NASA'S SPACE SHUTTLE AND INTERNATIONAL SPACE STATION PROGRAMS: STATUS AND ISSUES

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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NASA'S SPACE SHUTTLE AND INTERNATIONAL SPACE STATION PROGRAMS: STATUS AND ISSUES

TUESDAY, JULY 24, 2007

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

The Subcommittee met, pursuant to call, at 10:03 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mark Udall [Chairman of the Subcommittee] presiding.

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

Hearing on

NASA's Space Shuttle and International Space Station Programs: Status and Issues

July 24, 2007
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

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

Mr. Tommy Holloway
Chairman
ISS Independent Safety Task Force

Dr. G. Paul Neitzel
Professor of Fluid Mechanics
Georgia Institute of Technology

Ms. Christina Chaplain
Director
Acquisition and Sourcing Management
Government Accountability Office

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HEARING CHARTER

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

NASA's Space Shuttle and International Space Station Programs: Status and Issues

TUESDAY, JULY 24, 2007
10:00 A.M.—12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Tuesday, July 24, 2007 at 10:00 a.m., the House Committee on Science and Technology's Subcommittee on Space and Aeronautics will hold a hearing to examine the National Aeronautics and Space Administration's (NASA) Fiscal Year 2008 budget request and plans for the Space Shuttle and International Space Station (ISS) programs, the status of the programs, and issues related to the programs.

Witnesses

Witnesses scheduled to testify at the hearing include the following:

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

Mr. Tommy Holloway, Chairman, ISS Independent Safety Task Force

Dr. G. Paul Neitzel, Professor of Fluid Mechanics, Georgia Institute of Technology

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

Potential Issues

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

- *What are the main challenges to successfully flying the Space Shuttle until its planned 2010 retirement? How will NASA ensure the continued safety of Space Shuttle operations in the face of an ongoing labor strike, workforce transition uncertainties, competition with other NASA human space flight programs for resources, and a schedule driven by the need to complete International Space Station (ISS) assembly by the planned 2010 retirement date of the Shuttle?*
- *What are the main challenges to successfully completing the planned Shuttle mission to service the Hubble Space Telescope, and how firm is NASA's launch schedule for the Hubble servicing mission?*
- *What are the main risks to successfully assembling the International Space Station (ISS) by the time the Shuttle is retired? What will NASA do if the actual Shuttle flight rate turns out to be insufficient to complete all of the planned ISS assembly and logistics fights by the end of 2010, and what will be the impact on ISS utilization and operations?*
- *What actions, if any, is NASA taking to respond to the findings and recommendations of the ISS Independent Safety Task Force that raised a number of concerns about the program?*
- *Does NASA have a credible logistics plan for supporting ISS utilization and operations once the Shuttle is retired, and does that plan have adequate backup strategies for contingencies?*
- *What does NASA want to do with the ISS once it is assembled, and does NASA have well defined utilization plans and resource commitments in place that are aligned with those utilization objectives? Given the cuts to the microgravity research community, will a research community be available to effectively utilize the ISS once it is assembled?*

- *What would be required for NASA's ISS National Laboratory concept to become a reality, and what are the main impediments to its success? What will NASA do with the unused capacity and capabilities of the ISS if other agencies decide not to make significant use of it?*

BACKGROUND

Space Shuttle Program

Fiscal Year 2008 Budget Request for the Space Shuttle Program

The FY08 budget request for the Space Shuttle program is $4.007 billion. [A multi-year funding chart for the Space Shuttle and ISS programs is included as an attachment to this memo.] Funding for the Space Shuttle program is used to pay for the following:

(1) **Program Integration—**which includes flight software, system engineering, construction of facilities, safety and mission assurance, etc.

(2) **Flight and Ground Operations—**pre-flight planning, crew training, operations, mission support for each missions, maintenance and operation of support facilities, final integration and checkout of flight hardware for launch, etc.

(3) **Flight Hardware—**manufacturing and testing of the Orbiter, Space Shuttle Main Engines, External Tank, Solid Rocket Motors, and Solid Rocket Boosters, as well as any needed design and development activities.

The FY 2007 plans for the Space Shuttle program assumed that four Shuttle missions would be conducted during the current fiscal year. At present, NASA anticipates that it will be able to complete three. NASA's FY 2008 budget request assumes five Shuttle flights during FY 2008—four to the ISS and one to service the Hubble Space Telescope. Overall, NASA is projecting 12 Shuttle flights to the ISS, one to Hubble, and two ISS "contingency" logistics flights prior to the Shuttle's retirement.

