Figure 2: Completed and Projected Space Shuttle Flights Needed for ISS Assembly



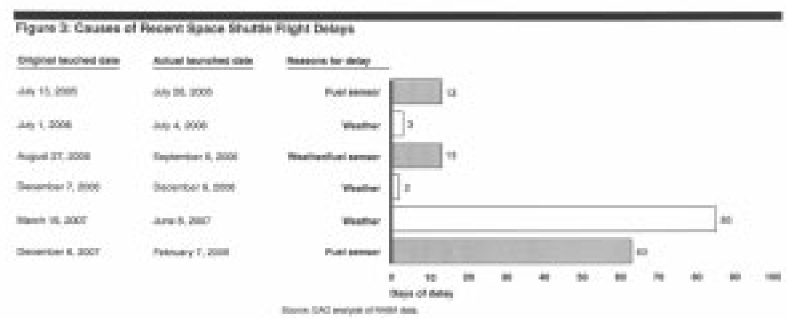
Source: GAO analysis of NASA data.

Potential Launch Delays Remain

NASA officials stated repeatedly that NASA is committed to safely flying the Shuttle until its retirement and will not succumb to schedule pressure. However, the compressed nature of the manifest will continue to test that commitment. Fuel sensor challenges continue to surface in the Shuttle fleet. For example, the recent Shuttle Atlantis launch was delayed two months while NASA addressed a fuel sensor problem associated with the Shuttle's liquid hydrogen tank. This is the same system that caused a two-week delay in the launch of the Shuttle Discovery in 2005.

There are also challenges associated with the Shuttle launch window. NASA officials told us that the duration of that window is dependent on a number of factors, which include changes in the position of the Earth and spacecraft traffic restrictions. NASA must consider its traffic model constraints for vehicles docking at the space station. According to the traffic model for ISS, no other vehicle can dock while the Shuttle is docked, and each vehicle has constraints on how long it can stay docked. For example, the Shuttle can dock for a maximum of 10 days, while the Soyuz can dock a maximum of 200 days. The docking of these two vehicles must be coordinated and meet other technical restrictions.

In addition, the Shuttle has experienced delays due to severe weather, such as when Atlantis's external tank was damaged by a hailstorm in 2007. In this case the delay was about three months. Figure 3 shows the delays in recent Shuttle launches related to weather and other causes.



Completion of ISS Needed to Expand Scientific Research

The ISS is scheduled to support a six-person crew as early as 2009 and maintain that capability through 2016. NASA officials said that equipment essential to support a six-person crew, such as systems for oxygen recycling, removal of carbon dioxide and transforming urine into water as well as an exercise machine will be delivered to the station this fall. In addition, there are two components that have been planned to hold this and other equipment needed for the six-person crew, which are scheduled to go up in April 2010. If unanticipated delays occur, NASA may need to hold back these two components—known as the Node 3 and the Cupola—which could constrain the ability to conduct research and the quality of life on the station for the crew.

NASA officials emphasized that NASA's intent was to have most science conducted on ISS only after the assembly of the ISS was completed. The ISS currently supports three crew members. NASA stated that the majority of the crew's time is spent maintaining the station, rather than conducting scientific study. According to NASA, the crew spends no more than three hours per week on science. Completion of the ISS would allow NASA to expand to a six-person crew who could conduct more research.

Since the ISS is designated as a national laboratory, the expectation is that it will support scientific experimentation. NASA is in the process of negotiating agreements with scientific organizations to support scientific research on the ISS. NASA officials told us that they are negotiating a Memorandum of Understanding with the National Institutes of Health to explore the possibility of scientific experimentation on-board the ISS. These officials also told us that NASA is in the process of negotiating with at least two other agencies.

The Need to Pre-position Replacement Units to Sustain the ISS May Also Affect Assembly

NASA's efforts to complete the ISS are further complicated by the need to put replacement units—the spare parts that are essential to sustaining the ISS—into position before the Shuttle retires. The two contingency flights of the Shuttle have been designated to deliver these key replacement units, which only the Shuttle is capable of carrying. According to NASA, the original approach to deal with these key components (also known as orbital replacement units—ORU[6]) was to take the ones that failed or reached the end of their lifetime back to Earth on the Shuttle, refurbish them and launch them back to ISS for use. As a result of the Shuttle retirement, NASA will no longer be bringing down ORUs to fix. Instead, NASA officials stated they have adopted a "build and burn" philosophy, which means that after the Shuttle retires, instead of being brought down to be refurbished, ORUs will be discarded and disintegrate upon re-entry into the atmosphere. To determine how many replacement units need to be positioned at the station, NASA officials told us they are using data modeling that has been very effective in determining how long ORUs will last. Table 3 illustrates the Shuttle manifest. This includes elements needed for the planned configuration to complete the station and delivery of critical spares.

[6] Orbital Replacement Units (ORU), according to NASA officials, are critical spares are necessary to sustain the ISS.

Table 3: Manifest of Remaining Space Shuttle Flights

Dates	Space shuttle	Element being delivered
May 31, 2008	Discovery	Kibo Japanese Experiment Module Pressurized Module (JEM-PM), one of two Japanese's research facilities. Japanese Remote Manipulator System (JEM RMS) are two robotic arms that support operations on the outside of Kibo.
Aug. 28, 2008	Atlantis	Final shuttle Mission to Hubble Space Station.
Oct. 16, 2008	Endeavor	Multi-Purpose Logistics Module (MPLM) are a reusable "moving van" carrying equipments, experiments, and supplies to and from the ISS.
Dec. 4, 2008	Discovery	Fourth starboard truss segment (ITS S6), power element. Fourth set of solar arrays and batteries-power element.
March 2009	Endeavor	Kibo Japanese Experiment Module Exposed Facility (JEM EF), the second Japanese research facility. Logistics Module Exposed Section (ELM-ES) is a pallet that can hold three experiment payloads. Spacelab Pallet Deployable 2 (SLP-D2) is a platform for mounting instruments.
April 2009	Discovery	MPLM Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC) is the carrier to carry experiments to the ISS. Galley-multi-purpose facility to handle meal preparations. Second treadmill Crew Health Care System 2 (CHeCS 2) are a suite of hardware on the ISS that provides the medical and environmental capabilities to ensure the health and safety of crewmembers during long-duration missions.
Aug. 2009	Endeavor	EXPRESS Logistics Carrier 1 (ELC1) and 2 (ELC2) are designed to carry external payloads and Orbital Replacement Units (ORUs).
Oct. 2009	Discovery	MPLM LMC
Feb. 2010 Contingency Flight	Endeavor	ELC3 and ELC4 are designed to carry external payloads and ORUs.
April 2010	Discovery	Node 3 is a habitation system with the Cupola observatory.
July 2010 Contingency Flight	Endeavor	ELC5 and ELC1 are designed to carry external payloads and ORUs.

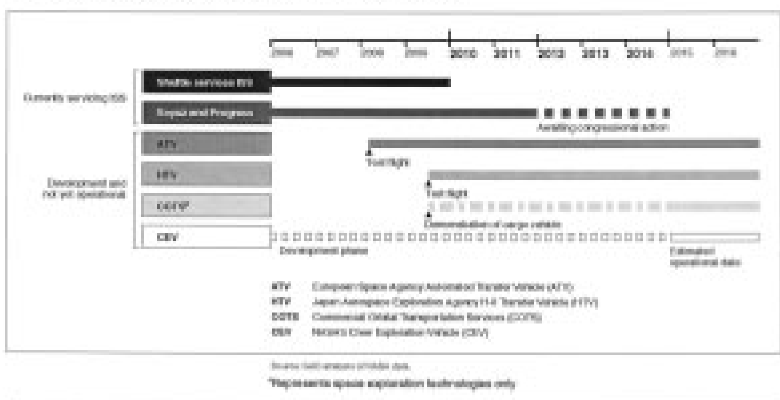
Source: GAO analysis of NASA's shuttle manifest.

NASA currently plans to use two contingency flights for these replacements because all other flights are planned with assembly cargo. Recently, the NASA Administrator publicly stated that these flights are considered necessary to sustain the ISS and have been scheduled to carry key spare units.

Alternative Vehicle Options to Service the International Space Station Pose Challenges

In the event that NASA completes assembly of the ISS on schedule and prepositions an adequate number of critical spares, the agency still faces a myriad of challenges in sustaining the research facility until its retirement, currently planned for fiscal year 2016. Without the Shuttle, NASA officials told us that they face a significant cargo supply shortfall and very limited crew rotation capabilities. NASA will rely on an assortment of vehicles in order to provide the necessary logistical support and crew rotation capabilities required by the station. Some of these vehicles axe already supporting the station. Others are being developed by international partners, the commercial sector, and NASA. (See Figure 4) Furthermore, some of these transportation services may face legal restrictions, and still others face cost, schedule, and performance issues that raise serious questions about their development and utilization. These issues will challenge NASA's ability to close the sustainment gap between the retirement of the Shuttle in 2010 and the availability of the Crew Exploration Vehicle (CEV) in 2015. Failure of any or some of these efforts would also seriously restrict NASA's options to sustain and maintain a viable space station.

Figure 4: Availability of Vehicles Serving the International Space Station



Russian Vehicles

With the exception of the Shuttle and the recently completed demonstration flight of the ATV, the only vehicles currently capable of supporting the space station are the Russian Progress and Soyuz vehicles. NASA officials stated that both of these vehicles have provided reliable service to the ISS. From the *Columbia* disaster in 2003 until return to flight in 2005, the Russian vehicles were the sole source of logistical support and crew rotation capability for the station. The Progress provides atmospheric gas, propellant, water, and pressurized cargo. It also has the capability to use its thrusters to change the Station's altitude and orientation. The Soyuz provides crew delivery and rescue capability for three crew members. Progress vehicles are expendable and offer no recoverable return capability, but provide important trash removal capabilities. Soyuz vehicles have a limited recoverable cargo capacity. However, some NASA officials have suggested that their limited capabilities restrict the capacity of the station to move to a six-member crew and significantly limit the scientific research because the vehicles cannot bring experiments to Earth for assessment. NASA currently purchases crew and cargo transport services from Russia through a contract with the Russian Federal Space Agency (Roscosmos).

NASA officials told us that after the initial ISS contract between Roscosmos and NASA expired, NASA entered into another contract that runs through 2011. However, according to NASA, the Iran Nonproliferation Act of 2000 restricted certain payments in connection to the ISS that may be made to the Russian government. In 2005, NASA requested relief from the restrictions of the Act, and Congress amended the Act.[7] Through this amendment, NASA and Roscosmos have negotiated quantities and prices for services through January 1, 2012.

NASA officials anticipate the use of four Soyuz flights per year and approximately six Progress flights beginning in approximately 2010. While NASA officials stated that they are making every effort to limit amount of fees they pay for usage of Russian vehicles, to date, NASA officials told us that they anticipate that from fiscal year 2009 to fiscal year 2012, NASA will spend $589 million on cargo and crew services from the Russians.[8] NASA officials also told us that the Roscosmos has suggested that it will charge NASA higher fees for usage of its vehicles.

European and Japanese Vehicles

NASA has stated it will use its international partners' vehicles to conduct some supply activities. Specifically, Japan's Aerospace Exploration Agency (JAXA) H–II Transfer Vehicle (HTV) and the European Space Agency's (ESA) Automated Transfer Vehicle (ATV) vehicles will be used for bringing up cargo. NASA's reliance on the ATV and HTV assumes that these vehicles will be ready to service the ISS by the time the Shuttle stops flying in 2010.

The new vehicles being developed by the European and Japanese space agencies are very complex. The ATV had a development timeline of 20 years. Its first operational test flight to the ISS was in March 2008. NASA has stated that both the European and Japanese vehicle development programs experienced technical hurdles and budgetary constraints, but are committed to fulfilling their roles as partners in the ISS program. NASA officials told us they have confidence the European vehicle will be available for ISS operations before retirement of the Shuttle, but they are not as confident about the Japanese vehicle's being ready by that time. The Japanese vehicle is still under development and has faced some setbacks. NASA officials told us that the HTV's first test launch is planned for July 2009.

Figure 5: The European Automated Transfer Vehicle (ATV)

The European Automated Transfer Vehicle (ATV) capability

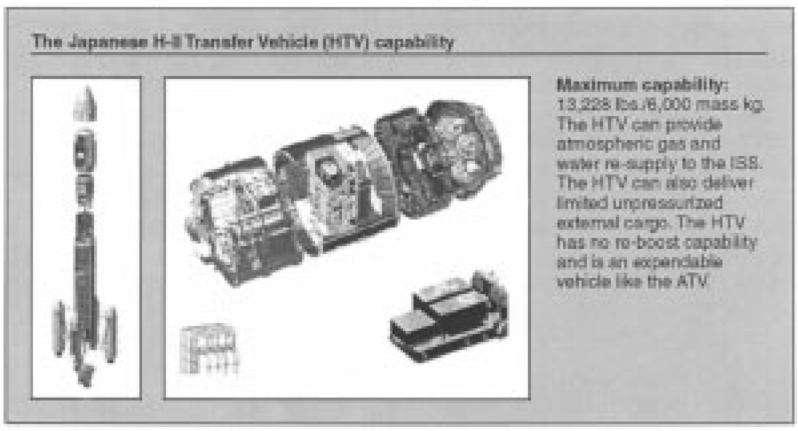
Maximum capability:
16,535 lbs./7,500 mass kg. The ATV is capable of performing many ISS reboost and altitude burns and resupplying ISS with water and atmospheric gas. The ATV has no external capability and is expendable and offers no recoverable return capability.

Source: GAO analysis of NASA data.

[7] The 2005 Amendment to the Iran Nonproliferation Act of 2000 altered the Acts definition of "extraordinary payments in connection with the International Space Station." NASA refers to this amendment as its "exemption."

[8] NASA and Roscosmos have negotiated quantities and prices for services through calendar year 2011. According to NASA it will require additional relief from the restrictions of the Act, currently entitled the *Iran, North Korea and Syria Nonproliferation Act.*

Figure 6: The Japanese H-II Transfer Vehicle (HTV)



Source: GAO analysis of NASA data.

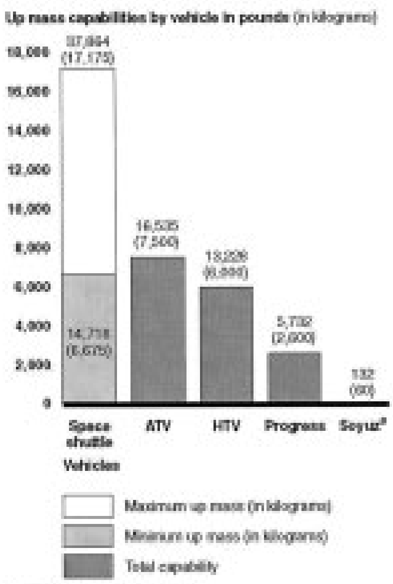
International Partner Vehicles Have Constraints in Ability to Ferry Crew and Cargo to and from the ISS in Comparison to the Shuttle

In addition to potential development challenges, the international partner vehicles have constraints in terms of what they can take to and from the ISS in comparison to the Shuttle. NASA's current plans to manage the gap after the Shuttle retirement do not take into account the possibility of delays in the development of these vehicles, and even if they do come on line on time, NASA officials estimate that there will be a significant shortfall to the ISS of at least 114,199 pounds (or 51.8 metric tons) in cargo re-supply capability. These vehicles were designed to augment the capabilities of the Shuttle and have significantly less capability to deliver cargo to the ISS. The Shuttle can carry a maximum cargo of close to 38,000 pounds (17,175 kg.). In comparison, the European ATV's maximum capability is 16,535 pounds (7,500 kg.) and the Japanese HTV's average capability is 13,228 pounds (6,000 kg.). The HTV and ATV are expendable vehicles. NASA can use them for trash removal, but cannot carry cargo or scientific experiments back to Earth because the vehicles disintegrate when re-entering the atmosphere.

The Russian Progress and Soyuz vehicles also have very limited cargo capacity. For example, the Progress has an average capability of 5,732 pounds (2,600 kg.)—roughly one-seventh the Shuttle's capability. The Progress, like the ATV and HTV, is an expendable vehicle. The Soyuz can transport three crew persons to the ISS and can serve as a rescue vehicle capable of taking three crew members back to Earth. Unlike the ATV and HTV, the Soyuz does have the capacity to bring down cargo—roughly 132 pounds (60 kg.). NASA officials have stated that until NASA deploys its new crew exploration vehicles or commercial vehicles become available, NASA will be dependent on the Russian vehicles for crew transportation services and on the Japanese and European vehicles for limited cargo services whenever they become available.

Figure 7 compares the up mass capabilities of the various vehicles.

Figure 7: Upmass capability by vehicle



Source: GAO analysis of NASA data.

[a] The Soyuz has the capability to bring down from the ISS up to 132 pounds of cargo.

Commercial Vehicles

NASA is working with the commercial space sector through its Commercial Orbital Transportation Services (COTS) program to develop and produce vehicles that can take equipment and crew to and from the space station. NASA expects that these vehicles will be ready for cargo use in 2010 and crew use in 2012. However, these vehicles have yet to be successfully launched into orbit, and some NASA officials have acknowledged that their development schedules leave little room for the unexpected.

Under the COTS program, NASA has pledged $500 million to promote commercial opportunities for space transportation vehicles. Using Space Act agreements[9] instead of traditional contracting mechanisms, NASA will make payments to companies based on the achievement of key milestones during the development of their vehicles. These agreements are both funded and unfunded, For the two funded agreements that have been reached, NASA stated that the commercial suppliers for space transportation services will have customers outside of ISS, including NASA's Constellation program, which plans to send humans back to the Moon and eventually Mars. The COTS program will occur in phases. In the first phase companies will demonstrate the vehicle launch and docking capabilities with the ISS. The second phase is the procurement of services for transportation of cargo and crew to the ISS, which is scheduled to begin sometime in the 2010 timeframe.

NASA had seven COTS agreements through the Space Act. NASA signed five unfunded Space Act agreements, which facilitate the sharing of technical and ISS integration information between commercial companies and NASA. NASA has funded

[9] COTS agreements are Space Act agreements issued pursuant to NASA's other transactions authority. These types of agreements are not contracts, and are therefore generally not subject to those federal laws and regulations that apply to government contracts. NASA has budgeted $500 million in fiscal year 2006 to fiscal year 2010 as an investment for the demonstration of commercial orbital capabilities and will be executed in two phases. The first phase consists of technical development/demonstration funded by the Space Act agreements. The second phase may include the competitive procurement of orbital transportation services.

two companies, Rocketplane Kistler (RpK) and Space Exploration Technologies (SpaceX). NASA officials stated that through the funded Space Act agreements, SpaceX has received $139 million for its project and is still working on successfully launching a vehicle that can reach low-Earth orbit. The company successfully completed a critical design review in August 2007 and told us that it is planning its first orbital demonstration test flight for June 2009. NASA officials told us that RpK received $37 million in funding, but then forfeited the remainder of its share because it did not meet certain financial development milestones. When NASA began to redistribute these forfeited funds, RpK filed a bid protest with GAO, which GAO denied. NASA officials then moved forward and awarded $170 million to Orbital Sciences Corporation in February 2008.

NASA officials acted quickly to award the forfeited money and expect that SpaceX will have cargo capability available in 2010 (by the time the Shuttle is retired) and crew capability 112012. While SpaceX has been meeting key milestones in the development of its vehicle, some officials at the Johnson Space Center were skeptical that COTS would be available on the current projected schedule. Additionally, the International Space Station Independent Safety Task Force (IISTF) reported that design, development and certification of the new COTS program was just beginning and that "if similar to other new program development activities, it most likely will take much longer than expected and will cost more than anticipated." In our opinion, the schedule is optimistic when compared to other government and commercial space programs we have studied. We will be studying the COTS program and schedules in more detail in response to a request of Members of Congress.