As part of the President's *Vision for Space Exploration,* NASA has been directed to *"focus use of the Space Shuttle to complete assembly of the International Space Station; and retire the Space Shuttle as soon as assembly of the International Space Station is completed, planned for the end of this decade."* As a result, NASA is also taking steps to begin the transition of the Shuttle workforce and facilities, including identification of assets that will not be needed for follow-on programs and thus can be decommissioned/disposed of by the agency. NASA has submitted some proposed legislative provisions to Congress intended to address Shuttle transition issues. Those legislative proposals will be the focus of a future Subcommittee hearing.

Approximately 500 members of the International Association of Machinists (IAM) have been on strike at the NASA Kennedy Space Center since June 14th of this year as part of a contract dispute with the United Space Alliance (USA), which operates the Space Shuttle for NASA. The IAM strikers have asserted that USA *"has abandoned safety, training, and paperwork requirements they have held us to for years"* during the strike. USA, for its part, has stated that replacement workers were *"properly trained and, where required, certified as proficient to safely perform the task supporting Shuttle processing."* Without attempting to judge the competing claims, Members may wish to see what steps NASA independently is taking to ensure that Shuttle processing activities are being conducted safely.

The following are a number of the challenges related to the FY08 budget request and five-year runout for the Space Shuttle program:

- Impact of reduced Space Shuttle reserves to address remaining program threats prior to retirement of the Shuttle
- Feasibility of safely completing the currently planned Shuttle launch schedule prior to the scheduled retirement date in light of the technical issues that have arisen during preparations for several of the missions since the Shuttle returned-to-flight
- Need to maintain necessary Shuttle workforce and skills through remaining flight schedule
- Potential Space Shuttle program transition and retirement requirements—budget submitted to Congress does not include funds to address these issues past FY 2010, with explanation given that the requirement are not yet well defined.

Space Shuttle Servicing of the Hubble Space Telescope

In late October 2006, NASA Administrator Michael Griffin announced plans to conduct a final Shuttle servicing mission to the Hubble Space Telescope. The servicing mission (SM4) will be the fifth Hubble servicing mission since the Hubble was deployed in 1990 and will improve and enable the telescope's continuing operations through 2013. The flight is currently manifested on Shuttle mission STS–125, which is targeted to fly on Atlantis in September 2008. It will be the only non-ISS-related Shuttle mission among the remaining Shuttle flights.

The servicing mission will involve a series of five challenging spacewalks to replace and upgrade components such as batteries and gyroscopes and to install new science instruments—the Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3). The COS will allow astronomers to look at the structure and composition of the universe and the WFC3 will look through the infrared, visible, and ultraviolet wavelengths of light to provide insight into planets, the formation of the solar system, the study of early and distant galaxies, and the formation of stars. Astronauts servicing the Hubble will also attempt to repair the Space Telescope Imaging Spectrograph (STIS) instrument installed in 1997, which lost power in 2004. That instrument performs high resolution studies of nearby stars and distant galaxies in visible and infrared wavelengths. Astronauts will also install a Soft Capture Mechanism to allow a vehicle to attach to the Hubble and safely de-orbit the spacecraft once it reaches the end of its mission.

The SM4 mission was intended to fly earlier in the decade. After the loss of the Space Shuttle *Columbia* in 2003, NASA decided, in January 2004 not to conduct the mission. The cancellation of the servicing mission and expected loss of the Hubble around 2007–2008 prompted an outcry from the public and science community. NASA continued to evaluate options for extending the Hubble's operating lifetime, including a possible robotic servicing mission. The National Academies' *Assessment of Options for Extending the Life of the Hubble Space Telescope* report recommended *"that NASA should commit to a servicing mission to the Hubble Space Telescope that accomplishes the objectives of the originally planned SM–4 mission."*

Aerospace Safety Advisory Panel (ASAP) Report

ASAP recently released its 2006 Annual Report. In that report, the Panel made several observations and recommendations related to the Space Shuttle program. Quoting the report, some of those are as follows:

- *"NASA has shown an appreciation of the persistence of risk associated with the Shuttle, and therefore the continuing need to properly assess it—so that appropriate measures can be taken to mitigate that risk through the remainder of the program."*
- *"The ASAP has observed that launch decisions are too regularly being elevated to the Administrator level, and the Panel noted the lack of an analytical risk-assessment process that is standardized, comprehensive and well understood throughout the agency."*
- *"The ASAP said it was concerned about NASA's shift away from an approach aimed at modifying safety culture to one that appeared to only monitor the status of the culture. . . Despite these concerns, the ASAP does find signs of improving safety culture, particularly indications that communications have become more open within the Agency."*
- *"For the Space Shuttle, as with other programs, it is management's responsibility to set priorities and assess risk—and eliminating all risk is an unrealistic goal. The Agency and the Shuttle Program must guard against developing 'tunnel vision' with respect to foam, which could distract them from potential problems developing in other areas."*