Ares I and Orion

NASA is under pressure to develop its own vehicles quickly as the Space Shuttle's retirement in 2010 means that there could be at least a five-year gap in our nation's ability to send humans to space. Among the first major items of NASA's development efforts to implement the Vision program are the development of new space flight systems—including the Ares I Crew Launch Vehicle and the Orion Crew Exploration Vehicle. Ares I and Orion are currently targeted for operation no later than 2015. NASA plans to use these vehicles as they become available to service the space station.

However, we recently testified that there are considerable unknowns as to whether NASA's plans for the Ares I and Orion vehicles can be executed within schedule goals, as well as what these efforts will ultimately cost. This is primarily because NASA is still in the process of defining many of the project's performance requirements and some of these uncertainties could affect the mass, loads, and weight requirements for the vehicles. Such uncertainty has created knowledge gaps that are affecting many aspects of both projects. For example, a design analysis cycle completed in May 2007 revealed an unexpected increase in ascent loads (the physical strain on the spacecraft during launch) that could result in increases to the weight of the Orion vehicle and both stages of the Ares I.

NASA recognizes the risks involved with its approach and it is taking steps to mitigate those risks. However, given the complexity of the Orion and Ares I efforts and their interdependencies, any significant requirements changes can have reverberating effects and make it extremely difficult to establish firm cost estimates and schedule baselines. If knowledge gaps persist, programs will cost more, fail to meet their schedules, or deliver less than originally envisioned. Ultimately, NASA's aggressive schedule leaves little room for the unexpected. If something goes wrong with the development of the Crew Launch Vehicle or the Crew Exploration Vehicle, the entire Constellation Program could be thrown off course and the return to human space flight further delayed.

Concluding Observations

The decision to retire the Space Shuttle in 2010 has had profound effects on the ISS program. It leaves little flexibility in the Shuttle schedule. Any delays could require NASA to choose between completing the station as planned and the pre-positioning of needed critical spares, The decision also leaves NASA dependent on Russia for crew rotation services until other vehicles are developed and demonstrated. And even with the development of these vehicles, NASA still faces a significant capacity shortfall in its ability to provide logistical support to the station. The shortfall may well impact support for a six person crew and the quality of research that can be conducted on the ISS. At the same time, it also provides opportunities to commercial suppliers to demonstrate capabilities that could have long-term benefits for future U.S. space exploration and development. We are not making recommendations as a result of our review as NASA is well aware of the predicament it faces with the station and has weighed options and trade-offs for the remainder of the schedule manifest. However, it is important that flexibility continue to be maintained as events impacting schedule occur and that decisions be made with the goal of maximizing safety and results.

Mr. Chairman, this concludes my statement. I would be pleased to answer any questions that you or the other Members may have at this time.

Individuals making key contributions to this statement include James L. Morrison, Greg Campbell, Brendan S. Culley, Masha P. Pastuhav-Purdie, Kea Vongvanith, and Alyssa B. Weir.

Appendix I:

Scope and Methodology

To identify the risks and challenges NASA faces in completing assembly of the International Space Station by 2010, we

- analyzed key documents and testimonies by NASA officials relating to the challenges associated with ISS completion. This included: the delivery schedule for ISS parts for assembly and the delivery schedule for replacement units, the Space Shuttle manifest, budget documents and the strategic maintenance plan, the ISS Independent Safety Task Force Report, and previous GAO reports relating to the ISS.
- interviewed NASA mission officials to obtain information on the status of the ISS. We also discussed these issues with the International Partners (Canadian Space Agency, European Space Agency and Japan Aerospace Exploration Agency) to get their perspectives.

To determine the risks and challenges NASA faces in providing logistics and maintenance support to the International Space Station after 2010, we

- analyzed documents related to the up-mass and down-mass capabilities of the International Partners and SpaceX vehicles, the shortfall in ISS up-mass for re-supply and sustainment, the new vehicles that will support ISS NASA's plans for using Russian vehicles to support ISS through what NASA refers to as its "exemption," and the impacts to the utilization of the ISS.
- We interviewed key NASA officials from NASA Headquarters, the Space Operations Mission Directorate, NASA's Commercial Orbital Transportation Services program, and the ISS program officials, and interviewed officials representing the International Partners.

To accomplish our work, we visited and interviewed officials responsible for the ISS operations at NASA Headquarters, Washington, D.C., and the Johnson Space Center in Houston, Texas. At NASA Headquarters, we met with officials from the Exploration Systems Mission Directorate and the Space Operations Mission Directorate, including representatives from the International Space Station and Space Shuttle programs. We also met with ISS and Space Shuttle mission officials at the Johnson Space Center.

We conducted this performance audit from July 2007 to April 2008, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

BIOGRAPHY FOR CRISTINA T. CHAPLAIN

Ms. Chaplain currently serves as a Director, Acquisition and Sourcing Management, at the U.S. Government Accountability Office. She has responsibility for GAO assessments of military and civilian space acquisitions. Ms. Chaplain has also led a variety of DOD-wide contracting-related and best practice evaluations for the GAO. Before her current position, Ms. Chaplain worked with GAO's financial management and information technology teams. Ms. Chaplain has been with GAO for 17 years. She received a Bachelor's degree, *magna cum laude,* in International Relations from Boston University and a Master's degree in Journalism from Columbia University.

Chairman UDALL. Thank you.
Dr. Sutton.

STATEMENT OF DR. JEFFREY P. SUTTON, DIRECTOR, NATIONAL SPACE BIOMEDICAL RESEARCH INSTITUTE

Dr. SUTTON. Mr. Chairman, Judge Hall, and distinguished Members of the Subcommittee, I thank you for the opportunity to testify here this morning.

I have the distinct honor of serving as the Director of the National Space Biomedical Research Institute or NSBRI. And NASA established NSBRI in 1997, and was charged to lead a national effort for accomplishing the integrated biomedical research necessary to support a long-term human presence development and exploration of space. That mission has not changed since inception.

And over the past decade NSBRI has brought unprecedented intellectual and institutional resources to help NASA address and reduce high-priority biomedical risks. And the focus has been on the team approach to develop counter measures or solutions to health-related problems in the physical and psychological challenges that men and women face on long duration space flights.

NSBRI is a success story for NASA. The Institute attracts outstanding scientists, physicians, and engineers across the country and coordinates them to advance in a cost-effective way biomedical science and technology for space and to apply results to enhance life on Earth.

We are excited by a number of things. We are excited by the scientific and technological achievements, by the growing number of young people who are participating in the science and education programs, and also by the accomplishments of the talented people in this endeavor. And we are particularly proud at this moment, Dr. Michael DeBakey, from Baylor College of Medicine in Houston, and Dr. DeBakey is a world-renowned heart surgeon, innovator, military veteran, leader, and humanitarian, and we are privileged that he is a dedicated and active member of the NSBRI Board of Directors. And yesterday in a magnificent ceremony in the Rotunda, the President and Congressional leadership presented Dr. DeBakey with the Congressional gold medal, the most distinguished award bestowed by the United States Congress, and on behalf of NSBRI, I thank you for your support of the award to Dr. DeBakey.

In my written testimony there are responses to a series of thoughtful questions posed by the Subcommittee concerning biomedical research and the ISS. What I would like to do here is to talk about three points that cut across the questions and the responses.

Now, the first is that ISS is critical to biomedical research needed to prepare for exploration beyond low-Earth orbit.

The second point is that there is a vibrant portfolio that exist right now in ground base biomedical research that is maturing toward flight studies for ISS.

And the third is that biomedical research for exploration leads to advances that enhances life on Earth. Let me talk about these three points in turn.

There is a broad range of human health risks associated with extended operations in the microgravity environment of space, and I know that Members are familiar with these examples being accelerated bone loss, muscle atrophy, changes in cardiovascular function, altered immune responses, sensory motor adaptations, issues concerning habitability, and a variety of other issues. And also how to deliver medical care, to provide medical capabilities in this environment.

We are familiar with how imaging has impacted medicine on Earth, the ability to make accurate diagnoses, to provide treatment. During missions in remote harsh environments, whether on Earth or in space, it is important to make the best possible assessment in the event of a medical contingency.

Since treatment decisions pertain not only to the affected crew member but also to the other crew members, the consumables and possibly the mission itself, in a collaboration involving academia, government, and industry, ultrasound training for non-physician crew members aboard the ISS has led to several scientific publications demonstrating the utility of ultrasound for health monitoring and medical imaging in space.

The findings and subsequent lessons learned unquestionably required ISS crew and resources could not have been done without ISS, and this project exemplifies how the ISS provides unique and invaluable capabilities. Their applications to Earth in military medicine, in the ability to make diagnoses in remote settings, air ambulances, and also applications to sports medicine, and in fact, the technologies were used during the last Olympic games.

The second point that I wish to make pertains to the way in which the NASA's human research program and NSBRI are working together. There is a significant portfolio of projects involving 70 universities in 26 states that are moving the way through a pipeline of counter-measure and technology development from research to development, to testing, to evaluation, and eventual operational integradation. There is a user panel of astronauts, current and former and flight surgeons, who are working together. I agree with Mr. Rohrabacher's statement that there is a need to conduct research on Station. This is why NSBRI was created, from the standpoint of NASA leveraging off the Nation's investment and biomedical research and being able to move projects to testing in the Space Station.

The third point that I wanted to make concerns the spin-offs, the first panel eloquently addressed this issue in the context of unique conditions of space, leading to novel insights and discoveries and also to spin-offs. And I want to echo the comments of the other witnesses and thanking NASA and the engineers for their ingenuity, hard work, and expertise in making ISS a reality. There is really an unprecedented opportunity here from the perspective of biomedical research, and that this endeavor will be collaborative international and would advance our nation as we build upon our legacy of innovation, discovery, and leadership.

Thank you very much for your time.

[The prepared statement of Dr. Sutton follows:]

PREPARED STATEMENT OF JEFFREY P. SUTTON

Mr. Chairman, Ranking Member and Distinguished Members of the Subcommittee:

Thank you for the opportunity to testify on the subject of *"NASA's International Space Station Program: Status and Issues."* Since 2001, I have had the privilege to serve as the Director of the National Space Biomedical Research Institute (NSBRI), a non-profit consortium competitively selected and supported by NASA to address and develop countermeasures for high-priority biomedical risks associated with long-duration human exploration of space.

The International Space Station (ISS) provides a unique, invaluable resource for the U.S. and its international partners to conduct scientific research, develop and demonstrate innovative technologies, test and evaluate procedures, protocols and products, and operationally integrate hardware, software and other components to advance space exploration goals. Designation of the U.S. segment of the ISS as a National Laboratory, as specified in Section 507 of the *NASA Authorization Act of 2005* (Public Law 109–155), underscores the importance of ISS as a facility for research and a means to enable exploration.

In the *"Vision for Space Exploration,"* presented by President Bush on January 14, 2004, the use of ISS to support space exploration goals is highlighted, with one focus being to understand how the space environment affects astronaut health and capabilities and to develop countermeasures. The potential of ISS as an essential platform for biomedical and technology research to support long-term human exploration of space has been described in several recent reports, including but not limited to (1) *"Review of NASA Plans for the International Space Station,"* prepared by the National Research Council in 2006, and (2) *"NASA Report to Congress Regarding a Plan for the International Space Station National Laboratory,"* submitted in May 2007.

It is prudent for the U.S. to foster scientific and technological achievements utilizing the unique attributes of the ISS. Innovation and discovery contribute to American leadership and economic growth. Accomplishments in space help inspire the next generation of scientists, physicians and engineers, support U.S. competitiveness, facilitate partnerships and international cooperation, and lead to advances that enhance life on Earth. NASA and the Nation face many challenges. As construction of the ISS nears completion and three scientific laboratories become operational, the time is ripe to capitalize on our country's investment in the ISS and all that it has to offer.

The present hearing examines the status of the ISS and issues related to its operation and utilization, including the planned and potential uses of the ISS to meet both NASA and non-NASA research needs. This testimony concerns itself with responses to a series of biomedical questions posed in the Subcommittee's invitation letter.

What biomedical research is needed to prepare for exploration beyond low-Earth orbit?

In the 47 years since the first human flew in space, a significant amount of knowledge and experience has been acquired relating to the inherent risks associated with human space travel. Missions in low-Earth orbit, especially long-duration flights aboard Skylab, Mir and ISS, have given insights into a broad range of human health risks associated with extended operations in the microgravity environment of space. Accelerated bone loss, muscle atrophy, changes in cardiovascular function, altered immune responses and sensorimotor adaptations occur. There are issues concerning proper nutrition, human-machine interfaces and habitability, neuro-behavioral and psycho-social factors, performance, sleep and chronobiology, radiation and medical care capabilities, including ineffectiveness of medication. Some risks, such as dust from the lunar or Mars surfaces, are unique to missions beyond low-Earth orbit. Not all astronauts are affected equally by the same risk or countermeasure, and individual differences need to be taken into account.

An understanding of the risks and issues is critical to determining what biomedical research is needed. The Institute of Medicine (IOM) report, *"Safe Passage: Astronaut Care for Exploration Missions,"* released in 2001, recommended that all relevant epidemiological data on astronauts be captured, and that a long-term, focused health care research strategy be pursued concerning health risks and their amelioration.

The Bioastronautics Roadmap (*http://bioastroroadmap.nasa.gov*), developed over the past decade by NASA in collaboration with the external biomedical research community, is consistent with this perspective. The Roadmap provides a framework for identifying, assessing and reducing the risks of crew exposure to the hazardous environments of space. It identifies 45 risks and assigns priorities to these for three reference missions: a one-year mission to the ISS; a month-long stay on the lunar surface; and a 30-month round-trip journey to Mars.

NASA and its non-government organization partner, NSBRI, have used the Bioastronautics Roadmap as a framework to build a biomedical research portfolio focused on high-priority areas, such as accelerated bone loss, radiation, neuro-behavioral and psycho-social factors, and exploration medical care. More recently, the partnership has been elucidating a level of detail necessary to prioritize risks across physiological disciplines and to compare strategies for how to manage a given risk across mission operational architectures.

Research on the ground and in space is needed to elucidate processes but the importance of accelerating countermeasure and technology development is also critical, as emphasized in an IOM report released in 2005 entitled *"A Risk Reduction Strategy for Human Exploration of Space."* To prepare for exploration beyond low-Earth orbit, the report stresses the need to establish safe radiation exposure levels for all relevant risks. This sentiment is echoed in a 2008 report from the National Research Council entitled *"Managing Space Radiation Risk in the New Era of Space Exploration."*

By its nature, research needs are dynamic as knowledge about risks matures and countermeasures and other risk-reduction strategies are implemented. ISS as a research platform provides an unparalleled resource to define requirements for exploration needs and to support research, development, testing, evaluation and operational integration of deliverables to support crew health and well-being.

What progress has been made to date?

Progress in biomedical research and development has been made in space and in ground-based investigations. Skylab, Space Shuttle (including dedicated life science missions such as STS–90 Neurolab), free flyers and the ISS have all pushed the frontier of biomedical knowledge and technology. Beginning with the arrival of Expedition 1 to the ISS in November 2000, and extending through the current Expedition 17 (launched April 8, 2008 with an expected return to Earth in October 2008) and Expedition 18 (expected launch and return in October 2008 and April 2009, respectively) missions, NASA reports a series of experiments devoted to human research and countermeasure development for exploration.[2]

A summary of these experiments with Earth applications follows:

- *Bone and Muscle Physiology in Space* Experiments include research seeking to understand the effects space flight on bone loss and muscle fatigue, kidney stone prevention, and developing countermeasures, such as the use of medicines and exercise. Potential Earth benefits include treatments and/or cures for diseases such as osteoporosis and spinal cord injuries.
- *Cardiovascular and Respiratory Systems in Space* Experiments include research to understand orthostatic intolerance, decompression sickness, and blood delivery to the brain. Earth applications include improved treatment of low blood pressure and prevention of cardiac deconditioning.
- *Human Behavior and Performance* Experiments include research on crew interaction, understanding behavioral issues and sleep cycles. Earth applications include improved treatment of insomnia and improved behavioral performance of people in high-stress situations.
- *Immune System in Space* Experiments include research on developing new wound healing technologies, understanding and monitoring immune system functions, and studying stress-induced reactivation of viruses. Earth applications include wound and tissue repair techniques that could prevent limb loss for military and civilian populations and rapid detection of stress-induced viruses, such as herpes, and improved treatment.
- *Integrated Physiology Studies* Experiments include research on development of telemedicine strategies, nutrition, and archiving of biosamples that will provide future research opportunities. Earth applications include remote medical diagnosis and treatment capabilities for rural health care and greater understanding of nutrition on health.
- *Microbiology in the Space Environment* Experiments include research on development of hand-held technology to detect biological and chemical substances, understanding the threat of pathogens inside spacecraft, and studying the effect of reduced gravity on pathogens. Earth applications include advances in vaccine development, new treatments of drug-resistant virus strains, and diagnosis for potential sources of microbial contamination.
- *Neurological and Vestibular Systems in Space* Experiments include research on facilitating recovery of functional mobility after long-duration space flight, understanding hand-eye coordination difficulties in space, and studying medications to treat motion sickness. Earth applications included improved treatment of neurological diseases, more effective motion sickness treatment, and reduced risk of falling in the elderly.
- *Radiation Studies* Experiments include research on the radiation environment, effects of radiation on the brain, and assessing the risk of genetic damage caused by radiation. Earth applications include benefits for brain tumor

[2] *(http://www.nasa.gov/mission_pages/station/science/experiments/Human_Research.html)*

treatment, insight on the origin of specific gene mutations, and improved radiation protection on military and civilian aircraft crews.

A significant step forward by NASA in implementing an integrated biomedical research program to support the long-term human presence, development and exploration of space occurred slightly more that a decade ago. In 1997, NASA competitively awarded, and has funded in increments based on performance, a cooperative agreement (NCC 9–58) to the National Space Biomedical Research Institute (*www.nsbri.org*). NSBRI works in partnership with NASA's Human Research Program, that is part of Advanced Capabilities within the Exploration Mission Systems Directorate. NSBRI leverages the Nation's substantial investment in biomedical research and brings unprecedented intellectual and institutional resources to solve problems for NASA. The focus is on a team approach to developing countermeasures and deliverables in close collaboration with NASA (see Attachments A and B).

NSBRI is a virtual institute that currently supports approximately 65 coordinated and openly competed science, technology and education projects at 70 universities in 26 states. There is a well established pipeline of products, maturing through countermeasure and technology readiness levels, in preparation for flight testing, evaluation and, if appropriate, operational integration. Some projects have matured to flight, while the bulk of the effort is ground-based and serves as a source of biomedical research for the ISS National Laboratory.

As a nationally acclaimed translational research institute, NSBRI adds unique value to NASA's Human Research Program. NSBRI is governed by 12 consortium members, with combined annual biomedical funding in excess of $3B from the National Institutes of Health (NIH). There are strong productive collaborations not only with institutes within the NIH, in the spirit of the recent NASA–NIH Memorandum of Understanding, but also with programs within the Department of Defense, Department of Energy, U.S. Naval Academy, and other entities. More than one-third of NSBRI projects actively engage industry, and there is an excellent education and outreach program spanning elementary through high school, undergraduate, graduate, and post-doctoral education, and continuing medical education efforts related to space. There is an eminent Board of Directors (Attachment C) and active involvement of current and former astronauts and flight surgeons (Attachment D).