International Space Station Program

Fiscal Year 2008 Budget Request for International Space Station Program (ISS)

The FY08 budget request for the International Space Station (ISS) program is $2.239 billion. [A multi-year funding chart for the Space Shuttle and ISS programs is included as an attachment to this memo.] Funding for the ISS program is used to pay for the following:

(1) **Flight Hardware—**It should be noted that, according to NASA, all U.S. ISS development activities will be completed with the exception of Habitability upgrades and improvements to the ExPRESS Logistics Carrier

(2) **ISS Operations Program Integration Activities**

(3) **ISS Spacecraft Operations Activities**

(4) **ISS Launch and Mission Operations**

(5) **Multi-User System Support (MUSS)**

(6) **ISS Crew-Cargo Services—**To be provided by commercial entities or International Partners (e.g., Europeans, Japanese, Russians). Over the near-term, the funding is primarily to pay the Russians for Soyuz and Progress services.

The ISS program is currently in the most challenging portion of the assembly phase. In FY 2008, "Node 2" will be launched, which is a key piece of ISS hardware that will allow the European and Japanese pressurized modules to be added to the ISS in 2008. In addition, the truss ["backbone"] of the ISS will be completed and additional solar power added. The European ATV cargo carrier is also scheduled to be launched to the ISS in late 2007 or early 2008. That will provide an additional means of getting cargo to the ISS besides the Space Shuttle and the Russian Progress cargo vehicle.

In addition, under the Commercial Orbital Transportation System [COTS] program, potential commercial cargo services providers will be continuing their development activities in FY08. NASA is proposing to carry out a competition to award a contract to one or more commercial providers for cargo delivery [and perhaps eventually crew transfer services] to the ISS. The Subcommittee plans to examine the status and issues related to COTS and logistical support of the ISS in a future meeting.

In the *NASA Authorization Act of 2005* [P.L. 109–155], Congress directed the establishment of an ISS Independent Safety Task Force to *"review the International Space Station program with the objective of discovering and assessing any vulnerabilities of the International Space Station that could lead to its destruction, compromise the health of its crew, or necessitate its premature abandonment."* The Task Force delivered its report to Congress earlier this year, and its principal observations and recommendations are listed in the following section of this hearing charter. The Chair of the Task Force will be testifying before the Subcommittee at this hearing.

The following are a number of challenges related to the FY08 budget request and five-year runout for the ISS program:

- The ISS program has depleted reserves through FY 2008 while facing the most challenging period of ISS assembly.
- According to NASA, there is a $300 million shortfall in the ISS Crew-Cargo Services budget based on current estimates, with an additional $600 million shortfall being held as a lien against the Exploration Systems Mission Directorate budget. The ISS Independent Safety Task Force was very concerned about the adequacy of the ISS's post-Shuttle logistics support.
- There are additional threats to reserves related to dealing with the impact of the Shuttle retirement.
- Although two of the remaining Shuttle flights are listed as "contingency" and have not yet been approved by OMB—although NASA says sufficient funds have been included in the budget—NASA indicates that those flights will be needed to deliver spares and logistics in advance of the Shuttle's retirement, i.e., they should not be considered optional flights.
- 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.
- 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 the reductions in funding. No well defined research and utilization plan yet exists, which raises concerns about the ability of NASA to make productive use of the ISS once it is assembled.

Summary of Principal Observations and Recommendations of the ISS Independent Safety Task Force

Principal Observations

- The International Space Station Program is currently a robust and sound program with respect to safety and crew health. Safety and crew health issues

are well documented and acceptable, and are either currently adequately controlled or mitigations are being developed to maintain acceptable risk levels.

- The International Space Station Program has strong and proactive crosscutting functions that—if continued—should provide advance indications and warnings that will avoid events that might lead to destruction of the Station, loss of the Station crew, abandonment of the Station, or development of untoward crew health issues. The International Space Station Program's operating procedures and processes are thorough and sound.
- The International Space Station currently has an experienced, knowledgeable, and proactive team, both internally and in its institutional technical checks and balances, that provides the defense for process and management failures that might lead to an ISS safety or major crew health issue. This posture must be maintained to continue the Station's successful operation.
- Micrometeoroid and orbital debris penetrating the living quarters or damaging critical equipment is a high safety risk to the crew and the Station.
- Spontaneous crew illness is a significant crew risk and may necessitate returning the crew to Earth for specialized medical attention, which would result in temporary abandonment of the Station. International Space Station medical and Program management officials are taking all reasonable precautions to minimize this risk.
- There are significant programmatic risks associated with completing the ISS Shuttle manifest and providing robust post-Shuttle logistics capabilities that threaten the ability to support a viable Station.
- Workforce composition is a growing concern throughout NASA because of the technical and specialized nature of most of the agency's work and the large-scale program transition now under way. The International Space Station Program is vulnerable to critical management losses, making strategic workforce planning as important as ever.
- Design, development and certification of the new Commercial Orbital Transportation System capability for ISS resupply are just beginning. If similar to other new program development activities, it most likely will take much longer than expected and will cost more than anticipated.
- The current International Traffic in Arms Regulation restrictions on NASA are a threat to the safe and successful integration and operations of the International Space Station.

Principal Recommendations

- The International Space Station Program should place the highest priority on options to decrease the risk of micrometeoroid and orbital debris.
- NASA should develop and implement plans to maintain Station critical skills and experienced managers.
- The Administration, Congress, and NASA should support the completion of the current Shuttle manifest to the International Space Station, including flights ULF–4 and ULF–5, to assemble a viable Station and provide spares for its long-term operation.
- The Administration, Congress, and NASA should support a proactive and phased post-Shuttle logistical transportation program, including adequate funding of approximately one billion dollars per year above current allocations to ensure that adequate logistics and spares are available to maintain a viable Station.
- NASA senior management should conduct a comprehensive review of the Automated Transfer Vehicle to ensure agreement of the policies, approach, and technical implementation of the safety strategy for the Automated Transfer Vehicle's demonstration flight. [Note: This review was conducted on January 8, 2007, and met the intent of this recommendation.]
- The Department of State should grant immediate relief from the International Traffic in Arms Regulation restrictions in the form of an exemption to allow NASA contractors direct interaction with the International Space Station's International Partners and their contractors. This must be affected no later than summer 2007 to support Automated Transfer Vehicle operations.
- The ISS Program should carefully consider implementing all IISTF recommendations to improve the overall safeguards and controls against vulnerabilities.

Utilization of the International Space Station

Current Status

NASA's priorities include completing the assembly of the International Space Station (ISS) by 2010 and then retiring the Shuttle. Based on current plans, starting in 2010 NASA intends to utilize the ISS to conduct research that supports mission-enabling objectives for the *Vision for Space Exploration.* A 2006 report by the National Academies that reviewed NASA's ISS plans states that *"these objectives represent a major shift in research goals compared to earlier versions of ISS plans. It has always been an ISS objective to study and develop countermeasures for the detrimental effects of space flight on astronauts. However, ISS plans had also previously included a major focus on basic research in a number of diverse fields of biological and physical sciences, with research projects directed at increasing fundamental scientific understanding as well as eventual terrestrial applications such as understanding disease or improving industrial technologies."* As part of that shift, NASA severely cut the support of scientists working on basic research and longer-term challenges in space biology and medicine and the physical sciences. According to the January–March 2007 Newsletter of the National Academies' Space Studies Board, the human research program lost 59 percent of its investigators, fundamental space biology lost 88 percent of its researchers, and the physical sciences lost 84 percent of its research community. Correspondingly large cuts were made to NASA's life and physical sciences microgravity research and applications budgets over the past several years.

Only a few years remain before NASA is scheduled to complete assembly of the ISS and focus on utilizing the Station. At present, however, NASA still lacks a well defined utilization plan with schedules, milestones, specific and prioritized research experiments to actually realize the broad research goals outlined by NASA, budgetary profiles and resource commitments (logistics, crew time, funding) needed to execute the plan.

In the face of these realities, issues that Members may wish to examine are whether a world-class research community that can support investigations to achieve NASA's utilization objectives will be available in 2010 under NASA's current approach, and whether experiments that contribute to NASA's mission-enabling objectives will be mature and ready for flight. Another issue is what the implications of the reductions to fundamental life and physical science research will be for NASA's ability to achieve its longer-term exploration goals as well as its ability to deliver the terrestrial benefits of ISS research that the Agency had long used to help justify the ISS program. According to a National Academies report, *An Assessment of Balance in NASA's Science Programs,* published in 2006, *"Analysis of the NASA FY 2007 budget suggests that funds will not be provided for the physical and biological research necessary to identify and define problems that are critical to human survival and function in long-term space flight or to develop new technologies and countermeasures to overcome these challenges."*