Examples of NSBRI supported science and technology projects include:[3]

- Understanding the harmful effects of space radiation in exacerbating bone loss caused by microgravity, with implications on Earth for patients receiving radiotherapy;
- Investigation of pharmacological countermeasures to limit hand and muscle fatigue in space, with applications on Earth to lessening muscle weakness following injury or surgery;
- Development and testing of a needle-free blood and tissue monitoring device for health assessment, science and medical care in space, with applications on Earth for use in ambulances, intensive care units, battlefield settings and monitoring of vascular function in diabetics;
- Research and applications of blue light to affect the human circadian pacemaker, performance and adaptation to shifts in work schedule, with applications on Earth to shift work;
- Delivery of a miniaturized time-of-flight mass spectrometer for environmental monitoring and medical assessment in space, with applications for homeland security;
- Research, development, testing and evaluation (aboard the NASA Extreme Mission Operations underwater habitat) of a psychomotor vigilance test for the objective assessment of fatigue and stress in mission-critical activities (Principal investigator awarded a NASA Distinguished Public Service Medal in 2007);
- Development of a microdosimeter instrument, tested aboard the MidSTAR–1 satellite, for real-time personal radiation monitoring, with applications to radiation assessment on Earth;
- Ultrasound training for non-physicians aboard the ISS for health monitoring and medical imaging resulted in a NSBRI/NASA/contractor collaboration leading to the first scientific publication from space,[4] with applications on Earth for remote-guided medical evaluation and sports medicine;

[3] See *http://www.nsbri.org/Research/index.html* for a complete listing of projects.
[4] *Radiology* 2005; 234(2):319–322.

- Development and testing of a high-intensity, focused ultrasound technique for non-invasive, bloodless surgery, with applications in space, emergency rooms and on the battlefield;
- Studies to determine oxygen requirements and means to concentrate oxygen in hypoxic, harsh environments, with applications on Earth to emergency and military medicine.

What role will the International Space Station play in addressing those questions?

While short-duration flights and ground-based research, including the use of analog environments, contribute to biomedical research for space exploration, the ISS provides the only resource with the capabilities to conduct certain types of research and to advance countermeasures and technologies. There are two immediate strategic goals the ISS can fulfill in the area of biomedical research to address exploration needs. It will serve as a proving ground for scientific and technological product development of deliverables currently in the pipeline. These deliverables may address specific standards and requirements. Secondly, access to the ISS would foster new project opportunities that leverage off the portfolio of projects currently addressing exploration needs.

What is needed to maximize the utility of the International Space Station for conducting the necessary biomedical research?

Affordable and reliable access to and from the ISS is key to the success of conducting the necessary biomedical research. Critical to this access is the availability of cost-effective transportation services.

Given adequate access to and from ISS, it is essential to have a robust management structure and leadership for conducting and integrating science. Research aboard the ISS should be of the highest merit, with ample preliminary work to ensure success. There should be clear justification as to why the ISS is the best, or perhaps only, laboratory to conduct the research. Some biomedical research is fundamental and can only be performed in a microgravity environment. However, much of the necessary biomedical investigations for space are translational. They mature through a pipeline from research, to development, to testing, to evaluation, to operational integration. To maximize the utility of the ISS in this context, it is wise to link the ISS National Laboratory to the full spectrum of space-related research being conducted throughout academia, industry and government.

Lastly, a countermeasure advancement process, developed specifically for utilization of the ISS National Laboratory, would be helpful to facilitate key research moving through the pipeline of development to advance to validation in space. Such a process will require strong program oversight and management rigor to assess the operational need and feasibility of the research, thereby maximizing the return on investment.

What, if any, critical enabling biomedical research for exploration cannot be done on the International Space Station and will have to be addressed by other means?

While many areas of biomedical research for exploration would benefit from access to the ISS, some research is not suitable for ISS and needs to be addressed by other means. Four examples follow:

Radiation Studies—Studies toward countermeasure development against the acute and chronic effects of radiation cannot be fully conducted in low-Earth orbit, given the presence of the Van Allen belts. The radiation spectrum beyond low-Earth orbit can be emulated utilizing beams of high-energy heavy ions, such as those found at Brookhaven National Laboratory.

Long-duration Exposure to Reduced Gravity—The effects of microgravity on the body during long-duration missions are well documented (e.g., approximately one percent bone loss per month). However, the effects of long-term exposure to reduced gravity are not known. Gravity on the Moon is one-sixth of Earth's gravity and on Mars it is three-eighths of Earth's gravity. There are many open questions, such as whether extra-vehicular activities in these gravitational environments obviate the need for supplemental exercise countermeasures.

Lunar Dust—Dust, such as on the Moon, poses an environmental risk that could result in mechanical failures in spacesuits and airlocks. Lunar dust is exceedingly small, making it easy to get deep into the lungs. The dust is littered with bonded shards of glass and minerals known as agglutinates, which have not been found on Earth. It is not known whether they can be expelled efficiently if inhaled.

Medical Emergency Management—Through the use of a high-fidelity patient simulator, astronauts and ground personnel involved in mission operations can practice management of medical emergencies. Ground-based simulation of medical contingencies complements activities to advance medical care capabilities that could be tested and evaluated aboard the ISS.

In closing, as ISS construction nears completion, there is an unprecedented opportunity to conduct biomedical and other research, and to test and validate critical technologies for human exploration of space. This endeavor will be collaborative, international and will advance our nation as we build upon our legacy of innovation, discovery and leadership.

Attachment A

NSBRI Research to pave the way for human exploration of space

National Space Biomedical Research Institute

The National Space Biomedical Research Institute (NSBRI) is a unique, non-profit scientific partnership with NASA committed to implementing the Vision for Space Exploration by providing practical, validated and effective solutions to support and maintain human health and performance during long-duration spaceflight. NSBRI engages academic, industrial and government researchers and educators, and the resources of the nation's leading biomedical research institutions, in a team-based effort to reduce the significant health risks associated with human space travel. The Institute's goal-directed, cost-efficient science, technology and education programs strongly impact both the safety of human space travel and the quality of life on Earth.

Mission

The Institute leads a national effort for accomplishing the integrated, critical path, biomedical research necessary to support the long-term human presence, development, and exploration of space and to enhance life on Earth by applying the resultant advances in human knowledge and technology acquired through living and working in space.

Overview

- **Public-Private Partnership**. NSBRI is a NASA-supported corporation that is responsive to NASA's needs. The Institute draws readily upon competitively-selected resources in universities and industry to address specific problems and provide a targeted, product-oriented research and development program.
- **Countermeasure Production**. Each project is part of an integrated plan to produce enabling technologies and countermeasures. Our directed approach links the knowledge base of academia with the expertise of spaceflight operations to identify, develop and deliver technology and countermeasure strategies that meet the needs of space exploration. The Institute has an Industry Forum to assist with the Earth-based applications of these advances.
- **Prioritized Team Approach**. The Institute is organized into teams that address major physiological or medical issues (e.g. bone loss, muscle alterations, smart medical care). Team efforts are concentrated on overarching programmatic goals for the development of risk-mitigation strategies to support exploration needs. Partnerships within and between teams provide integrated project suites addressing multiple aspects of human health and performance concerns.
- **Operational Focus**. The Institute's User Panel comprised of flight surgeons and astronauts ensures that the deliverables for reducing human risks are focused on operational NASA requirements and support directly the goals of the Vision for Space Exploration. NSBRI can test candidate strategies in analog environments to validate preflight readiness.
- **Strong Program Oversight and Management Rigor**. A Board of Scientific Counselors and an External Advisory Council composed of engineers, physicians and scientists with national and international reputations review progress and provide advice for continued program excellence.

Organization

- NSBRI program involves investigators from more than 70 universities and institutions across the United States.
- National education and outreach activities at all levels.
- Governed by a consortium consisting of Baylor College of Medicine, Brookhaven National Laboratory, Harvard Medical School, The Johns Hopkins University, Massachusetts Institute of Technology, Morehouse School of Medicine, Mount Sinai School of Medicine, Rice University, Texas A&M University, University of Arkansas for Medical Sciences, University of Pennsylvania Health System and University of Washington.
- Productive collaborations between the NSBRI and NASA centers, as well as with international partners, provide the best possible chance of solving complex biomedical problems related to a human presence in space.

For more information, contact:

National Space Biomedical Research Institute
One Baylor Plaza, NA-425
Houston, TX 77030-3498
713-798-7412
www.nsbri.org
info@www.nsbri.org

Attachment B

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AsMA News

Space Medicine Association News

National Space Biomedical Research Institute and Space Medicine

by Jeffrey P. Sutton, M.D., Ph.D.
Director, National Space Biomedical Research Institute

Founded in 1997 through a NASA competition, the National Space Biomedical Research Institute (NSBRI) is a non-profit organization dedicated to advancing biomedical research and space medicine to ensure a safe and productive long-term human presence in space. NSBRI serves a unique role for NASA by engaging and coordinating outstanding investigators and clinicians from across the country to participate in team-based approaches to address high-priority biomedical issues and problems associated with human space missions.

NSBRI leverages the nation's investment in biomedical research and supports projects at approximately 70 universities in 26 states. The Institute also has a nationally acclaimed education and outreach program that provides curriculum guides at the elementary through high school levels, develops web-based resources for teachers and faculty, and coordinates excellent programs at the undergraduate, graduate, postdoctoral, and early-investigator levels. There is also a Continuing Medical Education (CME) program in space medicine sponsored by Baylor College of Medicine, one of the twelve consortium institutions involved in the governance of NSBRI. The CME program operates primarily at NASA-Johnson Space Center, where NSBRI has close ties to NASA scientists, engineers, flight surgeons, astronauts, and management. Activities interfacing NSBRI and NASA are coordinated through a Steering Committee, as well as through other groups involving space medicine personnel.

The science and technology portfolio, education and outreach projects, and other information pertinent to NSBRI can be found at www.nsbri.org. Proposals that engage the academic community, incorporate aerospace physicians and individuals with flight experience, and that address operationally relevant problems are particularly important to NSBRI. These science and technology projects are often interdisciplinary and yield deliverables that mature through a pipeline spanning research, development, testing, evaluation, and operational integration.

To help ensure that NSBRI meets its missions to 1) lead a national effort for accomplishing the biomedical research necessary to support the long-term human presence in, and development and exploration of space, and 2) enhance life on Earth by applying the resultant advances in human knowledge and technology, the Institute has an active User Panel comprised of current and former astronauts and flight surgeons. Leroy Chiao, Ph.D., a veteran of four space missions, including the command of Increment 10 of the International Space Station, chairs the Panel. Jonathan Clark, M.D., past president of the Space Medicine Association, is also on the Panel and additionally serves the Institute as NSBRI/NASA Space Medicine Liaison.

The majority of science and technology projects and educational opportunities are solicited through open announcements, released either by NSBRI alone or jointly with NASA. The solicitations typically occur annually and are posted on the NSBRI and NASA websites. Some projects are acquired through directed tasks, generally from NASA. All projects, regardless of acquisition mechanism, undergo peer review and are vetted through oversight councils prior to selection.

Funded science and technology projects are assigned to 1 of 10 teams in the following areas: Bone Loss; Cardiovascular Alterations; Human Performance Factors, Sleep and Chronobiology; Muscle Alterations and Atrophy; Neurobehavioral and Psychosocial Factors; Nutrition, Physical Fitness and Rehabilitation; Radiation Effects; Sensorimotor Adaptation; Smart Medical Systems; and Technology Development. Each team is under the leadership of a nationally recognized expert in science, medicine, and/or engineering. NSBRI management and NSBRI/NASA liaisons work with investigators, team leadership, and NASA to facilitate progress and maturation of deliverables. Projects are often funded for 4 yr and are competitively renewable.

In addition to supporting top-tier academic investigators and teams to work on high-priority biomedical problems, and to develop countermeasures to reduce risks inherent with human spaceflight, NSBRI has expanded its connections to industry and the international community. Approximately 40 companies are now strategically linked to the Institute, and there has been considerable growth in science and education efforts through international collaborations. The Institute is a success story for NASA and a model for how a national translational research program can run in a productive and cost-effective manner.

NSBRI welcomes inquiries and suggestions from the Aerospace Medical Association membership and affiliates. The Institute adds demonstrable value to the NASA Human Research Program and is well positioned to make further positive contributions in important areas interfacing aerospace and medicine. For more information, visit us at www.nsbri.org or contact us as info@nsbri.org.

Attachment C

NSBRI Board of Directors

NSBRI Chairman and CEO
Bobby R. Alford, M.D.
Baylor College of Medicine

William L. Allen
National Geographic Magazine (ret.)

Carl W. Anderson, Ph.D.
Brookhaven National Laboratory

James B. Bassingthwaighte, M.D., Ph.D.
University of Washington

MajGen. Charles F. Bolden, Jr., USMC (ret.)
Former Astronaut

Joseph V. Bonventre, M.D., Ph.D.
Harvard-MIT Division of Health Sciences and Technology
Harvard University

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Rice University

Peter F. Davies, Ph.D.
University of Pennsylvania Health System

Michael E. DeBakey, M.D.
Baylor College of Medicine

Theresa W. Fossum, D.V.M., Ph.D.
Texas A&M University

Glen N. Gaulton, Ph.D.
University of Pennsylvania Health System

Martha L. Gray, Ph.D.
Harvard-MIT Division of Health Sciences and Technology
Massachusetts Institute of Technology

Sandra A. Harris-Hooker, Ph.D.
Morehouse School of Medicine

Fritz A. Henn, Ph.D., M.D.
Brookhaven National Laboratory

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Morehouse School of Medicine

Richard J. Johns, M.D.
The Johns Hopkins University

Kristina M. Johnson, Ph.D.
The Johns Hopkins University

Eugene H. Levy, Ph.D.
Rice University

Robert E. McGehee, Jr., Ph.D.
University of Arkansas for Medical Sciences

Larry D. Milne, Ph.D.
University of Arkansas for Medical Sciences

Warren Olanow, M.D.
Mount Sinai School of Medicine

John A. Parrish, M.D.
Harvard Medical School

Hon. John E. Porter
Partner, Hogan & Hartson LLP

Alan L. Schiller, M.D.
Mount Sinai School of Medicine

Jeffrey A. Simmons, Ph.D.
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Baylor College of Medicine

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Hospital for Special Surgery
NSBRI External Advisory Council Chairman

Ex Officio
Jeanne L. Becker, Ph.D.
NSBRI Associate Director

Ex Officio
Jeffrey P. Sutton, M.D., Ph.D.
NSBRI Director

Director Emeritus
Joseph P. Kerwin, M.D.
Wyle Laboratories (ret.)

Director Emeritus
J. David Litster, Ph.D.
Massachusetts Institute of Technology

Director Emeritus
Arnold N. Weinberg, M.D.
Massachusetts General Hospital

Director Emeritus
Torsten N. Wiesel, M.D.
Rockefeller University

Attachment D

NSBRI User Panel

The User Panel, comprised of former and current astronauts and flight surgeons, ensures the NSBRI research program is focused on astronaut health and safety.

Leroy Chiao, Ph.D.
Chairman
Former Astronaut

Ellen S. Baker, M.D.
NASA-Johnson Space Center
Astronaut

Daniel W. Bursch
Former Astronaut

Eileen M. Collins
Former Astronaut

Walter Cunningham
Former Astronaut

J.M. "Mike" Duncan, M.D.
NASA-Johnson Space Center
Flight Surgeon

David Hilmers, M.D.
Baylor College of Medicine
Former Astronaut

Thomas Jones, Ph.D.
Former Astronaut

Joseph P. Kerwin, M.D.
Former Astronaut

Richard M. Linnehan, D.V.M.
NASA-Johnson Space Center
Astronaut

Shannon Lucid, Ph.D.
NASA-Johnson Space Center
Astronaut

J.D. Polk, M.D.
NASA-Johnson Space Center
Flight Surgeon

Richard A. Scheuring, D.O.
NASA-Johnson Space Center
Constellation Medical Operations
Flight Surgeon

Donald A. Thomas, Ph.D.
Former Astronaut

James S. Voss
Former Astronaut

Executive Secretary
Jonathan B. Clark, M.D.
NSBRI/NASA Space Medicine Liaison

BIOGRAPHY FOR JEFFREY P. SUTTON

Jeffrey P. Sutton, M.D., Ph.D., is President and Institute Director of the National Space Biomedical Research Institute (NSBRI). He was unanimously appointed to this position in 2001 by the NSBRI Board of Directors. NSBRI partners with NASA to support science, technology and education at more than 70 universities across the U.S., with a focus on developing solutions to health-related problems associated with human space exploration. NSBRI also has extensive partnerships with industry, U.S. Government programs and international collaborators.

Dr. Sutton guided the maturation of NSBRI into a premier, internationally acclaimed institute of excellence in translational biomedical research. Under his leadership, NSBRI has developed and continues to generate important and operationally-relevant countermeasures and deliverables to enhance health in space and on Earth. Partnerships with government and industry have tripled, and NSBRI is now a main portal to the extramural community for NASA-sponsored human research. NSBRI's portfolio of projects is team-based and addresses high-priority areas, innovation and successful product development.

Dr. Sutton has been at the forefront of several award-winning education and outreach initiatives in science, medicine and engineering. These programs inspire and support the next generation of space explorers, within the U.S. and abroad. He has streamlined business practices, and enhanced efficiencies and entrepreneurship.

Dr. Sutton was born in New York City and holds an M.D. degree (1982), an M.Sc. in medical science (neuroscience, 1985) and a Ph.D. in theoretical physics (1988), all from the University of Toronto. His residency training was at Harvard Medical School. He is a Diplomat of the American Board of Psychiatry and Neurology, and a Fellow of the Royal College of Physicians and Surgeons of Canada. He practiced medicine for 19 years.

Prior to his present position, Dr. Sutton was NSBRI Smart Medical Systems Team Leader from 1999–2001, and also served as interim Team Leader for the NSBRI Technology Development Team. He established and from 1995–2002 was Director of the Neural Systems Group at the Massachusetts General Hospital and the Harvard-MIT Division of Health Sciences and Technology. Dr. Sutton was on the faculty of Harvard Medical School from 1991–2002. He is currently on the faculty of Baylor College of Medicine and has been an affiliate faculty member in the Harvard-MIT Division of Health Science and Technology, Massachusetts Institute of Technology, since 1995. During his career, he has taught and mentored many students and physicians at various levels of training.

Dr. Sutton's research expertise is in smart medical systems, computational neuroscience and neuroimaging. He has made significant contributions to these fields, is the author of numerous scientific articles and holds several patents. He has received many accolades, including a National Institutes of Health Scientist Development Award, a President's Citation from the Society of NASA Flight Surgeons, and a Harvard-MIT Division of Health Science and Technology Award for Clinical Medical Education Excellence. He has been a founder of several start-up informatics companies and holds a variety of advisory positions with academia, government and industry.

Discussion

Chairman UDALL. I thank the panel for that very important set of presentations.

We are going to move right now to the first round of questions. I am going to recognize myself for five minutes.

Cost of ISS Operations

I want to start with Mr. Gerstenmaier. In the interest of clarification, I wanted to ask you how much will the taxpayer, our taxpayers invest in the Station, including Shuttle flights? There were some comments made in the previous panels about the numbers. I want to make sure we had the correct number for the record.

Mr. GERSTENMAIER. Are you talking about the basic Space Station sustaining an operations budget on an annual——

Chairman UDALL. I am talking about all, I think the capital costs, the operational costs. There was a number of $100 billion mentioned in the last panel. I am not sure that is correct, and I wanted to at least——

Mr. GERSTENMAIER. I would like to take that question for the record so we can get the details of what goes into that. There is a range of numbers that sits out there, and I would like to get a common basis and provide a detail.

Chairman UDALL. That would be helpful to the Committee, and if you would include the Shuttle flights, I think, in total. You could break those out, it would be useful.

Mr. GERSTENMAIER. And we can include that with transportation, with all the various pieces in there so then you could see what the investment is. But it would be, it is much better to do written than——

Chairman UDALL. I would agree.

LOGISTICS FLIGHTS

Let me continue questioning Mr. Gerstenmaier. I wanted to follow up on your statement that the approach will, to the Shuttle will, to the Station, I should say, will require living off spares flown up by the Shuttle and taking some limited degradation and ISS capabilities if there is a delay in the commercial services.

In your engineering judgment, how do you pinpoint to analyze the contingency of logistics flights to bring critical spares to the ISS? Are they needed? If so, why?

Mr. GERSTENMAIER. Again, we have two contingency flights that sits in our manifest. Those flights deliver critical spares as you described, and the purpose of those spares are essentially to give us some margin if the commercial re-supply services are delayed a little bit, those spares are in place, so if a component fails, that critical component has a ready spare available on station to go ahead and replace it.

It allows the commercial re-supply sector to be a little bit later in their delivery. So I consider those flights to be critical to us, very important for us.

We also are monitoring actively what components are failing, and we are going to change kind of in real time exactly what components we put on those flights. So we have a candidate list of things we would like to fly today, but we reserve the right to change that around a little bit after we see how the actual hardware operates.

And we have just activated a lot of our systems on the outside of Space Station. We are getting more runtime on the equipment, learning how to balance that, and we will position the proper spares that will give us the most longevity of Space Station to allow research to occur.

Chairman UDALL. Could you speak further to the risk, the level of risk that we incur if we didn't fly those two Shuttle flights?

Mr. GERSTENMAIER. It is difficult to quantify exactly. It is a function of how this, the current equipment operates and how well it performs. We see some components do very well, actually operate much longer than we have anticipated. We have seen some not work quite as well. The beta gimble, a large motor that rotates that tracks the sun with the outboard rays, and then there is a large alpha joint, a big joint about 10 foot diameter, a steel ring that rotates that has some degradation in it. We are probably going to have to make some changes there. The control moment gyros that provide attitude to station, it was supposed to last about eight years. We have lost two of those in two or three years.

So there is significant degradation in some components but then other components have run much longer than we have anticipated. Our judgment has to be how do you anticipate what those failures are, place them on the Shuttle, and then that gives us the robustness to continue.

Chairman UDALL. Are those flights a part of the manifest?

Mr. GERSTENMAIER. Those flights are, we treat them as part of the manifest. They are shown there. We don't have approval to fly those yet. We still need to seek approval to do that. They are budgeted, and we are planning those actively to be in the manifest, but they need to occur. We need to justify that they need to occur. Then they need to occur before the——

Chairman UDALL. Any back-up plan if we weren't to fly those two logistic flights?

Mr. GERSTENMAIER. Again, if for some reason those flights had to be dropped for some reason or they didn't occur for some reason or we weren't approved, given approval to fly those, we would anticipate what hardware we lose and then we would, again, provide back to the community the risks associated with not having those, that hardware based on the latest data at that time, and we would make an informed judgment about what we should do.

Chairman UDALL. Ms. Chaplain, do you care to comment?

Ms. CHAPLAIN. I agree with what has been said. I would also comment that if this does get pushed off to when the COTS vehicles are available, they might not necessarily have that kind of capability to take up some of these larger spares, and that would also constrain their ability to carry other things up to the Station, and that is already a tight area right now.

Chairman UDALL. Thank you for that insight.

I see my time is expired. I want to recognize Congressman Hall for five minutes.

Mr. HALL. Thank you, Mr. Chairman.

Mr. Chairman, you mentioned the risks if we didn't fly those two flights, and I am sure you are talking about the flights that they have said they intend to fly. We just don't know their status. I think you pretty well straightened that out.

SOYUZ SAFETY ISSUES

I guess my question is what if we do fly some flights, and Mr. Gerstenmaier, with NASA's reliance on Soyuz during the five-year gap and could you provide us with the details of the two previous re-entry problems? And I think I was one of the, among the first to insist on some escape module money for the four birds, and I was always told it was either too heavy or too expensive. I couldn't accept too expensive, but too heavy I had to accept it.

But we have that in the new bird that is coming along, and so I think reliability and safety are as much as what if we don't fly them that I am interested in. I guess if you give us the details of the two previous re-entry problems and what actions are being taken by the Russians to ensure the continued safety and reliability of Soyuz and is Soyuz a safe vehicle, and what insight does NASA have into the Soyuz Program?

In five minutes.

Mr. GERSTENMAIER. Okay. I have talked a little bit about both of those flights. Both of the flights had a ballistic entry on the Soyuz vehicle and by ballistic entry instead of the Soyuz actively flying and controlling the trajectory with the lift vector pointed in a specific direction, it essentially just spins the capsule much like a bullet coming out of a rifle shell, and then essentially provides stability for the Soyuz and ends up significantly shorter in location on the Earth where it lands on the trajectory, but it is stable in the sense that it is on track. It is just short by 400 kilometers, and that is what we saw in both of these cases.

It also appears that on both of these Soyuz vehicles we saw a failure of the instrumentation module and propulsion module to separate from the Soyuz vehicle. When the Soyuz departs from Space Station, it does a de-orbit burn, removes velocity from the spacecraft. It starts to re-enter then goes into an attitude in the orbital section, comes off, and the propulsion and instrumentation section also comes off and then it is just a little return capsule that returns.

It appears that that lower section did not properly release. We saw that, the Russians saw that, and they showed us the data that conclusively that that was still attached. We had telemetry going across a cable that should have severed when that came loose. So we know for sure on the previous Soyuz that that occurred.

On the most recent one it is subjecture that that has occurred. We need to get the capsule back to Moscow to understand that. The Russians will do that. The Russians have given us very good insight into their program. They understand the risk of what is going on. They are as concerned as we are about this event. The fact that we have similar occurrences of something that we thought we understood on two vehicles calls into question some design problems or maybe a manufacturing change, something has changed in the vehicles. The Russians will work that. They performed an independent commission. They will provide us with the results of that. We will, before we use the Soyuz for any other critical activities, we will make sure we have looked at the safety, we have looked at what we understand from this event that occurred, and we will make sure that we understand the risks that is going forward to our crews.

Mr. HALL. With that I thank you. I want to ask you one other quick question. You may have to answer it in writing if I don't have the time.

EXCEPTION TO INKSNA

As you well know, in order for NASA to continue buying Soyuz spacecraft from the Russians during the upcoming so-called gap, Congress has to provide a new exception to the *Iran, North Korea, Syria, Nonproliferation Act* called INKSNA, and that is a place where your recommendations and of these two groups here and Congress have to come together, and we have to do something together.

What would be the consequences if this Congress were to fail to provide that exception this year? And would NASA be able to place a timely order with the Russians if legislative relief were provided by say next spring?

Mr. GERSTENMAIER. We really need that relief now so we can complete the negotiations with the Russians. The time that we understand and the Russians have provided to us, which we agree with, is about three years to have those vehicles manufactured. We need to get those contracts in place. We need that relief this summer so we can complete those negotiations and have the vehicle there.

They are mandatory for us to keep a U.S. crew presence on-board Space Station. We need a U.S. crew presence on-board Space Station to operate the U.S. segments. The U.S. segment then provides power, cooling, water, air circulation for the other partner modules, including some of the Russian segments. So we need a U.S. presence there to maintain the Space Station so we need our crew members there. The only way to get them there when the Shuttle retires, initially is the Soyuz vehicle. So we need that relief. It is, and it is mandatory this summer.

Mr. HALL. And another alternative is that we might have to abandon the ISS. We don't want to do that. And the affect it has on our international partners. It is very, very important.

I thank and I yield back my time.

Chairman UDALL. Thank you, Congressman Hall.

The Chair recognizes Congressman Lampson.

ALPHA-MAGNETIC SPECTROMETER

Mr. LAMPSON. Thank you, Mr. Chairman.

I may sound like a broken record, Mr. Gerstenmaier, when I talk about the AMS, the Alpha-Magnetic Spectrometer, but that is one of the things that there has been a great deal of hope that would go to the International Space Station. And presently it does not have a location on the manifest for a Shuttle flight.

So I hope, first of all, that the two so-called contingency flights so, indeed, get funded and are made to happen. I think they are critically important.

But is there a possibility first that the AMS can go up on a Shuttle before we end the use of the Shuttle Program? And I guess beyond that, what other experiment, either facilities or hardware that have been developed to support research investigations, have been completed but are not planned for a flight? And what, if any, plans does NASA have to fly that hardware to the ISS, free flyers or other microgravity platforms?

Is there a lot? And who has participated in those things? Can you elaborate some on that for me?

Mr. GERSTENMAIER. Yes. In terms of the AMS, right now we don't see a spot in the current Shuttle manifest remaining ten flights to fly the AMS, and that is because of the discussion we just had on the criticality of the spares. The problem is if I took those spares off and replaced it with AMS, then I have hurt the basic infrastructure that is needed on-board Space Station to support the AMS.

So in other words, AMS needs power, it needs data, it needs cooling. If I don't fly the spares that could provide power, data, and cooling and have to take those off for AMS, then AMS is on-orbit, but it may not be able to be supported by Space Station.

So I need those flights to fly the spares.

Mr. LAMPSON. But now those don't include the two contingency flights?

Mr. GERSTENMAIER. No. Those two contingency flights are for those spares I just described.

Mr. LAMPSON. They are full. So even beyond the contingencies we don't have a place for the AMS.

Mr. GERSTENMAIER. Not in the existing manifest with those two contingencies.

Mr. LAMPSON. What if——

Mr. GERSTENMAIER. There is not room.

Mr. LAMPSON.—what about the other facilities and experiments and such?

Mr. GERSTENMAIER. The other facilities, I don't think there is any facility that is actually on the ground ready to be flown. There are ones that have been cancelled earlier like the large centrifuge module that was talked about earlier. That was cancelled very early in its development phase or not very early but in its development phase, and it is in nowhere ready condition to go fly.

We do have many facilities scheduled on the remaining Shuttle flights on the multi-purpose logistics flights. There is a combustion rack that is going to go up. There is a window observation facility that will fly.

So the basic research racks that were originally designed are still present on the manifest, and they are still there. Our goal is to outfit Space Station with the best racks we could to provide a wide variety of research capability for Space Station, and that is the goal we are still on, and we still have plans for those equipment.

But I will take it for the record to go investigate a little bit deeper to see if there is anything that is completed that is not getting to fly. But my recollection is there is none.

Mr. LAMPSON. But is it worth this Congress giving consideration to the additional money necessary to get those things, even if it is just down to the AMS, and I think there are some other things related and otherwise. Is it worth our country to look at the potential investment necessary for the hope of the return that would come from these things?

Mr. GERSTENMAIER. Again, that is tough for me to pass judgment on. I am an engineer who builds the basic laboratory. I think it would be better posed to the scientists and the researchers associated with AMS than to myself.

Mr. LAMPSON. Thank you. Thank you for that. The candor. I appreciate it. I really think that we have set some unfortunate policy along the way, and we really have been shortsighted on a number of things that we have done. Perhaps if we would have finished the crew return vehicle when we did the X-38, if you all remember that, that we shut down prematurely, we were at the end of its development, and we actually spent more money to shut it down than we would have to fly it. And perhaps that could have been used today to have been the crew return, I mean, crew exchange vehicle.

So I hope that we are getting our ducks lined up properly. I would sure like for us to give consideration as this panel and as a Congress to what we can do to identify other of those pieces of hardware, and I think we also have to consider what we have done as far as relationship is concerned of the nations that spend more than a billion dollars just on that one project, for us to renege on our promise to help put it up there to completion.

Mr. Chairman, I wanted to editorialize there at the end.

Mr. HALL. Would the gentleman yield just one moment?

Mr. LAMPSON. I would indeed.

Mr. HALL. Part of the problem is the expectations of a lot of universities that have put considerable work and requests in and were promised certain things on certain flights——

Mr. LAMPSON. Yeah.

Mr. HALL.—that have not been flown. Where it is important to go with our international allies, it is also important to keep the word with the universities. That is the reason we need these two flights if we can get them. Texas A & M being one in particular that you are very interested in protecting.

Mr. LAMPSON. Absolutely.

Mr. HALL. And I yield back my time.

Mr. LAMPSON. And reclaiming my time. Thank you very much. I think it is critically important for our reputation among other nations of the world and if we are going to entice countries to want to work with us on other science-related activities, that if we say we are going to do something, we ought to keep our word. We ought to do it. And I guarantee you that when we make that commitment, the return to us is going to be no different than what it was during the Apollo years. We will get so much back, more or beyond the investment that we make to make those things happen. It will be extremely worth our while.

I hope and pray that we don't lose our position to other nations in this space race.

I yield back my time. Thank you, Mr. Chairman.

Chairman UDALL. Thank you, Mr. Lampson. It has been said you give two Texans a lever, you can move the world. We are going to continue to try to find you all a lever, so you can do so.

The Chair recognizes Congressman Rohrabacher for five minutes.

RUSSIAN COOPERATION AND CAPABILITIES

Mr. ROHRABACHER. Maybe you could tell us about the willingness now of the Russians and their cooperation to meet the challenges that the Space Station, or excuse me, the retirement of the Shuttle, are going to present? Is there a willingness on the part of the Russians or a lack of willingness on the part of the Russians to expand our cooperation to make up for that loss?

Mr. GERSTENMAIER. I think we have really come to work together as an international partnership. When we had the *Columbia* tragedy and the Shuttle was lost, and we lost our transportation capability to Space Station for a temporary period of time, the Russians rose to that challenge and provided us with Soyuz vehicles and Progress vehicles that essentially kept Space Station viable during that period. So during those two years when we were not flying the Shuttle, if it were not for the Russians and their support to us, we would not have had a Space Station.

As we go to the future, they need our crew on-board Space Station as much as anyone does because I described, you know, we provide power to their segment, and we provide attitude control for the entire Space Station, which saves them propellant. We have many synergistic things that we share with them back and forth, so they need our U.S. crew presence there. They recognize they can't maintain the U.S. segment on their own.

So they will help us in that venture, but, again, they are going to want compensation in terms of financial contract with us, and we will work with them to work out the details.

Mr. ROHRABACHER. Are they capable of delivering spare parts and the other type of things that are necessary to maintain the Station?

Mr. GERSTENMAIER. They are capable of delivering the spares needed for their segment and to keep it operating. For our segment we will use the commercial re-supply services to deliver those components to Space Station for our equipment that needs to be——

Mr. ROHRABACHER. If it is, we don't have that capability now.

Mr. GERSTENMAIER. We do not have that capability now. We can also use the Automated Transfer Vehicle that the Europeans are building and the Japanese are building an——

Mr. ROHRABACHER. Which they don't have the capability now. The only people now who have got the capability are the Russians. Is that correct?

Mr. GERSTENMAIER. No. The ATV recently docked to Space Station. We brought it up so we have proven at least one time that that is a good capacity. It performed exactly the way it should. We flew it in within 10 meters, backed it back out, flew it back and successfully docked, and it is viable.

The Japanese have a full up test, propulsion test article they are test firing in Japan. Their vehicle is scheduled to fly next year.

Mr. ROHRABACHER. But this is, I am talking about something that is online, not something that we have done once.

Mr. GERSTENMAIER. The thing that is online is the ATV.

Mr. ROHRABACHER. Okay. And so that will, that capability will permit us then once the Shuttle is retired, to deliver these spares that we need?

Mr. GERSTENMAIER. We are going to need a combination of services when the Shuttle is retired. We are going to need the ATV, the HTV, and commercial re-supply.

Mr. ROHRABACHER. Okay. Let me note that to the degree that we are not, that we have been shortsighted, and to the degree that we have been shortsighted in some of the decisions that we have been making, number one, we, of course, it was hard to project that we would lose Shuttles as we have. And also let me just note that Congress, this body here, this committee no differently, and others have been unwilling to prioritize. It is not that there is not enough money being spent. It is just we have not prioritized what spending would be, so whatever it is that we are lacking, I think that we could trace it back to the fact that there are things that we are unable to say no to that should have less priority than, for example, the successful completion of this space station mission, this project that we endeavored to move forward on 20 years ago.

ADDITIONS TO THE ISS

We heard about today microscopic imaging and storage would be two things that would be added that would help us be, utilize this great asset to a way that we could actually achieve more.

Are there any thoughts of what it would cost to provide that to the Station?

Mr. GERSTENMAIER. We have a micro, we have a minus 80 degree freezer that is currently on-board Space Station that can provide I believe the cold storage. We need to talk to Dr. Nickerson and understand exactly what her needs are.

We also have some small centrifuges, not large, but small, that may provide some other information that she could use. So we have some dialogue I think we need to have with her and her needs to see what is already available. They may not be our equipment. They may be European equipment or maybe Japanese equipment that we have access to. We need to work with the Committee to make sure we understand what their needs are and see what is available.

Mr. ROHRABACHER. And indeed, if these things will, if there are additions to the Space Station, that will have great value as we heard from Mr. Pickens today. There is a great value to be achieved from what we have constructed. Now, if by adding a couple million dollars of a piece of equipment here or there to achieve billions of dollars worth of return, it would seem to me that we need to codify that and to go down and understand it and perhaps even the private sector might be interested in investing a $10 million piece of equipment or something like that that cost a certain amount to put it on the Station. If there is going to be a return from the private sector, maybe these private sector entities might even be willing to invest in that.

We should be thinking creatively out of the box and especially we should be thinking about how we can work with the Russians.

Oh, we have another round of questions, so that is, but we should be thinking of a way we could work with the Russians constructively.

Mr. Chairman, I will be visiting Russia at the end of May, and I am meeting with their space people, also meeting with the space people in Berlin, and any type of guidance that NASA would like to throw in my direction as to what we can do to try to further the cooperative spirit that would be mutually beneficial, I am open to suggestions.

So thank you very much.

Chairman UDALL. I thank the gentleman. I would note that we have about 10 minutes left. We have to vacate the hearing room around 12:30 to prepare for another hearing at 1:00. That will leave us 10 minutes of a round of questions from the Chair and from the Ranking Member if he so desires.

Let me turn—so the Chair does recognize himself for five minutes.

INKSNA AMENDMENT

Let me go back to what Chairman Hall mentioned. Mr. Gerstenmaier, NASA's amendment would remain in effect until the end of the International Space Station's life. What would be the impact if a shorter time period were written into the statute, for example, January, 2016?

Mr. GERSTENMAIER. We have two aspects we need. We need the crew transportation, and we need that until either a commercial capability comes on line or our CRV comes on line, and we could no longer need that exception after those vehicles are available.

For other small things such as docking mechanisms, some of our toilet activities, those kind of things that we purchased from the Russians, we need some small sustaining stuff. We do some small engineering studies with the Russians. Those kind of activities need to be around for the life of Space Station.

So they are small. They are very low-dollar value, but there are some engineering analysis, studies sustaining engineering kind of thing that need to be there throughout the life of Station. So we have tried to structure our language such that it meets those two requirements. It ends when we no longer need the capability, but the exception continues for those other small items that are needed for the life of Station.