The ISS as a National Laboratory

The *NASA Authorization Act of 2005,* apart from establishing requirements for NASA-supported exploration and non-exploration ISS research, designates the ISS as a national laboratory. The Act seeks to increase the utilization of the ISS by other federal agencies and the private sector. NASA prepared a report for Congress, *International Space Station National Laboratory Application Development,* dated April 2007, as required under the Act. According to the report, NASA's primary strategy for the ISS national laboratory is *"early efforts on identifying qualified end-users from the public and private sectors."* To that end, NASA has taken the following steps:

- led an interagency task force to explore how ISS might be used for science, technology, engineering, and math (STEM) activities;
- entered into discussions on a Memorandum of Understanding with the National Institutes of Health on use of the ISS;
- issued a Sources Sought announcement seeking commercially-provided water generation services on the ISS.

The report indicates that NASA will support the operations and maintenance of the ISS. Public and private sector partners seeking to use the ISS will most likely be required to pay for transporting any experiments, equipment, and supplies supporting their utilization to the ISS. According to the report, NASA identifies the *"availability of cost-effective transportation services"* as the most significant risk factor in the success of the national laboratory. NASA plans to begin managing the operations and utilization of the ISS national laboratory internally. If non-govern-

mental interests in using the ISS grow, NASA may develop an institute to manage non-governmental utilization.

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."* The report discusses potential educational projects that non-NASA users could conduct on the ISS national laboratory and also discusses the opportunities for American students to participate in international projects and benefit from the international cooperative environment that the ISS offers.

According to NASA's ISS National Laboratory report, the success of the ISS National Laboratory concept will, in part, determine how long NASA plans to operate the ISS. As described in the report, the ISS has a 15-year design lifetime, based on the launch of the first element in February 2001, and NASA's budget for ISS operations reflects the 15-year period. NASA has therefore estimated FY 2016 as the end of the operations of the ISS. The report notes that NASA will allow four years, FY 2011–FY 2014, to assess the "value" of the ISS as a national laboratory, at which point NASA would need to extend the "certified design lifetime." That process could involve tests and analyses that would require lead time and decisions on costs versus benefits.

Alpha Magnetic Spectrometer (AMS)

The Alpha Magnetic Spectrometer (AMS) is a particle physics experiment proposed by Dr. Samuel Ting of the Massachusetts Institute of Technology to search for antimatter in the universe. AMS, which is sponsored by the Department of Energy (DOE), is designed to be flown on the Space Shuttle and attached to the exterior of the ISS. Some 16 international partners are involved in the project and have funded and performed the majority of its construction. In 1995, NASA entered into an agreement with the DOE to provide AMS with three years of operation on the ISS. Space Shuttle Discovery flew a prototype of the experiment in 1998.

Following the Space Shuttle *Columbia* accident, NASA focused on the return-to-flight of the Shuttle and completion of the ISS consistent with the *Vision to Space Exploration.* In a 2005 letter from NASA to DOE, NASA stated that it *"cannot commit to a Shuttle flight for AMS to the International Space Station (ISS) given current constraints."* In a 2006 letter from the NASA Administrator to Senator Kay Bailey Hutchinson, NASA maintained its position that it could not commit to a Shuttle flight for AMS and noted that *"NASA intends to proceed with the payload integration process within the existing AMS budget in order to preserve the option of a future launch."* NASA personnel have indicated that they believe that alternatives to a Shuttle launch, including launch on a foreign launch vehicle, would require significant and costly modifications to the payload and launch vehicle. Thus, at this point, NASA has no plans to fly the AMS to the ISS.

ATTACHMENT 1 FY 08 NASA Budget Request - Space Operations

(Budget authority, $ in millions)	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
SPACE OPERATIONS	**6,108.3**	**6,791.7**	**6,710.3**	**6,625.7**	**3,036.6**	**2,978.0**
Space Shuttle	4,017.6	4,007.5	3,650.9	3,634.5	116.2	
Space Station	1,762.6	2,238.6	2,515.1	2,609.2	2,547.5	2,600.8
Space Flight Support	328.1	545.6	544.3	382.0	372.9	377.2
Year to Year Change		**11.2%**	**-1.2%**	**-1.3%**	**-54.2%**	**-1.9%**