Chairman UDALL. I need to pursue this line of questioning further. The proposed amendment would exclude from the exception any payments for crew transportation or rescue services provided by Soyuz vehicle once, number one, the U.S. Orion crew exploration vehicle reaches full operational capability, or a U.S. commercial provider of crew transportation rescue service demonstrates the capability to meet ISS requirements.

When do you envision full operational capability for the CEV vehicle?

Mr. GERSTENMAIER. I think our current planning shows it being in 2016, or so. The first flights are in 2015, and then about one year of other things until we get to full operational capability. I know that is at the end of the Space Station life, but we would see how that comes about.

We are looking at some things to see if there is some things that we can do to advance. We have some internal schedules that are looking—we will see how that plays out. And commercial, it is really probably better asked to the commercial sector what they think their schedules are for this.

Chairman UDALL. Regarding the possibility of U.S. commercial crew transportation and rescue services, what specifically would those providers need to demonstrate to meet the provision? I know you have spoken to that, but I want to make sure we are as clear as possible for the record.

Mr. GERSTENMAIER. Again, I think the recent Soyuz experience has shown us how difficult this environment is we are flying in. This return was, you know, the Shuttle, the Soyuz vehicle has been around for 30 years or so. This is a tough environment going from 17,000 miles an hour down to zero landing on the Earth. And it is not trivial. They need to show us that there is robustness in their systems designed to take and accomplish that re-entry, that it is safe to return. They need to show us that they can stay docked on-board Space Station for a six-month period, and then perform that re-entry exercise.

So there is many engineering assessments and evaluations that we need to see, as we would for our own vehicle to make sure that the vehicle is really viable in performing the design it wants, and it can safely transport our crew to and from Station.

Chairman UDALL. Amendment would also allow NASA to obtain ancillary goods and services from Russia in addition to crew transport and rescue. Just how important is it for NASA to be able to purchase unique tools from Russia, and would the safe operation of the Station be in jeopardy if those services were not available?

Mr. GERSTENMAIER. Those services are extremely important to us or are mandatory for us. There are in a whole variety of areas. We use an air-safe pump that actually pumps down the atmosphere of our air lock to go do space walks. That is a Russian-provided pump. We need to keep that up and operating so we can continue to use the air lock to go out and do space walks.

So and there is a variety of components I can give you that are small but are Russian provided that need to be there for the life of the Station. So I would say that that is critical to the long-term viability of Space Station.

Chairman UDALL. NASA has indicated that relief through the life of the ISS may be necessary even after a U.S. commercial capability is available because some potential providers have Russian contractors, Russian-supplied hardware, or other relationships with the Russian entities that could trigger INKSA's extraordinary payment prohibition.

Would you provide any specifics?

Mr. GERSTENMAIER. Some of the potential bidders for the commercial re-supply services, they use Russian components, they use Russian engines, and they would, I think be subject to the INKSA legislation, so they are going to need relief in that same manner. So some of these things, even Atlas V uses an RD–180 engine underneath it. If that becomes one of the options for the commercial re-supply that gets bid back to us in this request for proposal, then that would potentially fall under this INKSA restriction, and they would require relief as well.

SOYUZ LANDING PROBLEMS

Chairman UDALL. I have completed this line of questions. I would, I just have a few second. I wanted to, kind of a personal interest. You talked about the Soyuz landing 400 kilometers short of the designated landing area. This is on the plains of Cossack, the high steppes. I couldn't help but think about Colorado. If you landed 400 miles, 400 kilometers short of the landing zone, you have 1,400 foot peaks on the western side of Colorado, about 400 kilometers from where I think you would try and land. That could cause an additional problem, but in the high steppes you have a lot of open terrain I assume.

Could you identify the situation for me a bit more?

Mr. GERSTENMAIER. There is a lot of land that is open.

Chairman UDALL. And I know you were just there, so you can speak from personal experience.

Mr. GERSTENMAIER. It is not nearly as pretty as the mountains of Colorado, but it is nice for landing. It is nice and flat, and there is not much out there. I think there is one power line. They did land near some farmers that were burning some grass off the steppes, which added a little more interest.

Chairman UDALL. Yes. The story was the astronaut team opened the hatch, peered out, and immediately closed the hatch again as this fire moved toward them. Is that right?

Mr. GERSTENMAIER. That is true. They saw the burning, and we are still not sure exactly what caused the burning. The parachute itself was consumed. It appears that it blew down into an area where the grass had been previously burned, and the parachute caught on fire. The crew saw the fire, closed the hatch, waited until the fire extinguished itself, and then opened the hatch. And by that time the Cossack farmers in the area were there to help the crew and assist them——

Chairman UDALL. Thank you for that——

Mr. GERSTENMAIER.—exiting the spacecraft.

Chairman UDALL.—narrative. We have about five minutes left. I want to recognize the Ranking Member for five minutes to wrap things up from his point of view, and then we will conclude the hearing.

Mr. HALL. Thank you, sir, and I will take the five minutes. I just want to compliment this group here. Thank you very much.

You know, I have counted one, two, three, four, five, six, seven, eight, nine past Chairman of this committee, and I have worked with seven of them. I think the one I didn't work with was Olin Tiger Teague, who first started really the NASA thrust. And my kids think I was here with Overton Brooks, but I wasn't here in the teens.

But I want to recognize Mr. Gerstenmaier. You have carried out the book on you. You are the best doggone NASA program manager we have ever had, and I want to thank you and thank for your, for the gifts of all three of you and the other members.

I yield back my time. Thank you, sir.

Chairman UDALL. I thank the Ranking Member.

The previous panel, Judge Hall talked about longevity of the human lifespan and the health challenges we face, but I think they ought to put you in the program to find out why you are so robust and so engaged and so energetic. We may not need to know more from outer space if we can study you.

Mr. HALL. You know, if the dean of the United States House of Representatives is the oldest, I am the dean.

Chairman UDALL. You are the dean in my book.

Mr. HALL. And I run three miles every morning, do about 50 situps, and I can outwork any of the rest of those guys over there.

Chairman UDALL. I should probably leave it there. I think Judge Hall, though, probably meets the requirement. My father-in-law lived to be 90, and I asked him for his secret. He used to like to drink a little wine, eat a little chocolate, but he got up every morning and walked two or three miles and worked out, and he said, my secret is everything in moderation, including moderation, and I think maybe that fits what I know of Judge Hall.

Again, on a less serious note, I want to thank all the witnesses for being here today. This is very, very important testimony, helpful to the Committee as we move forward.

If there is no objection, the record will remain open for additional statements from the Members and for answers to any follow-up questions the Subcommittee may ask of the witnesses.

Without objection, so ordered.

In addition, I would also like to include a statement for the record that the American Society for Gravitational and Space Biology is submitting for today's hearing. Without objection, so ordered.

This hearing is now adjourned.

[Whereupon, at 12:30 p.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Edward B. Knipling, Administrator, Agricultural Research Service, U.S. Department of Agriculture

Questions submitted by Chairman Mark Udall

Q1. What do you see as the most significant challenges with respect to the Department of Agriculture's involvement in the ISS National Laboratory and how should those challenges be addressed?

A1. The two major challenges to USDA's participation in research on the ISS are funding and relevancy. Although the program is designed to provide free access to the ISS, considerable funds must be expended by the USDA to develop the experiment intellectually and physically. Technical expertise for working in microgravity would have to be developed by USDA scientists. This work is not currently programmed; therefore, any additional funds would have to be obtained from other programs or industrial partners. Relevancy of many possible experiments is difficult to assess because of the unfamiliar potential of work in microgravity.

Q2. How can the use of the ISS National Laboratory help improve American agriculture?

- *Is the research that USDA intends to conduct on the ISS at the level of basic research, applied research or both?*
- *What type of outcome would the USDA require in order to characterize its ISS utilization as successful?*

A2. The level of work discussed by USDA is at both basic and applied levels. Successful ISS utilization would ultimately be characterized by USDA as having solved a problem for American agriculture. Interim success would be characterized by USDA as having developed new scientific knowledge that demonstrates significant promise for solving a problem of American agriculture.

Q3. How significant is the need to be able to return cargo from the Space Station—for example, research samples or lab equipment—for the type of research initiatives you expect to pursue on the ISS? What are the implications if this return cargo capability is not available?

A3. Some experiments would benefit from the return of cargo to the Earth. For example, one hypothesis proposes that cells induced to grow into a functioning organ in microgravity would transform to cells capable of doing the same at Earth gravity. Returning the cells to Earth would be the only way of evaluation. On the other hand, behavioral tests of insects or documentation of plant growth would not require the return of any material to Earth.

Q4. There has been no commitment by the current Administration as to how long the U.S. will participate in the International Space Station program, although the Administration's budget plan for NASA would end funding for the program after 2016. On the other hand, NASA has indicated in previous testimony that it sees no technical or operational barriers to continuing ISS operations until 2020. What service life do you think would be optimal or required for the types of research activities that you envision the Station being utilized for?

A4. The longer service life of the ISS (until 2020) would be better for agricultural research. Very little agricultural research has been done in microgravity, therefore more study will be required to move from elementary to advanced studies.

Q5. Dr. Stodieck indicated in his prepared statement that three actions are required for the ISS National Laboratory to be successful:

1) creation of an independent management organization;

2) provision of modest funding to support utilization; and

3) assurance of reliable and frequent transportation to and from the ISS.

- *Do you agree that these are required actions necessary to ensure the Laboratory's success?*
- *If not, could you please discuss the priority steps that you believe need to be taken?*
- *What, in your view, would be an effective mechanism for coordinating and managing the use of the ISS National Laboratory?*

A5. The creation of an independent management organization might be useful to promote the best research on the ISS; however, other organizational models (e.g., a department within NASA) would probably also function well. ARS generally does not have sufficient unobligated funding to pay for the development of experiments for the ISS, and thus provisions for funding augmentation to support ISS utilization would be helpful. Those experiments will require payload costs ($20K per kilogram) and engineering costs to develop automated, self-contained experimental systems (likely at least $200K per experiment). Regular and frequent transportation to the ISS would be necessary for continuous experiments, but not for the single-use experiments discussed so far.

The priority steps for developing agricultural experiments on the ISS are:

1) Define the technical parameters of work on the ISS; specifically, the space available, the potential time frames of experiments, and the possibility of manual participation by astronauts.
2) Identify experiments and strategic research directions that are considered mutually valuable.
3) Find funding for priority experiments.
4) Integrate the experiments into the program requirements of ARS.

The ARS portion of research on the ISS could be effectively managed by a committee formed from ARS National Program Staff with representatives from NASA.

Questions submitted by Representative Tom Feeney

Q1. During the upcoming five-year gap, it appears there will be no—or very limited—ability to bring back research samples, experiments, and other materials from station. What are your thoughts about the usefulness of ISS as a laboratory if there is no down-mass capability? Will the inability to return research samples to Earth seriously jeopardize the attractiveness of using ISS to carry out research? What steps can research take to compensate?

A1. The lack of a down-mass capability will not inhibit many kinds of experiments that are more oriented toward basic science rather than product development. Experiments that gather data in place and that do not involve returning samples to Earth could have good relevance.

Q2. Several witnesses recommended. that NASA identify an organization to manage research conducted on ISS. How does NASA manage ISS research today, and how would a newly established research management organization differ from the current model?

A2. ARS is unable to answer this question, since it concerns NASA management. From an ARS perspective, the current National Program Staff would be the logical administrative mechanism for coordinating research.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Louis S. Stodieck, Director, BioServe Space Technologies; Associate Research Professor, Aerospace Engineering Sciences, University of Colorado at Boulder

Questions submitted by Chairman Mark Udall

Q1. Your prepared statement notes that the success of the ISS National Laboratory will require "regular, reliable and frequent transportation access to and from the ISS."

Q1a. What level of frequency and reliability in access to the ISS do you anticipate will be needed and why?

A1a. As the ISS is nearing completion, it is important to consider how to utilize this world-class facility in ways analogous to that of ground-based facilities. On the ground, research investigations can be designed, carried out and data analyses completed with a comparatively short turnaround. This allows results from each investigation to be fully incorporated into the next so that progress to a final result or product can occur within a reasonable timeframe. It also allows for investigation failures to occur, whether due to human error, flawed experiment designs, equipment problems and so forth, such that an investigation can be promptly repeated. To be most productive, transport of research equipment, supplies and samples to the ISS should occur at a minimum frequency of four times per year. A greater frequency would be even better.

In the biotechnology, pharmaceutical and biomedical fields, the ability to analyze samples on board the ISS remains very limited. As such, return of materials processed on orbit will be essential for the foreseeable future. Ideally, the frequency and quantity of transportation return from the ISS (down-mass) should be 75–90 percent of the transportation to the ISS (up-mass).

It is also important to try and provide a certain degree of reliability in transportation access capabilities. Reliable transportation refers to a number of important aspects including reliably meeting a launch schedule (launching on time), reliably delivering utilization cargo to the ISS (successful rendezvous and docking) and reliably returning materials to Earth. Ideally, reliable transportation should include late stowage and early retrieval access for time sensitive biological materials. Finally, the process for approving samples and equipment for transport to the ISS should be streamlined so that the transportation manifest can be kept flexible as late in the timeline as possible. This will accommodate late-breaking research results and optimized equipment and samples. In essence, the reliability goals and services for transportation access to and from the ISS should be viewed in a similar manner to commercial carriers such as Federal Express and the UPS.

Q1b. What are the implications if this return cargo capability is not available?

A1b. Productivity on the ISS will be highly dependent on the frequency, range of services and reliability of available space transportation carriers. Without return capability, research studies will be limited to those that produce electronic data on the ISS that can be down-linked to investigators on the ground.

To give an example in the life sciences, modern sample analysis methods have become substantially based upon molecular analyses of messenger ribonucleic acid or mRNA expression. So called gene expression data or closely aligned protein analysis data have become a mainstay of modern biology. In theory, these data could be generated on board the ISS. However, to do so, samples must be processed using hazardous chemicals, multiple fluid addition and removal steps, centrifugation and heating and cooling steps to produce the final preparation that can then be analyzed. The analysis might be done using a spectrophotometer, plate reader, gene chip reader or another piece of similar equipment. Because of the use of hazardous chemicals, all steps must be done with redundant levels of containment in place to protect the crew member carrying out the process. Crew members will require extensive training on the sample processing and analysis protocols or will need to be trained life scientists. Some work has been done by NASA to develop automated methods for relatively simple molecular analyses in space but these technologies are still too limited to be of much value for a productive ISS laboratory. Without a significant investment in new sample processing hardware, the complexity of these analyses will dictate that the samples are processed on the ground by highly trained personnel.

Conducting modern biotechnology and biomedical research and development on the ISS will be severely hampered without a sample return capability. If sample return after the retirement of the Shuttle is limited to the small down-mass capability of the Russian Soyuz vehicles, then the ISS will be unable to meet any significant commercial or academic R&D demand. The return sample requirements of NASA's exploration program alone will almost certainly exceed the Soyuz transportation capability. This will create a severe bottleneck for research and discourage potential users whether they are researchers from industry, universities, the NIH, the USDA or any other government agency. Effectively, the productivity of the ISS National Laboratory will be reduced to a fraction of what otherwise would be possible.

In addition to trying to minimize this risk by fostering the development of commercial transportation capabilities, NASA could do more to support the development of flight certified equipment that could enable on orbit modern analytical methods.

Q1c. Could you please elaborate on how you arrived at 20–25 percent as a potential figure for volume on ISS supply missions that is devoted to National Laboratory work?

A1c. Research investigations, samples and equipment are currently typically housed within mid-deck lockers on the Space Shuttle. Experiments are either stowed within a NASA—provided locker or the locker can be removed and replaced with a customer—provide payload. A mid-deck locker "package" is often referred to as a mid-deck locker equivalent or MLE. Each MLE can weigh or carry up to 32 kg in total mass. Based on the history of the Space Shuttle program during the 1990's when it was used extensively for research and not being used to assemble the ISS, flight of research equipment and materials exceeded 50 to 75 MLEs per year. This range of transportation need would enable productive use of the ISS National Lab and would equate to 1.6–2.4 metric tons (MT) of research utilization supplies and equipment per year.

NASA recently released a Request for Proposals for ISS Commercial Resupply Services (CRS). Within this solicitation, NASA included a model task order that estimated the requirement for pressurized cargo delivery to the ISS of 7.4 MT per year. Assuming that this figure does not include ISS National Lab requirements, the estimate for ISS National Lab users would need to be added to NASA's logistics and exploration research requirements. This equates to a range of 18–25 percent of the total ISS transportation requirements. Again, to be most effective as a National Lab, delivery should be distributed across a minimum of four to five flights per year.

Q2. There has been no commitment by the current Administration as to how long the U.S. will participate in the International Space Station program, although the Administration's budget plan for NASA would end funding for the program after 2016. On the other hand, NASA has indicated in previous testimony that it sees no technical or operation barriers to continuing ISS operation to 2020.

- *What service life do you think would be optimal or required for the types of research activities that you envision the Station being utilized for?*

A2. The answer to this question depends on a number of key assumptions:

- Transportation of research to and from the ISS will not be overly constrained after the Space Shuttle is retired.
- Demand from multiple end users (commercial, government and academic) will grow as the ISS assembly is completed and the benefits of conducting research in space are clearly recognized.
- Resources, including funding, to support productive use of the ISS will be available.
- No major technical or operational problems will occur to prevent continued use of the ISS.
- A six-member crew will be available to support a robust research and development utilization program on the ISS.

Based on these assumptions, then a 10-year operational life for the ISS after the assembly is complete should produce a high yield of products, technologies and scientific data. This would suggest that utilizing the ISS through 2020 would be appropriate. By 2020, the development of commercially viable alternatives to the ISS for space-based R&D could reasonably be expected to be available. If so, and if the continued cost of maintaining and operating the ISS are high, then ending the ISS Program would seem appropriate. Of course, the ISS lifetime can be evaluated on an ongoing basis and adjusted as necessary.

If one or more of the assumptions listed above do not come to fruition, then productivity of the ISS will be limited and the return on investment to the Nation will be reduced. In this case, consideration should be given to an operational lifetime beyond the 2020 timeframe.

Q3. Given your experience as director of a research center that deals with universities, federal agencies, and industry in conducting space life sciences research, what factors do you believe are essential for the management of the ISS National Laboratory? What should NASA consider as it explores options for managing the ISS National Lab?

A3. A key responsibility for the management organization will be to form partnerships and agreements with commercial, academic and government agency organizations that wish to access the ISS National Lab. A number of additional key responsibilities for the ISS National Lab management organization were outlined in written testimony. In brief, these additional responsibilities include:

- Performing outreach across multiple disciplines and multiple organizations to educate scientists and managers on the benefits of conducting research and development in space.
- Working to seamlessly integrate and fly research as a turn-key process so the researchers can focus on the research and not on the processes to get their research flown on board the ISS.
- Working closely with the ISS Payloads Office to streamline the process of integrating and certifying research for flight.
- Maintaining a database with key specifications for all available space flight research hardware that might be used on the ISS.
- Assisting NASA to archive results from work performed on the ISS and effectively communicating these results to the public.

To carry out these responsibilities, the ISS National Lab management organization would need to have a number of technical discipline experts who understand the type of research that can be done on the ISS, the processes that must be followed for the research to be successfully executed on orbit and the capabilities (and limitations) that exist in available flight hardware. In other words, this organization will need to consist of scientists and engineers working side by side to support the many university, government and commercial end users of the ISS. Thus, the most critical factor for success of an effective management organization will be in developing an organization consisting of scientists, engineers and managers with space flight research expertise.