ATTACHMENT 2

National Aeronautics and Space Administration

LAUNCH SCHEDULE

Consolidated Launch Manifest

Space Shuttle Flights and ISS Assembly Sequence

Launch Target	Assembly Flight	Launch Vehicle	Element(s)
Aug. 7, 2007	13A.1	Endeavour STS-118	• SPACEHAB Single Cargo Module • Third starboard truss segment (ITS S5) • External Stowage Platform 3 (ESP3)
Oct. 20, 2007	10A	Discovery STS-120	• Node 2 • Sidewall - Power and Data Grapple Fixture (PDGF)
Dec. 6, 2007	1E	Atlantis STS-122	• Columbus European Laboratory Module • Multi-Purpose Experiment Support Structure - Non-Deployable (MPESS-ND)
Feb. 14, 2008	1J/A	Endeavour STS-123	• Kibo Japanese Experiment Logistics Module - Pressurized Section (ELM-PS) • Spacelab Pallet - Deployable 1 (SLP-D1) with Canadian Special Purpose Dexterous Manipulator, Dextre
April 24, 2008	1J	Discovery STS-124	• Kibo Japanese Experiment Module Pressurized Module (JEM-PM) • Japanese Remote Manipulator System (JEM RMS)
Sept. 10, 2008	N/A	Atlantis STS-125 (HST-SM4)	• N/A
Under review	15A	Endeavour STS-119	• Fourth starboard truss segment (ITS S6) • Fourth set of solar arrays and batteries

Under review	ULF2	Discovery STS-126	• Multi-Purpose Logistics Module (MPLM)
Under review	2J/A	Endeavour STS-127	• Kibo Japanese Experiment Module Exposed Facility (JEM EF) • Kibo Japanese Experiment Logistics Module - Exposed Section (ELM-ES) • Spacelab Pallet - Deployable 2 (SLP-D2)
Under review	17A	Discovery STS-128	• Multi-Purpose Logistics Module (MPLM) • Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC) • Three crew quarters, galley, second treadmill (TVIS2), Crew Health Care System 2 (CHeCS 2)
Establish Six Person Crew Capability			
Under review	ULF3	Endeavour STS-129	• EXPRESS Logistics Carrier 1 (ELC1) • EXPRESS Logistics Carrier 2 (ELC2)
Under review	19A	Discovery STS-130	• Multi-Purpose Logistics Module (MPLM) • Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC)
Under review	*ULF4	Endeavour STS-131	• EXPRESS Logistics Carrier 3 (ELC3) • EXPRESS Logistics Carrier 4 (ELC4)
Under review	20A	Discovery STS-132	• Node 3 with Cupola
Under review	*ULF5	Endeavour STS-133	• EXPRESS Logistics Carrier 5 (ELC5) • EXPRESS Logistics Carrier 1 (ELC1)

* Two shuttle-equivalent flights for contingency

Chairman UDALL. This hearing will come to order. Good morning to all of you who have assembled here. I want to begin by welcoming all of our witnesses to today's hearing. This morning we will be examining NASA's Space Shuttle and International Space Station programs. I think it is appropriate that we consider both of these programs at the same hearing since the Shuttle and Station activities are tightly coupled and issues affecting one program can have a direct impact on the other.

As we all know, NASA successfully completed its Shuttle mission to the ISS last month, and another Shuttle mission to the ISS is scheduled for early next month. And by all accounts last month's STS–117 flight was a very challenging ISS mission during one of the hardest parts of the Station's assembly phase.

It is a testament to the skill of the entire NASA team that they have made assembling the ISS in orbit look relatively easy, when the reality is that it is anything but easy.

So in that spirit I want to congratulate you, Mr. Gerstenmaier, on last month's success and wish you well on next month's mission.

NASA also is preparing for next year's Shuttle mission to service the Hubble Space Telescope. Many of us were very concerned when that servicing mission was canceled by the previous NASA Administrator, and I am pleased that it is back on the Shuttle manifest. We all look forward to hearing about its status at today's hearing as well.

However, assembling the ISS and servicing Hubble are only two of the challenges that NASA will need to address over the next several years in its human space flight programs. The Space Shuttle is scheduled to be retired upon the completion of the ISS at the end of this decade, and there are a great many issues that will need to be addressed during this transition period, and dealing with workforce concerns is clearly an important one.

This subcommittee held an initial hearing on NASA's workforce in May, and I anticipate that we will examine NASA's plans for the Shuttle workforce, including its legislative proposals, in greater detail at another hearing later this year.

Another area of great concern is how the ISS will be supported logistically once the Shuttle is retired. It is not yet clear that NASA's budget for logistical support of the Station is sufficient for the task or that all of the planned capabilities will be available when needed. I hope that today's hearing will shed some light on the situation.

Yet all of the work being done to assemble the Station and support it logistically is not meant to be an end in itself. Rather, it is the degree to which it is utilized productively that will determine the ultimate success or failure of the ISS.