Currently, NASA has formed an ISS National Lab management office within the Space Operations Mission Directorate. This organization is effectively developing partnerships across the various academic, government and industry sectors. However, more could be done to grow the demand for ISS utilization and to support those organizations that are interested but do not know how to conduct research on the ISS. NASA should consider growing this organization within the agency or partner with outside organizations to assume more of the responsibilities and expertise described above.

Questions submitted by Representative Tom Feeney

Q1. During the upcoming five-year gap, it appears there will be no—or very limited—ability to bring back research samples, experiments, and other materials from station. What are your thoughts about the usefulness of ISS as a laboratory if there is no down-mass capability? Will the inability to return research samples to Earth seriously jeopardize the attractiveness of using ISS to carry out research? What steps can researchers take to compensate?

A1. These questions have largely been addressed above. Indeed, having limited ability to return samples to Earth during the gap period will seriously jeopardize the ISS National Lab concept. Commercial users will be unable to pursue any reasonable business development activities. Non-NASA academic or government scientists will be unable to have any reasonable level of scientific productivity and will be discouraged from even trying to use this national asset.

As mentioned above, if modern analytical techniques could be employed on the ISS, then data could be produced and down-linked to researchers on the ground. For this to work, investment by NASA and/or other agencies would be needed now so the required equipment could be developed and pressed into operation on the ISS. The protocols and equipment required to prepare and analyze samples on orbit would not be easily obtained but could be an effective alternative to inadequate sample return capacity.

Q2. Several witnesses recommended that NASA identify an organization to manage research conducted on ISS. How does NASA manage ISS research today, and how would a newly established research management organization differ from the current model?

A2. As indicated above, NASA has formed an office within the Space Operations Mission Directorate that is focused on developing the ISS National Lab. This NASA office currently is working on identifying and forming agreements with prospective ISS National Lab end-users including those from industry, non-NASA government agencies and academic institutions. The goal of this office is to provide access to the ISS for research and development once the assembly of the station is complete. To date, NASA has Memoranda of Understanding and Space Act Agreements with a number of government agencies and companies and with our university.

The ISS National Lab Management office at NASA Headquarters works closely with the ISS Payloads Office at NASA–Johnson Space Center. The JSC Payloads Office supports all NASA and non-NASA users of the ISS by prioritizing payloads, manifesting Shuttle transportation and integrating payload hardware and operations requirements across all NASA and non-NASA payloads. The Chief Scientist of the Payloads Office also supports scientific and public outreach.

These NASA offices work well together and do an excellent job of supporting the full range of science being conducted on the ISS. However, these offices are limited in their ability to market the unique and outstanding R&D potential that the ISS represents. With the completion of the ISS only two years away, NASA must continue to develop a broad ISS user community that can take advantage of what the ISS has to offer.

It is important to remember that a large research user community had been developed by NASA through the former Office of Biological and Physical Research. This office and the community that it supported was vastly reduced and reorganized under the current Exploration Systems Mission Directorate. As a result, the non-exploration user community of the ISS National Lab now has to be effectively reformed from sponsors outside of NASA. The potential certainly exists for the NIH, USDA, DOD, DOE, ED, NSF, universities, colleges, foundations and various industry sectors to benefit through R&D conducted on the ISS. Many of these organizations have already recognized this potential and have formed or are in the process of forming agreements with NASA to utilize the ISS. The ISS National Lab user community should be re-established through the sponsorship of these many organizations.

As the demand for the ISS grows, one of the most critical issues in supporting a robust and productive set of R&D activities on the ISS will be funding. The organizations that are interested in benefiting from the ISS should not have to redirect funds from other high-priority, ground-based research programs. Rather, new funds should be made available to support the translation of high-potential R&D to the ISS National Laboratory operating in orbit. This point cannot be overly stressed. The demand is now growing and should be grown even further. Congress should make strategic investments through NASA and the non-NASA agency sponsors of the envisioned ISS R&D.

By expanding the ISS National Lab office at NASA and/or through the development of appropriate partnerships, an ISS National Lab management organization could assume some of the additional responsibilities described above that are not currently being supported by any NASA office. As an example, our center continues to provide support for scientists who are conducting space-based research so that they can focus on their research and not on learning how to develop, flight qualify, integrate and operate a payload or experiment on the ISS. While our center is happy to provide this level of service to enable flight research, this set of services will need to be expanded if the ISS is to become even more productive after the assembly is complete. It will probably be inefficient for the NIH or the USDA or a commercial user to develop such in-house expertise. Establishing an organization that can support both science and engineering aspects of a broad space research program would help assure ultimate success of the ISS National Lab.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Cheryl A. Nickerson, Associate Professor of Life Sciences, School of Life Sciences, Center for Infectious Diseases and Vaccinology, The Biodesign Institute, Arizona State University

Questions submitted by Chairman Mark Udall

Q1. Up until now, your experiment return needs have been met by the Shuttle. With the retirement of the Shuttle in 2010, this will no longer be available to you. How significant is the need to be able to return cargo from the International Space Station—for example, research samples of lab equipment—for the type of research initiative you expect to pursue on the ISS? What are the implications if this return cargo capability is not available?

A1. The loss of down-mass resulting from the retirement of the Shuttle will have a dramatic impact on the types of analyses performed and the information gathered from ISS scientific research. Ground based analysis of samples has historically allowed more thorough analyses and "real time" changes in procedures to optimize and maximize research findings. Loss of down-mass will especially affect research that requires equipment which cannot be easily miniaturized or multiple pieces of equipment to fully evaluate the sample. While not preventable, scientific losses can be mitigated, in part, by the provision of flight hardware that can be utilized by multiple investigators. Examples include laboratory basics, such as centrifuges and specialized microscopes that would prevent the need for repetitive up-mass for individual experiments. In addition, the development of specialized hardware for flight, such as miniaturized molecular genetic analysis equipment, will allow experimental samples to be analyzed during flight by the crew.

Q2. There has been no commitment by the current Administration as to how long the U.S. will participate in the International Space Station program, although the Administration's budget plan for NASA would end funding for the program after 2016. On the other hand, NASA has indicated in previous testimony that it sees no technical or operational barriers to continuing ISS operations until 2020. What service life do you think would be optimal or required for the types of research activities that you envision the Station being utilized for?

A2. The International Space Station is a unique facility that will likely not be reproduced in our lifetimes. Accordingly, every effort should be made to extend the life and scientific use of this *one-of-a-kind* laboratory as long as possible. The field of microgravity research has only begun to be investigated and holds enormous potential for ground-breaking biotechnology and biomedical innovations and discoveries to globally advance human health. ISS will be a critical platform for research (exploration and non-exploration) as long as it remains operational.

Q3. Dr. Stodieck indicated in his prepared statement that three actions are required for the ISS National Laboratory to be successful:

1) *creation of an independent management organization*
2) *provision of modest funding to support utilization*
3) *assurance of reliable and frequent transportation to and from the ISS*

Q3a. Do you agree that these are required actions necessary to ensure the Laboratory's success?

A3a. I believe that key modifications are needed to the actions proposed by Dr. Stodieck.

Q3b. If not, could you please discuss the priority steps that you believe need to be taken?

A3b. Dr. Stodieck's proposal for the creation of an independent management organization for the ISS National Laboratory would appear at first glance to be beneficial; however, the development and operation of such a board is not a trivial matter. Many complex issues would have to be addressed by such an organization in a clear, concise and non-biased manner for such an approach to be even marginally effective. For example, how would they "integrate" with NASA, the European Space Agency, etc.? How would this board interact with and coordinate interdisciplinary research between multiple scientists—or between commercial investors/investigators? How would intellectual property and conflict of interest issues be handled? Who determines the merit of the research to fly and when it will be manifested on ISS? What are the research priorities? Both Exploration (mission applied) and non-Exploration (non-mission/terrestrial-driven) research goals should be funded—how does the board make these decisions? What is the composition of the proposed management organization—NASA, other Federal Government agencies, academic, commercial? Regardless, this board would still have to interact closely with NASA flight operations, so the establishment of another level of complexity in the scientific process is not inherently an improvement over the current paradigm. Alternatively, could the current NASA management paradigm be modified to be more effective in operation—thus precluding the need for another complicated and perhaps detrimental level of management.

Dr. Stodieck's second recommendation was for modest funding to support ISS utilization. This language is of serious concern to me, as "modest" funding levels do not work well for robust life sciences research programs on Earth, much less for flight experiments. While this type of language may appear more palatable, the correct phrase is "appropriate funding." You get what you pay for—and hypothesis-driven, innovative, cutting edge research requires investment. The goal is not to fly something simply to say that it has flown in space, but rather, to use the novel enabling research platform of space flight to translationally advance our understanding of biological and physical phenomenon that will provide long lasting return to the protection of humans as they explore space and for the general public here on Earth. Accordingly, experimental requirements and applications for space research should be clear and the funding adequate for successful completion. Running a space research program on a "shoestring budget" is not the way to conduct cutting edge science that is critical for exploration, nor is it the way to maintain US leadership in space exploration. Exploration drives science and science drives exploration—the two cannot be separated. Unfortunately, the currently adopted paradigm has negated the critical value of space research as an essential component of NASA. This has led to slashing the already minimal life support funding system for space research—and in so doing, has both decimated and alienated a large segment of the U.S. space life sciences research community and has seriously undermined the position of the U.S. as the world's leader in space exploration. Our nation's *Vision for Space Exploration* is dependent on the space life sciences community to generate knowledge leading to solutions to ensure safe passage for humans beyond Earth, to train the future workforce to maintain U.S. leadership in space exploration, and to translate findings from this work into human health benefits for the general public on Earth.

Q3c. What, in your view, would be an effective mechanism for coordinating and managing the use of the ISS National Laboratory?

A3c. NASA's current structure provides an acceptable mechanism for the operation of the ISS National Laboratory; however, several changes at NASA would benefit the science that can be performed. First, the direction of the fundamental science that is performed should be guided by long-term, well coordinated goals to benefit general science. NASA has previously assembled "blue ribbon" panels that have made recommendations regarding the vision, direction and priority of research goals, (including commissioned Decadal Studies by the National Academy of Sciences). However, NASA's commitment to these collective expert recommendations over time has been inconsistent. Thus, in order to provide meaningful vision, direction and continuity of research over time, a standing science advisory board with members representing NASA, other federal agencies (e.g., NIH, USDA, etc.), and academia should be established. This board would guide fundamental research (both mission and non-mission-oriented) and should not be confused with NASA's own research goals to benefit the exploration of space. For example, the development of countermeasures to protect crew health during flight would remain under the purview of NASA. Second, scientific collaboration and resource sharing should be facilitated with the international partners of the station. While other factors do govern the exchange of funding and intellectual property, NASA should be provided some exception to these constraints to fully utilize this unique resource. Finally, it is critical to stress that consistency in both access to the ISS and funding for research is key for any successful utilization of the ISS as a National Laboratory.

Questions submitted by Representative Tom Feeney

Q1. During the upcoming five-year gap, it appears there will be no—or very limited ability to bring back research samples, experiments, and other materials from station. What are your thoughts about the usefulness of ISS as a laboratory if there is no down-mass capability? Will the inability to return research samples to Earth seriously jeopardize the attractiveness of using ISS to carry out research? What steps can researchers take to compensate?

A1. Yes, lack of down-mass will limit use and jeopardize the usefulness of ISS as a laboratory. It will drive a need for improved and self sufficient analysis equipment and other resources needed to complete the work on orbit in the future (i.e., without the need to return payloads)—for example, microscope with greater imaging and functional capabilities, easy access to knowledge of available and functional hardware for research use (this is currently difficult information for researchers to obtain), molecular genetic tools, and available space. These self-sustaining in-flight research technologies will be critical to leave low-Earth orbit, when lack of resupply is a critical issue!

**Also, please see response to Question #1 from Chairman Udall above.*

Q2. Several witnesses recommended that NASA identify an organization to manage research conducted on ISS. How does NASA manage research today, and how would a news established research management organization differ from the current model?

*A2. * Please see response to Questions 3b and 3c from Chairman Udall above.*

ANSWERS TO POST-HEARING QUESTIONS

Responses by Thomas Boone Pickens, III, Chairman and Chief Executive Officer, SPACEHAB, Inc.

Questions submitted by Chairman Mark Udall

Q1. What do you see as the most significant challenges with respect to SPACEHAB's involvement in the ISS National Laboratory and how should those challenges be addressed?

A1. SPACEHAB's announcement of a Space Act Agreement with the National Aeronautics and Space Administration (NASA) for use of the International Space Station (ISS), for research, development and industrial processing purposes removed one of our most significant challenges. This agreement will provide SPACEHAB with flight opportunities on the Space Shuttle for the remaining assembly phase of the ISS, as well as appropriate on-orbit ISS resources during both the pre- and post-assembly phases. The largest remaining challenge for SPACEHAB is the uncertainty of flight opportunities to the ISS following the final Shuttle flight, currently scheduled for 2010.

Q2. How significant is the need to be able to return cargo from the Space Station—for example, research samples or lab equipment—for the type of commercial initiative you expect to pursue on the ISS? What are the implications if this return cargo capability is not available?

A2. The commercial initiatives we are pursuing, including vaccine development and protein crystal growth, require return cargo capability from the ISS National Laboratory. While research and development could occur on the ISS, the samples would need to be returned to Earth in order for this research to be commercially viable. If the return cargo capability is not available, it would change the direction of SPACEHAB's current commercial initiatives in space. Our research has indicated that most identified research and development would require return cargo capability.

Q3. What types of results would SPACEHAB and the broader investment community need to see in order to gain confidence in the use of ISS for commercial drug development or other initiatives? On what timescale would they need to see these results?

A3. SPACEHAB is already seeing results of microgravity research with our recent discovery of a salmonella vaccine target giving us a great deal of confidence for further research and development through the use of the ISS. Our successful flights prove that scientists can continue to rely upon the development of microgravity products on the ISS for years to come.

Q4. What are the implications for your business model if NASA decides not to operate the ISS past 2016?

A4. This would take away an incredibly valuable national resource that has already proven to save lives on earth with our salmonella vaccine discovery work however we have just begun and many more experiments need to be conducted. We reviewed over 2,000 experiments that have already been sent to microgravity and have chosen those that have showed the most commercial near-term value. We saw many experiments that had great promise but needed more work on-orbit before we could get comfortable with an acceptable level of risk/reward. Therefore, the longer the ISS is in service the more experiments will fly and the more commercially viable products will be discovered. It is simply a ratio between having access to microgravity and continuing to discover products that will enhance and save lives on earth. Having spent 15 years and over $100 billion on this unique environment, it seems a shame to have it fully operational for only five or six years when mankind could benefit from its service for many decades.

Q5. You discussed SPACEHAB's involvement in the Space Technology and Research Students (STARS) program. What do you believe has been the impact of the STARS program on STEM education?

A5. The STARS program gave students a heightened enthusiasm for STEM by giving them the opportunity for hands on participation in microgravity research. By utilizing the allure of space, STARS is able to attract students to STEM that might otherwise not show an interest in these areas.

Questions submitted by Representative Tom Feeney

Q1. During the upcoming five-year gap, it appears there will be no—or very limited—ability to bring back research samples, experiments, and other materials from station. What are your thoughts about the usefulness of ISS as a laboratory if there is no down-mass capability? Will the inability to return research samples to Earth seriously jeopardize the attractiveness of using ISS to carry out research? What steps can researchers take to compensate?

A1. See response to question two from Chairman Udall.

Q2. Several witnesses recommended that NASA identify an organization to manage research conducted on ISS. How does NASA manage ISS research today, and how would a newly established research management organization differ from the current model?

A2. Working with NASA to fly samples on the Shuttle is an add hock process that offers no assurances as to participating organizations and making it nearly impossible to convince the investment community that there is assured access to microgravity. While NASA has been very accommodating to date, there is a lack of confidence that we will make the next flight, even up to the final hours prior to liftoff. This makes it very difficult to attract and commit capital for the expensive preflight processing when all would be lost if we were told we would not be on the next flight due to cargo priorities.

It would therefore be very helpful if there was a policy that required NASA to fly both pre-commercial experiments and commercial samples to microgravity. Previous attempts to promote commercial uses of space by NASA have been largely unsuccessful as we feel the more people that are involved slows down and complicates a process that is already very understood and streamlined. Therefore, in response to the question, we would recommend only a change in the NASA policy to be mandated to send these payloads without exception but use the existing structure of selection and flight safety review as this seems to be appropriate at this time.

ANSWERS TO POST-HEARING QUESTIONS

Responses by William H. Gerstenmaier, Associate Administrator for Space Operations, National Aeronautics and Space Administration (NASA)

Questions submitted by Chairman Mark Udall

Q1. How much will NASA have spent in total developing, building, and operating the International Space Station when it is completed in 2010? Please provide the direct costs for development, operations and utilization, cargo and crew transport, Shuttle transportation costs, and other costs to NASA.

A1. The total direct cost of the International Space Station (ISS) from FY 1994 through assembly complete in FY 2010 is estimated to be $47.0B. This includes $14.0B for development, $16.0B for operations and utilization, $1.0B for cargo and crew transportation, $13.0B for Space Shuttle transportation costs, and $3.0B in other costs to NASA. These figures exclude costs for phases A, B, and C (i.e., the Freedom Program) and International Partner costs.

Q2. What, if any, mechanisms exist for ISS users to communicate their transportation requirements to potential and future ISS commercial cargo providers, or do you expect individual researchers to be working directly with commercial companies?

A2. International Space Station (ISS) user transportation requirements for both NASA users and non-NASA, National Laboratory users must first be integrated into a cohesive, time-phased delivery plan before being passed on to future ISS commercial cargo providers. This ensures that user payloads are scheduled for deployment and operation on the ISS during a period when payload resources and accommodations are actually available. The ISS Payloads Division within NASA's ISS Program Office collects all U.S. domestic user transportation requirements in order to accomplish this function. This is done through the formal ISS Payload Integration Agreement process. The ISS Program Office then integrates U.S. user payload transportation requirements with requirements for payload and system operations and maintenance from Canada, Europe, Japan, Russia and the U.S. The result is a time-phased cargo transportation plan that is optimized across the international mixed fleet of transportation vehicles, in order to both maintain the ISS system successfully and operate payloads productively within the user resource allocations specified in the international agreements. This function is accomplished through regular, periodic Technical Interchange Meetings across the ISS partnership.

Individual users may also work directly with commercial companies in order to ascertain possible future transportation costs and available physical accommodations during the transport phase. In the future, some portion of the available commercial transportation capacity may be set aside on commercial flights for the service provider to market directly to paying customers; however, user payloads bound for the ISS must first be assigned physical accommodations and operating resources before being manifested for flight. As this scenario evolves, it will be important that the ISS Program Office continues to work closely with the commercial service providers, so that all payloads arriving at the ISS can be physically integrated and productively operated.

Q3. How does NASA plan to validate vendors' claims that they can meet the Agency's ISS cargo requirements in a credible and safe manner?

A3. NASA released an ISS Commercial Resupply Services (CRS) Request for Proposals (RFP) on April 14, 2008, for resupply and return of ISS and utilization cargo. Proposals were due back to NASA at the end of June 2008, with an award expected at the end of calendar year 2008. The RFP identifies the specific criteria that NASA will utilize in evaluating industry proposals. The criteria that NASA will utilize includes evaluating such areas as: the offeror's capability to meet the statement of work based on the level of development maturity of those capabilities; the production and annual delivery capability, and processing lead times; how the offeror's schedule and planning for ISS integration will impact the delivery of services under this contract; the offeror's understanding of the risks of providing the ISS resupply services, completeness in identifying risks, and the appropriateness of their mitigation plans; and, the offeror's approach for safety (range, ground, flight, etc.), reliability, maintainability, supportability, quality, software assurance, and risk management for completeness and effectiveness at meeting the contract requirements.