That is why a number of us have been so concerned about the severe cutbacks in NASA's Space Station research program and budget over the past several years. Those cuts have largely decimated the research community that had planned to use the Station, with potentially serious implications for the productivity of the Station as a research facility once it is assembled.

In addition, NASA has yet to develop a well-defined research program for the Station that contains clear milestones, prioritized research objectives and experiments, and resource requirements. We

all understand that funding is tight and that funding for the Station research has to compete with other NASA priorities.

However, the Nation has invested substantial funds over many years to develop and build the Station. And the NASA team represented by Mr. Gerstenmaier worked hard to make the Station a reality. It seems to me that we need to insure that the Nation gets an adequate return on that investment.

We have a great many issues to cover at today's hearing, and again, I want to welcome our witnesses, and I look forward to your testimony.

The Chair now with great pleasure recognizes Mr. Feeney, the Ranking Member, for his opening statement.

[The prepared statement of Chairman Udall follows:]

PREPARED STATEMENT OF CHAIRMAN MARK UDALL

Good morning. I want to welcome all of our witnesses to today's hearing.

This morning we will be examining NASA's Space Shuttle and International Space Station programs. I think that it's appropriate for us to consider the programs at the same hearing, since the Shuttle and Station activities are tightly coupled and issues affecting one program can have a direct impact on the other.

As you know, NASA successfully completed a Shuttle mission to the ISS last month, and another Shuttle mission to the ISS is scheduled for early next month. By all accounts, last month's STS–117 flight was a very challenging ISS mission during one of the hardest parts of the Station's assembly phase. It is a testament to the skill of the entire NASA team that they have made assembling the ISS in orbit look relatively easy, when the reality is that it is anything but easy!

So I want to congratulate you, Mr. Gerstenmaier, on a last month's success and wish you well on next month's mission.

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We all understand that funding is tight, and that funding for ISS research has to compete with other NASA priorities. However, the nation has invested substantial funds over many years to develop and build the International Space Station. And the NASA team represented by Mr. Gerstenmaier has worked hard to make

the ISS a reality. It seems to me that we need to ensure that the nation gets an adequate return on that investment.

Well, we have a great many issues to cover at today's hearing. I again want to welcome our witnesses, and I look forward to your testimony.

Mr. FEENEY. Well, thank you, Chairman, for holding today's important hearing on the Space Shuttle and International Space Station, where we will examine the interrelationships between these programs and gain insight about supporting and operating the ISS in the post-Shuttle era.

As you know, Mr. Chairman, many of my constituents at Kennedy Space Center prepare Space Station components and the Space Shuttle for launch. I appreciate the fact that you are considering holding a hearing later this year to examine NASA's Shuttle to Constellation transition planning, which is very important in my district as well as many other areas that are interested in space.

I look forward to working with you on this hearing. We can't repeat past mistakes like the Apollo to Shuttle transition where America frittered away hard-earned, space-faring skills which are almost impossible to replace.

NASA faces many challenges, both now and in the future, chief among them is to safely maintain the International Space Station, support its research agenda, and insure the safety of the crews while transitioning to the new Orion spacecraft and the Ares launch vehicles. To do this NASA intends to increase reliance on our international partners and the new Commercial Orbital Transportation System capacity, COTS. We need to better understand the implications of this strategy, and in fact, I note that Mr. Holloway in his testimony expresses some concerns about heavily relying on COTS until it is a proven technology. I hope to explore that today.

In the post-Shuttle era COTS will hopefully provide a viable replacement of the Shuttle's capability to deliver cargo and crew to the International Space Station. Establishing private commercial providers to perform these tasks will bring a new and much desired dimension to space faring.

NASA may also increase its reliance on international partners. The Russians will continue to play a significant role but NASA also plans to use the European Automated Transfer Vehicle that will have roughly three times the cargo capability of Russian progress. Development of the ATV has been delayed, but the first one is currently being shipped to its French Guiana launch site with launch scheduled for January of next year. If we become more reliant on the international community, I want to understand the effect of the International Traffic in Arms Regulation restrictions on NASA's ability to work with our international partners, and, again, Mr. Holloway's report addresses some concerns in that area.

As NASA works to complete the International Space Station it should fully examine the capabilities for exploration-related as well as non-exploration related International Space Station research. The success of the International Space Station as a National Laboratory depends in part on maintaining sufficient research capabilities, which the Chairman mentioned in his opening remarks, needed to prepare humans for long-duration lunar missions among other things.

I remain vigilant about the temptation to backslide into pre-*Columbia* behavior, burdening NASA to do too much with too little. Demands on NASA must be tempered. Furthermore, this Administration and Congress must deliver the resources needed to complete what has been assigned. That means adequate budgets in fiscal year 2008, and beyond.