Q4. What effect will the increase to a six-person crew on ISS have on crew time to support research and other utilization activities? Will the time available for research double?

A4. In the early 2009 timeframe, when the ISS is still operating with three crew, there will be approximately 40 crew-hours per week available, on annual average, to operate, maintain and utilize the U.S. Operating Segment (USOS). This assumes that 1.5 of the three crew members is working on the USOS, and that each astronaut works approximately 32.5 hours per week. This is equivalent to approximately 48.75 crew hours per week, and is reduced to approximately 40 crew-hours per week after joint Shuttle-Station assembly period operations are subtracted out. Also during this timeframe, 37-40 crew hours per week will be needed for USOS systems operations and maintenance. Under these circumstances, up to three crew-hours per week are estimated to be available for USOS utilization.

By late 2009, ISS crew complement will increase to six and, assuming three of the six astronauts are working on the USOS, will yield approximately 85 crew hours per week to operate, maintain and utilize the USOS. By this timeframe, the remaining assembly elements will have been integrated and it will then require approximately 65 crew-hours per week to operate and maintain the USOS, and there will be approximately 20 crew-hours per week available to utilize the USOS. The time available for research in the USOS increases from up to three hours per week (three crew) to 20 hours per week (six crew).

During the post-assembly period, the crew time capability for the USOS is estimated to further increase to approximately 100 hours per week because there is no longer the need for joint Shuttle-Station assembly operations, while the requirement to operate and maintain the USOS remains constant at 65 hours per week. At this stage, approximately 35 hours per week are projected to be available for USOS utilization.

The table below summarizes this evolution in USOS crew time capability, reflected in hours per week.

USOS Crew Time Margin for Utilization

	2009 3-crew	2009 6-crew	2010-2015
USOS Capability	40	85	100
USOS Housekeeping Demand	37 - 40	65	65
Margin for USOS Utilization	**0-3**	**20**	**35**

Q4a. How will crew time be allocated for ISS utilization activities?

A4a. Crew time will be allocated according to payload operating priorities as determined by the tactical level, multilateral Research Planning Working Group in accordance with strategic level NASA Headquarters policy direction and international Memorandum of Understanding provisions.

Q4b. Do ISS crews need to be trained in advance to support research and other utilization activities occurring through the National Laboratory? If so, how much lead time is required for this crew preparation and when would NASA need to know what research would be flown?

A4b. Yes, virtually all utilization activities require some level of crew familiarization and training. These requirements vary widely depending on payload complexity. Nominally, a two-year planning horizon is desired so that specific utilization activities can be identified in the Increment Definition and Requirements Document; however, the Space Station Program is currently integrating relatively small (e.g., mid-deck locker scale) experiments within six months of launch, particularly when re-flights of flight-certified apparatus are involved. Future utilization demand appears to be evolving largely in the direction of the life sciences and biotechnologies where experiments are being planned at the cellular and molecular levels. In these cases, locker-scales are common and integration is relatively straightforward.

Q5. Regarding cargo transport to the ISS, your testimony notes that "The ISS Program continues to evaluate the up mass requirements and spares procurement strategy to sustain nominal system and research operations."

Q5a. When does NASA anticipate being able to provide firm up mass requirements to potential commercial providers?

A5a. NASA issued a Commercial Resupply Services Request for Proposals in mid-April of this year, and proposals were due by the end of June. Following proposal evaluation, NASA plans to enter into firm fixed-price contracts for commercial transportation services by the end of calendar year 2008. These contracts will specify up-mass requirements.

Q5b. Will those requirements include down-mass?

A5b. The contracts will also include down-mass requirements for those service providers that can deliver the capability.

Q5c. How much additional up-mass and down-mass would be included in NASA's requirements to support ISS National Lab users?

A5c. The specific transportation requirements for National Laboratory users have not yet been defined in detail because the U.S. Government agencies and private firms that have entered into agreements with NASA to use the ISS are just beginning to plan their respective research programs. NASA has estimated that a throughput capacity of as much as three metric tons per year could be available on the International Space Station to support National Laboratory users.

Q5d. When do potential commercial cargo suppliers need to know the full breadth of cargo requirements in order to assess the potential market and respond accordingly?

A5d. Commercial cargo suppliers have been informed of the full breadth of cargo requirements throughout the Request for Information and Request for Proposals processes over the last several years. The International Space Station cargo requirements have been well-defined and stable, and are highly representative of future needs.

Q6. What is NASA's timeline for determining a management structure for the ISS National Lab?

A6. As outlined in the report NASA submitted to Congress in April 2007 regarding International Space Station (ISS) National Laboratory Applications Development, the strategy to first identify credible and qualified end-users was emphasized. Since that report, NASA has entered into separate Memorandum of Understanding with the National Institutes of Health and the U.S. Department of Agriculture's Agricultural Research Service. In addition, two Space Act Agreements (SAAs) with private firms and one with a state university have been signed, while additional SAAs remain under development. Finally, a self-organizing Biotechnology Space Research Alliance has been formed in southern California that consists of university, industry and municipal government partners. As a result of these developments, NASA is well along in the process of identifying credible and qualified end-users.

In FY 2010, efforts will turn to: (1) defining the respective research programs for each of the new partners and translating their strategic research objectives into an executable portfolio of specific payload plans with detailed specification of requirements for ISS resources and accommodations; and, (2) working with the new partners to determine the most effective and appropriate management structure(s) for the post-2010 real-time operations timeframe. In this latter activity, the ISS Program's Payload Office will perform a central role in physical, analytical and operations integration, while NASA's Space Operations Mission Directorate continues to manage policy aspects of ISS National Laboratory operations in concert with direction from the Executive and Legislative branches. Decisions regarding ISS operations post 2016 will be made by future Administrations and Congresses.

Q7. Section 2006 of the America COMPETES Act *directs NASA to* "develop a detailed plan for implementation of I or more education projects that utilize the resources offered by the International Space Station." *What is the status of NASA's work on developing this plan?*

A7. Working with the established interagency ISS National Laboratory Education Concept Development Task Force, NASA has completed a plan in response to the provisions of Section 2006 of the *America COMPETES Act* (P.L.110–69) and a report outlining the plan was submitted to Congress on June 20, 2008. The report identifies a series of specific education projects conceived by the cooperating agencies that could be conducted using the International Space Station.

Q8. The America COMPETES Act *also directs NASA to develop a plan for ISS research that will serve to increase U.S. science, technology, and engineering com-*

petitiveness and to consult with organizations that have agreements to use the ISS National Lab in developing the plan. What is the status of this planning effort?

A8. NASA has brought this provision of the *America COMPETES Act* (P.L. 110–69) to the attention of each of the new ISS National Laboratory partners. In each case, we expect these partners to develop specific research and development (R&D) plans in the coming year that can be made available to the Congress in direct response to the Act. For instance, NASA is currently cooperating with the National Institutes of Health (NIH) on development of a Funding Opportunity Announcement to be issued by NIH by the end of FY 2008. The response to this announcement and the proposals selected by NIH will represent their initial R&D plan for the ISS. It is important to note that these plans may be constrained by the availability of appropriated funds at each partner Agency.

Q9. I understand that you have recently met with the Russian company making the Soyuz.

Q9a. Do you have any insight into their quality control processes?

A9a. The Soyuz has long track record of success. NASA's insight into their quality control process is part of the reporting in the contract and is handled through regular contract progress reviews and anomaly reporting. Additionally, the Russians have been responsive to specific requests for information concerning the April 2008 ballistic re-entry.

Q9b. Since NASA will be relying on Soyuz during the gap, are you taking any additional precautions following the last ballistic Soyuz re-entry to ensure the safety of U.S. and partner astronauts using the Soyuz to return from the ISS?

A9b. The International Space Station is an interdependent partnership. NASA and the Russian Federal Space Agency share the goal of fully understanding mission anomalies to ensure the safety of all of crew members. NASA will continue to work closely with Russia on our respective anomaly reporting and correction processes, during both manufacturing and operations phases.

On July 10, 2008, Cosmonauts Sergei Volkov and Oleg Kononenko performed RS EVA #20A. The primary task on EVA #20A was the inspection and retrieval of a pyrobolt from one of the five latches on the Soyuz. This was done to support the investigation of the ballistic descent of the last two Soyuz vehicles. Kononenko's Orlan suit was outfitted with a U.S. Wireless Video System to allow ground specialists to monitor real-time views from his helmet camera during the retrieval. While no anomalies were observed during the EVA, the pyrobolt will be returned for close inspection as part of the ongoing investigation process. NASA is working closely with Roscosmos to thoroughly evaluate all aspects of Soyuz design and operations, and assist in the performance thermal and structural analyses related to the re-entry conditions.

Q10. It has been reported that the Russians will need additional funding to complete construction of its ISS research facilities.

Q10a. Have the Russians informed NASA of delays to its planned Multi-Purpose Laboratory Module and Research Module?

A10a. In the most recent review of Russian activities, the Russians reported that all their modules are on schedule.

Q10b. How do these delays factor into the planning needed to complete ISS construction and begin full operations?

A10b. There is no impact to the U.S. program if the Russian modules are delayed.

Questions submitted by Representative Tom Feeney

Q1. At the hearing, concern was raised about the future cost of carrying research experiments and samples to and from ISS on cargo flights. Specifically, the research community fears that the cost of integrating the experiment for launch to and from ISS, plus the cost of the operations and safety certification, and transportation on cargo flights, could prove to be too expensive for many researchers. What are NASA's plans with respect to managing and pricing experiments to be conducted on ISS?

A1. There are six categories of cost related to conducting research and development (R&D) projects within the utilization capacity of the International Space Station

(ISS) USOS U.S. Operating Segment (USOS) in its role as a National Laboratory. The "user community" consists of other U.S. Government agencies (e.g., National Institutes of Health and Department of Agriculture), private firms (e.g., SPACEHAB and Zero Gravity, Inc.) and universities (e.g., Bioserve Space Technology Center at the University of Colorado) that have entered into formal Memoranda of Understanding and/or Space Act Agreements for use of the ISS for R&D purposes. Each of these categories is discussed below.

1. Cost of ISS USOS On-Orbit Resources and Accommodations: NASA does not intend to charge any user fees for U.S. use of ISS National Laboratory accommodations and resources. These costs are subsumed under the annual operations and maintenance cost of the ISS USOS.

2. Cost of Participating R&D Personnel: The research community that NASA has entered into agreements with for use of the ISS as a national laboratory recognizes that it is their responsibility to cover the cost of their own R&D personnel. In the case of government agencies, this includes the cost of external grant recipients and/or internal research staff. In the case of private firms and universities, this includes the cost of company personnel and/or university employees and students.

3. Cost of Space Certified Equipment and Facilities: In most cases, R&D plans will rely on the use of existing payload equipment and facilities that have been developed and flight-qualified previously in the ISS Program (e.g., Express racks & pallets, rack-scale special purpose research facilities, mid-deck lockers and drawers, refrigerators and freezers, etc.). A complete listing of flight equipment can be found at: *http://www.nasa.gov/mission_pages/station/science/experiments/Discipline.html*

4. Cost of Payload Analytical and Operations Integration: These costs include: definition of payload characteristics, properties and requirements in a formal Payload Integration Agreement; training crew for on-orbit payload operations; and, final integration of the payload into the on-orbit operations timeline. The ISS Program Office is currently budgeted to perform these functions for full use of the ISS USOS utilization capacity.

5. Cost of Payload Physical Integration and Safety Certification: The build-up of specific payload configurations, document production, verification testing, and safety certification is a responsibility of the end-user. NASA has worked aggressively to minimize these costs within the safety and mission assurance environment. The key to cost containment is the re-flight of previously qualified flight equipment that can maximize the use of existing hardware/software systems and documentation products. Experienced end-users have developed a close familiarity with the rigors of NASA payload physical integration and safety certification practices, and are knowledgeable in minimizing the associated costs.

6. Cost of Space Transportation: NASA is currently in the midst of acquiring domestic, commercial space transportation services (Request for Proposals released in mid-April with plans for award of firm fixed-price contracts by the end of 2008). At this time, the cost and availability of these services is not clear; however, these aspects will continue to mature in the coming years as U.S. commercial service providers evolve and demonstrate their capabilities and pricing strategies. A transition period can be anticipated during which end-user payloads are initially transported in the marginal capacity of ISS re-supply missions purchased by NASA and later manifested directly by the commercial service provider. The specific prices, practices and procedures will become clearer as this capability emerges in the post-assembly, post-Shuttle period.

Q2. The Europeans, Russians, and soon the Japanese, have—or will have—their own research facilities on-board ISS. What steps are taken among the international partners to ensure there is no duplication of research activities on ISS, and that the science return is maximized?

A2. Each ISS partner is free to pursue research at its own discretion in accordance with provisions of the bilateral agreements. Some degree of duplication is anticipated and indeed encouraged, in order to foster unique approaches to solving common scientific issues and advancing the state-of-the-art. Nonetheless, cooperation is also encouraged where beneficial to both, or all, partners. For example, we establish arrangements for research from one partner to be conducted in the facilities of another partner to maximize the science return from those facilities on orbit. This is fostered through scientific working groups in discipline-specific areas, such as life sciences and microgravity sciences. For example, the International Life and Microgravity Science Working Group (ISLSWG), composed of the Japanese, Canadian, and several European space agencies (ESA, DLR, CNES, ASI), meets twice a year to discuss and coordinate research activities, many of which will be conducted on the ISS.

Q3. What options does NASA have in place should COTS not prove viable? Will ATV and HTV be able to meet station needs until Orion/Ares becomes operational?

A3. Services to deliver cargo transportation requirements are being acquired through the Commercial Resupply Services competitive procurement, which is open to all bidders, including existing COTS partners (holders of both funded and unfunded COTS Space Act Agreements). In the event domestic commercial cargo resupply services are delayed, NASA will further optimize its usage of other cargo delivery capabilities, while aggressively managing the degradation in ISS systems and adjusting U.S. utilization of the ISS until the services become available.

In addition to commercial services, NASA's strategy is to pre-position ISS system spares on the flights which remain before Space Shuttle retirement in 2010. NASA also receives a share of the cargo capacity on all ATV and HTV flights as a part of the barter agreement for launch of European and Japanese elements to the ISS on the Space Shuttle. Finally, NASA has contracted with Russia to continue to provide cargo on Progress flights through the end of calendar year 2011.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Cristina T. Chaplain, Director, Acquisition and Sourcing Management, U.S. Government Accountability Office

Questions submitted by Chairman Mark Udall

Q1. Your prepared statement concludes that any delays in flying the Shuttle could "require NASA to choose between completing the station as planned and pre-positioning of needed critical spares." In your view, what would NASA need to consider in making such a tradeoff?

A1. There would be little value in bringing up additional components to the station, if the station itself could not operate effectively until 2016 or beyond. Therefore, NASA would have to consider what spares are vital to sustaining the station that require the lift capacity of the Shuttle and give them high priority. This is a fluid situation as NASA is still learning about the lifespan of its spares and is continually identifying parts that need special attention.

Q2. What does GAO think about NASA's acquisition strategy for acquiring commercial cargo transportation services? What do you think about the schedule it has laid out in the ISS re-supply services request for proposal?

A2. On the surface, it would seem that NASA is prematurely awarding a launch contract given that COTS capabilities have not been demonstrated. However, the government's liability for costs is limited by the fact that the contract is an Indefinite Delivery Indefinite Quantity (IDIQ) contract, which provides for an indefinite quantity of supplies or services within stated limits during a fixed period of time. More specifically, the government is only obligated to purchase a minimum amount of supplies or services. Under NASA's solicitation, the agency may select multiple vendors to participate in this contract; they all will be subject to NASA insight and approval for notice to proceed and or approval of requirements, plans, tests, or success criteria; there are stated criteria as to what capabilities need to be demonstrated; and NASA will determine if vendors are successful. Therefore, while NASA has already awarded the contract to one vendor, it is our understanding that the vendor still needs to demonstrate capability before more than the minimum amount of services will be ordered. Moreover, other vendors, including those who are not being paid under Space Act agreements, can eventually participate in the IDIQ if they develop capability that would suit the station.

Q3. Your prepared statement indicates that NASA has stated it will use international partners' vehicles to conduct some supply activities. Since partners have already committed these significant portions of these vehicles' capacity to carry their own cargo, how much additional cargo capacity would NASA have access to?

A3. NASA is conducting ongoing assessments on how ISS re-supply will be supported by international partner vehicles. International partner vehicles differ in what cargo they can carry and each has an internal capacity of roughly 2,000 kilograms. However, even with the use of these vehicles in some fashion, NASA still faces a capacity shortfall of over 50 metric tons between 2010 and 2015.

Q4. In your prepared statement you indicate that if unanticipated construction delays occur, NASA may need to hold back two components—Node 3 and the Cupola—which could constrain the ability to conduct research and the quality of life on the station for the crew. What research would be impacted?

A4. It is difficult to identify what research would be impacted by not installing the Cupola and Node 3. Both elements are not specific to the conduct of research. However, failure to install these elements would further limit the availability of storage space on the station. A shortfall in storage capacity could impact research if some of the laboratory modules are used to store materials and supplies. We will be examining this question more specifically in a follow-on review for this subcommittee.

Q5. In your prepared statement, you indicate that Johnson Space Center officials were skeptical that commercial transportation services would be available on the projected schedule. How do you reconcile this skepticism with the accelerated pace embodied in the schedule for the new Commercial Resupply RFP?

A5. The schedule goals for the COTS program may well be optimistic as our testimony emphasized. However, the launch services RFP itself only obligates the government to purchase a minimum amount of services or supplies.

Questions submitted by Representative Tom Feeney

Q1. What options does NASA have in place should COTS not prove viable? Will ATV and HTV be able to meet station needs until Orion/Ares become operational?

A1. NASA's options for servicing the International Space Station (ISS) are limited if Commercial Orbital Transportation Services (COTS) do not prove viable. The European Automated Transfer Vehicle (ATV) and the Japanese H–II Transfer Vehicle (HTV), along with the Russian Progress vehicle, can provide limited capabilities to deliver cargo and supplies to ISS, but NASA predicts a 51.8 metric ton shortfall to ISS re-supply needs relying on these vehicles alone after Shuttle retirement. The ATV has a cargo capability of 7,500 kg (primarily for water and atmospheric gas); the HTV has a cargo capability of 6,000 kg (primarily for water and atmospheric gas, but also for limited unpressurized external cargo); and the Progress has a cargo capability of 2,600 kg (including some pressurized cargo). None of these vehicles has the capability to carry crew members. Additionally, none of these vehicles has a cargo return capability because they disintegrate during return to Earth. Lastly, only limited numbers of the ATV and HTV are being produced.

According to NASA officials, without COTS, only Russian Soyuz vehicles can provide for crew rotation and very small cargo return capabilities. Currently, NASA reliance on Russian vehicles for ISS support is permitted under an exemption to the *Iran Nonproliferation Act of 2000* (now entitled the *Iran, North Korea and Syria Nonproliferation Act*), which expires January 1, 2012.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jeffrey P. Sutton, Director, National Space Biomedical Research Institute

Questions submitted by Chairman Mark Udall

Q1. Your prepared statement refers to "strategic goals the ISS can fulfill in the area of biomedical research to address exploration needs." *Could you please elaborate on these goals, the progress being made to date, and what more needs to be done to achieve these goals?*

A1. Two broad strategic goals are outlined in my prepared statement regarding the International Space Station (ISS) and biomedical research to address exploration needs. The first goal is that ISS serves, and needs to be utilized, as an invaluable platform for biomedical science and technology projects that are currently under way. These projects have substantial promise for yielding results, countermeasures and technologies that will enable safe human exploration of space. Some of the projects are ground-based studies that are working their way through a product pipeline toward ISS flight testing and evaluation over the next several years. Other projects are presently ready for flight definition and study aboard the ISS. As ISS nears completion and research capabilities grow, it is strategically prudent to capitalize on investments made in the current portfolio of research and technology development.

A second goal is to take advantage of the efforts associated with the first goal and foster new opportunities in biomedical research and development for exploration. One area to look at is emerging partnerships between academia and industry, where there has been positive activity to share costs on projects. Another area of opportunity lies in the integration and synergy among projects that make up an expanding portfolio of flight studies. Integration among projects is important and adds value to the scientific enterprise. It is also timely as the depth and breadth of ISS capabilities as an orbiting, microgravity laboratory expand. Moreover, integration fosters international cooperation, international crew participation, and can lead to new, unanticipated discoveries to advance knowledge and countermeasures to complex biomedical risks.

These two goals were presented in the context of the important role the ISS can have for biomedical research and exploration. There are other considerations as well. For example, beneficial information for exploration is gained on human performance, psychosocial adaptation and team cohesion while accruing operational experience aboard ISS. Furthermore, it should not be construed that the goals stated in my testimony are inconsistent with the goals and sub-goals put forth in the "2006 NASA Strategic Plan."

With this clarification in mind, it is laudable that progress in ISS biomedical research has been achieved, given the (1) challenges of conducting biomedical research in general, (2) constraints imposed by mass, power, volume, cost and crew time, (3) impacts from the *Columbia* tragedy, and (4) limitations imposed by performing research within a facility simultaneously undergoing construction. Progress in specific areas is summarized in my prepared statement, which provides references for the principal U.S.-sponsored biomedical experiments aboard the ISS. Ground-based projects that are ready for, or in the process of maturing toward, ISS testing and evaluation, are also listed with references.

Regarding matters that need to be addressed in order to achieve the goals, it is vital to have adequate and consistent funding to enable continuity in science and technology efforts. At present, there is a small but critical mass of outstanding and dedicated investigators from acrossthe Nation, who are conducting necessary investigations to enable safe human exploration of space. These investigators are scientific, technical and educational leaders, who are at the forefront of their fields and are at premier academic institutions, biotechnology companies and government laboratories (NASA and other agencies). They have the unique, collective expertise to drive U.S. achievements in space biomedical research forward, while at the same time inspiring and training the next generation of scientists, engineers and physicians. It is therefore important that their projects and teaming with each other, with younger investigators entering the field, and with the operational community at NASA be sustained and appropriately augmented as ISS capabilities expand.

Along similar lines, as NASA looks to implement memoranda of understanding with other federal agencies, such as the National Institutes of Health, new appropriations for collaborative ISS research should be considered. These new appropriations are also relevant to the success of the ISS National Laboratory. It is not apparent how ISS science endeavors can be implemented by relying only on funds redirected from within agencies with relatively flat budgets.

In strengthening the pipeline of biomedical research that requires ISS utilization, it is further recommended that NASA permit the National Space Biomedical Research Institute (NSBRI) to be more engaged in transitioning and managing science and technology development for the ISS. The 1996 NASA Cooperative Agreement Notice 9–CAN–96–01, "Soliciting Proposals for the Establishment of the National Space Biomedical Research Institute," states in Section 7.0, and reiterates in Section 10.4, that "it is NASA's intent that responsibility for all appropriate NASA-sponsored Space Station human experiment opportunities be transferred to the Institute." Although NSBRI is NASA's primary partner for biomedical research, and has multiple international collaborations, NASA has not utilized the resources and expertise of NSBRI to help review, select or manage research for the ISS. This is an area that should be revisited.

Q2. NASA has developed a Human Research Program Utilization Plan for the ISS, which identifies the risks for human exploration of space and the research on the ISS that can help mitigate the risks and lead to the development of countermeasures.

Q2a. Do NASA's current plans for ISS utilization enable the agency to adequately address the risks outlined in the plan and to develop countermeasures?

A2a. NASA's "Human Research Program Utilization Plan for the International Space Station" identifies 25 human health and performance risks requiring the ISS in order to perform research needed to quantify the risks and validate countermeasures and technologies. For each risk, there is a brief description of the planned activities and a top-level schedule, wherein a significant portion of the proposed work will be completed by 2016. Some risk assessment and countermeasure validation will occur beyond this date.

As stated in the document, the plan is subject to change based on multiple considerations. Nevertheless, in its current instantiation, the plan summarizes important risks and the development of countermeasures. Some risk areas are described in more detail than others, but in general, limited information is provided in the document.

NASA's current plans for ISS utilization enable the agency to address the risks. The question is what constitutes *adequate* risk mitigation? It is apparent that a more detailed, integrated utilization plan is needed to ensure as much progress and success as possible within the proposed time frame.

Q2b. If not, what else needs to be done?

A2b. Items to be done are listed as recommendations for the Human Research Program Utilization Plan for the ISS:

- Prioritize the risks into categories to identify those among the 25 that are the most urgent to mitigate utilizing the unique capabilities of the ISS;
- Expand each risk section to provide a more comprehensive listing of proposed research, countermeasures and technologies;[1]
- Characterize the current pipeline of biomedical projects feeding into, and already approved as part of, the portfolio of research, development, testing and evaluation to be conducted aboard the ISS;
- Identify current science and technology gaps in the risk reduction plan utilizing the ISS;[2]
- Outline the flight resources and manifest opportunities;
- Describe current and planned experiment hardware and associated engineering needs;

[1] For example, ISS research to address the first risk in the plan, "Risk of Inability to Adequately Treat an Ill or Injured Crew Member," is scheduled for FY08, FY09 and FY11. It would be helpful to list all relevant technologies at high readiness levels for flight that are candidates for testing and evaluation aboard ISS. Near infrared spectroscopy for non-invasive blood and tissue chemistry, and in-flight blood lab-on-a-chip technology for astronaut health monitoring are two such technologies. While both projects are currently funded by NSBRI, neither project is identified in the plan.

[2] This is important to do now as there is often a significant lead time to procure the needed studies and mature them to ISS-ready status.

- Discuss opportunities for integration and added value among studies addressing different risks;[3]
- Depict the roles and extent of industry involvement in the enterprise;
- Estimate the crew time dedicated to participate in research activities;
- Describe the metrics to be used to assess risk mitigation effectiveness and outcomes for the planned ISS activities;[4]
- Address plans for data sharing;
- Address plans for how intellectual property will be handled;
- Expand on issues concerning ISS partner participation;
- Discuss how research, development, testing and evaluation will be supported.

Q3. In your prepared statement, you indicate that affordable and reliable access to and from the ISS are key to the success of conducting biomedical research. You go on to say that critical to this success is the availability of cost-effective transportation services. How critical is a down mass capability for biomedical research?

A3. The physical return of samples and other materials is critical to the success and reproducibility of biomedical experiments aboard the ISS. Down mass capability is essential to guarantee the quality of certain types of biological specimens (fluids, cells and tissue) being returned to Earth. Access to powered, large-volume, pressurized lockers for transport is necessary.

Given the need for this capability, whenever possible, it is anticipated that on-orbit resources would be utilized to characterize findings, and that digital data would be down-linked to Earth. In my verbal testimony, I referred to the successful use of on-orbit ultrasound to perform medical imaging on ISS crew members. Streamed video and still images of clinical quality from a series of studies were obtained without the need for down mass capability.

The U.S. orbiter and the Russian Soyuz have served as the primary means to ensure safe return of biomedical samples from research conducted aboard the ISS. Both vehicles are capable of providing powered mid-deck locker return, when necessary, for valuable experimental materials. It is desirable to have configurable soft-packs when power and/or pressurization is not necessary.

The transfer vehicles in development by international partners (the European ATV and the Japanese HTV) do not provide down mass capability. Although these vehicles play an important role in delivery of cargo to the ISS, their utility for transferring experimental samples and other materials from the ISS to Earth is absent. Similar to the conditions provided by the orbiter and Soyuz, the Space X Dragon capsule, currently under development for NASA's Commercial Orbital Transportation Services program, is expected to be able to accommodate both pressurized and non-pressurized cargo in a mid-deck locker-like configuration. Other developments are also in progress.

Q4. Given your experience in leading an institute that involves universities, federal agencies, and industry in conducting research to support human space exploration, what should NASA consider as it explores options for managing the ISS National Lab?

A4. NASA should consider management options for the ISS National Lab that have been successfully implemented in other large-scale, ambitious research and engineering projects of national and international importance. Within NASA, excellent examples include the Apollo and Hubble Space Telescope programs. There are many non-NASA examples, including the Manhattan Project, which exemplify how outstanding scientists have been brought together to work on teams, with an upper-level management structure guiding and integrating teams to achieve a single common purpose of paramount significance.

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[3] For instance, NSBRI is supporting a project to develop an ultrasound catalog for autonomous medical care. The catalog will provide, among other deliverables, an atlas of normal human anatomy and physiology acquired using ultrasound aboard the ISS, starting with Expedition 6. Studies should continue on this project which addresses multiple risks, including but not limited to the "Risk of Inability to Adequately Treat an Ill or Injured Crew Member," "Risk of Accelerated Osteoporosis," "Risk of Cardiac Rhythm Problems," and "Risk of Intervertebral Disc Damage."

[4] All projects within the Human Research Program can be assigned countermeasure and/or technology readiness levels. The rate of change of these levels with time provides an estimate of when projects are ready for flight testing and evaluation. Not all projects mature to flight and some projects enter the system as flight studies. There are also other measures to characterize the pipeline beyond readiness levels and their time rate of change.

There is not necessarily a single, best way to manage the ISS National Lab. Substantial resources exist, and more are being put into place, aboard the ISS. There is a wealth of biomedical research and technological infrastructure within universities, medical schools, industry and government laboratories to enable ISS National Lab achievements. As mentioned previously, there is a cadre of outstanding investigators who have, and students who are acquiring, the necessary skills to generate productive and meaningful discoveries in space, in partnership with ISS crews. Funding, reliable access to and from the ISS, and international limitations are challenging issues but fundamentally solvable.

Two items that NASA should focus on regarding management are requirements and leadership. A strategic and tactical plan that is consistent with, but includes more detail than the reports presently available on the ISS National Lab, should be developed, with particular attention paid to requirements. The management options are narrowed by considering only those systems that allow the requirements to be met. In formulating the strategic and tactical plan, it can be useful to assemble a small working group of NASA and non-NASA experts, whose membership includes experience in leading large scientific institutes, conducting basic and applied biomedical research in space, partnering with industry and successfully implementing international science and technology programs. Attention should be paid to the needs and expectations of key stakeholders, and the plan should be thoroughly vetted before being implemented.

Leadership is a key consideration for success in managing the ISS National Lab. The Director should possess not only the necessary credentials, experience, skills and integrity to perform his or her duties, but must also have a bold vision for the ISS National Lab that is embraced by NASA, other federal agencies, Congress, and to the greatest extent possible, the American public. The ISS National Lab must have a strong leadership team to effectively implement the strategic and tactical plan, and to modify the plan accordingly, in order to achieve maximum return on, and benefit from, our Nation's investment in the ISS and its precious resources.

Questions submitted by Representative Tom Feeney

Q1. At the hearing, you outlined a number of initiatives conducted by the National Space Biomedical Research Institute related to developing countermeasures for long-term human exploration of space. Which among these has generated the most promise, and which, in your opinion, continues to pose the greatest challenges?

A1. Ten NSBRI-sponsored science and technology projects, all generating substantial promise, are highlighted in my prepared statement. Three are described in more detail here to illustrate the extent of promise within NSBRI's portfolio. This is followed by remarks concerning an NSBRI initiative, which despite considerable promise, poses great challenges.

NSBRI took a strong position in enhancing near-infrared spectroscopy analysis and subsequently developing a small, lightweight, portable means of performing non-invasive blood and tissue measurements for use in space.[5] By assessing tissue pH and lactic acid in real-time during exercise, it is possible to adapt exercise countermeasures and efficiencies for individual crew members. This device has been tested on astronauts exercising at Johnson Space Center, and the technology is maturing toward evaluation aboard the ISS. There are medical applications for space exploration (e.g., assessing tissue viability in the case of a crush injury or exposure to extreme temperatures) and applications to health care on Earth (e.g., assessing the microvasculature in diabetics).

Light in the blue part of the spectrum is being used as a countermeasure for performance errors associated with circadian desynchronization, sleep loss and adaptation to shifts in work schedule. NSBRI has sponsored research published in leading journals, such as *Science* and *Nature,* delineating mechanisms associated with blue light effects. The Institute has also taken the lead in developing, testing and evaluating the countermeasure in operational settings, and in working with NASA to modify the lighting in designs for the crew exploration vehicle. There are several applications of this countermeasure on Earth.

NSBRI assessed the utility of several portable medical imaging technologies (dual energy X-ray absorptiometry, magnetic resonance imaging, diffuse optical tomography and ultrasound) for use in space. In partnership with NASA, a series of elegant studies were performed aboard ISS using ultrasound, which has become the

[5] The device is reminiscent of the medical tricorder used by Dr. McCoy in the fictional series Star Trek.

medical imaging technology of choice. NSBRI therefore shifted its portfolio to reflect the promise of ultrasound, and currently supports novel countermeasure development projects using scanning confocal ultrasound and high-intensity focused ultrasound (HIFU). HIFU shows particular promise in addressing the risk of inability to adequately treat an ill or injured crew member. NSBRI has co-sponsored, with the Department of Defense, a small portable ultrasound system capable of sensing and then (using autonomous image guidance) performing non-invasive surgery with HIFU.[6] This countermeasure, employing an integrated sensor-effector platform, has applications on Earth in emergency medicine and on the battlefield.

One of the most challenging risks to mitigate, for human space exploration, is the harmful effects of radiation. A recent report from the National Research Council, entitled "Managing Space Radiation Risk in the New Era of Space Exploration" (2008), provides an insightful assessment of the risk and efforts to protect against exposure to space radiation. NSBRI supports NASA's radiation program in several ways.[7] The Institute funds the development of gas and solid-state dosimeters for real-time assessment of radiation exposure to astronauts. This is particularly important for missions beyond low Earth orbit. A number of projects on NSBRI teams, such as those dealing with bone and the cardiovascular system, have a radiation component. Countermeasures are being investigated to protect against the harmful effects of radiation to these and other systems.

Perhaps the most significant contribution of NSBRI in addressing radiation risks is a new initiative addressing the mitigation of effects due to acute radiation exposure. In February 2008, NSBRI released an announcement "Research Opportunities Soliciting an NSBRI Center of Acute Radiation Research for Ground-Based Studies on Acute Radiation Effects."[8] The goal is to develop countermeasures to acute effects that could potentially compromise crew members and even the mission itself. Countermeasure development in this area is challenging, but it is an essential part of supporting long-duration, human exploration of space.

[6] See *http://www.nsbri.org/Research/Projects/viewsummary.epl?pid=158*

[7] It is worth noting that NASA's radiation program, within the Human Research Program, is supported at an amount that is 50 percent greater than the entire NSBRI. To accomplish its mission, the Institute relies on its ability to leverage resources in innovative ways.

[8] See *http://www.nsbri.org/Announcements/rfa08-02.html*

Appendix 2:

Additional Material for the Record

STATEMENT OF THE AMERICAN SOCIETY FOR GRAVITATIONAL AND SPACE BIOLOGY

ASGSB PRESIDENT, DANNY A. RILEY, PH.D.
PROFESSOR OF CELL BIOLOGY, NEUROBIOLOGY AND ANATOMY
MEDICAL COLLEGE OF WISCONSIN

The American Society for Gravitational and Space Biology (ASGSB), founded in 1984, provides a forum to foster research, education and professional development in the multidisciplinary fields of gravitational and space biology. We are a diverse group of *scientists, engineers and students* who exchange ideas that bridge basic and applied biological research in space and gravitational sciences. Our society of ~350 professionals and students from universities, government, and industry represents the core community that works with NASA to create and disseminate knowledge about how living organisms respond to gravity and the space flight environs.

For many years, our members have worked toward the reality of an International Space Station (ISS) as a platform for conducting the cutting edge research, as described in the multiple National Research Council (NRC) reports.[1] We consider the ISS National Laboratory an essential and unique tool for probing biological function and adaptation during long-term space flight. The studies are essential for human space exploration and, at the same time, return multiple health and economic benefits to America. There is no substitute on earth. Moreover, the U.S. has already invested at least $100 billion in the ISS. This is not the time for us to abandon the investment or the opportunity.

Our Society has been decimated by the unprecedented retraction and termination of funding of non-exploration fundamental biology. *The viability of our community is foundationally linked to the ability to conduct cutting edge research on ISS.*

The American Society for Gravitational and Space Biology considers the following elements ESSENTIAL to make the International Space Station productive for research:

Viable ASGSB research community

- Substantial and long-term commitment of NASA to fund fundamental biology ground and flight research programs
- Active community of plant and animal scientists and engineers engaged in world class, fundamental and applied space research
- Stable research and training environments to attract and educate next generation scientists and engineers
- Continuous pipeline of meritorious, peer-reviewed investigations encompassing fundamental and applied research in space-related biological sciences

ISS Resources and Environment

- Hardware and instrumentation to support animal and plant housing and experimentation on ISS, including bio-containment work stations and variable speed centrifugation capabilities
- Frequent and affordable transportation to and from ISS
- Commercial and basic research entities participating jointly on missions
- Ground personnel and facilities support for flight experiments
- Crew member involvement in the conduct of investigations

ISS National Laboratory Management

- Empowered and budgeted administrative unit within NASA to fund and integrate the flight hardware and science for non-exploration fundamental biology
- An ISS National Laboratory management unit, a consortium of stakeholders, tightly coupled with external advisory and peer review to implement NRC-defined research priorities
- External science advisory structure with oversight and influence on NASA programmatic priority decisions

[1] An Assessment of Balance in NASA's Science Programs (2006). Review of NASA Plans for the International Space Station (2006). Science in NASA's Vision for Space Exploration (2005).

To revitalize and establish all of these elements requires immediate attention, time and a renewed national commitment as well as supportive leadership at NASA Headquarters.

ASGSB life scientists have conferred extensively with their counterparts in the physical sciences. The consensus is that, for the U.S. to prevent the utter destruction of the human capital and living knowledge in the space life and physical sciences, there must be an infusion of "keep alive" funds in 2009. We jointly estimate such *"keep alive funds" at $91M* for the coming fiscal year. Such funds must be assigned to "non-exploration research" in the space life and physical sciences at NASA. Moreover, for NASA to engage in the mandated *"America COMPETES" initiative, $160M of additional funds* are required for the life and physical sciences at NASA.

It is ironic that the loss of financial support for the life sciences and our research on the ISS began in 2004, immediately after President Bush announced the *"Vision for Space Exploration"* and asserted that the ISS would be completed because the U.S. finishes what we start. He also recognized explicitly that we must *use the ISS to learn about long-term space exposure* on the body, in order to venture safely and successfully into space.

Failure to utilize fully U.S. investment in the space station and neglecting, to the point of destruction, the ASGSB community is antithetical to competitive national goals and interests. We look forward to working with Congress *to regain American leadership in the space enterprise* and to continue to make great contributions to health and knowledge *while cultivating the next generation of scientists and engineers.*

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