I am concerned about this year's appropriations. The $18 million reduction from NASA's request for International Space Station reserves and the $85 million reduction in needed replacements for the tracking and data relay satellite system represent a fiddling at the margins that cumulatively invites more serious consequences down the road.

When the world thinks of NASA, it envisions human space exploration. We are once again laying the foundation to explore beyond low-Earth orbit. Human space flight is one of the most inspirational undertakings we do as a nation. Indeed, other nations now strive to emulate our successes because they recognize the great national prestige that accompanies human space exploration.

By the way, I have been heartened in reading the testimony of the witnesses about where we are in the space program today. Looking back, I was a newly elected Congressman a couple of weeks into my tenure when we had the last disaster, and it is with a great deal of optimism that I read the remarks and the testimony about where we are today given where we could be.

Finally, NASA often makes the difficult look easy, but significant challenges await. I welcome today's distinguished panel, and thank you for taking the time to help us better understand and prepare for those challenges. In particular, I want to thank Mr. Bill Gerstenmaier and thank you for your long-term, dedicated service.

With that, Mr. Chairman, again, I appreciate the work that you and the staff has done to prepare us for this hearing.

[The prepared statement of Mr. Feeney follows:]

PREPARED STATEMENT OF REPRESENTATIVE TOM FEENEY

Thank you Mr. Chairman for holding today's important hearing on the Space Shuttle and International Space Station (ISS). We will examine the interrelationships between these programs and gain insight about supporting and operating ISS in the post-Shuttle era.

As you know Mr. Chairman, many of my constituents at the Kennedy Space Center prepare Space Station components and the Space Shuttle for launch. I understand you are considering a hearing later this year to examine NASA's Shuttle to Constellation transition planning. I look forward to working with you on this hearing. We can't repeat past mistakes—like the Apollo to Shuttle transition—where America frittered away hard-earned spacefaring skills.

NASA faces many challenges, both now and in the future. Chief among them is to safely maintain the International Space Station, support its research agenda, and ensure the safety of the crews, while transitioning to the new Orion spacecraft and Ares launch vehicles. To do this, NASA intends to increase reliance on our international partners and the new Commercial Orbital Transportation System capability (COTS). We need to better understand the implications of this strategy.

In the post-Shuttle era, COTS will hopefully provide a viable replacement of the Shuttle's capability to delivery cargo and crew to ISS. Establishing private commercial providers to perform these tasks would bring a new and much desired dimension to spacefaring.

NASA may also increase its reliance on international partners. The Russians will continue to play a significant role. But NASA also plans to use the European Automated Transfer Vehicle (ATV) that will have roughly three times the cargo capability of the Russian Progress. Development of the ATV has been delayed. But the first one is currently being shipped to its French Guiana launch site with launch

scheduled for January 2008. If we become more reliant on the international community, I want to understand the effect of the ITAR (International Traffic in Arms Regulation) restrictions on NASA's ability to work with our international partners.

As NASA works to complete the ISS, it should fully examine the capabilities for exploration-related, as well as non-exploration-related ISS research. The success of ISS as a National Laboratory depends in part on maintaining sufficient research capabilities needed to prepare humans for long duration lunar missions.

I remain vigilant about the temptation to backslide into pre-*Columbia* behavior—burdening NASA to do too much with too little. Demands on NASA must be tempered. Furthermore, this Administration and Congress must deliver the resources needed to complete what has been assigned. That means adequate budgets in FY08 and beyond. I'm concerned about this year's appropriations. The $18 million reduction from NASA's request for ISS reserves and the $85 million reduction in needed replacements for the Tracking and Data Relay Satellite System represent a fiddling at the margins that cumulatively invites more serious consequences.

When the world thinks of NASA, it envisions human space exploration. We are once again laying the foundation to explore beyond low-Earth orbit. Human space flight is one of the most inspirational undertakings we do as a nation. Indeed, other nations now strive to emulate our successes because they recognize the great national prestige that accompanies human space exploration.

NASA often makes the difficult look easy, but significant challenges await. I welcome today's distinguished panel and thank you for taking the time to help us better understand and prepare for those challenges. In particular, I want to welcome Bill Gerstenmaier and thank you for your dedicated service.

Chairman UDALL. Thank you, Mr. Feeney. At this point I would like to make it clear that if there are Members who wish to submit additional opening statements, those statements will be added to the record. Without objection, so ordered.

At this time I would like to introduce our panel of witnesses today, and I will introduce all four witnesses, and then we will move back to my left, and we will start with Mr. Gerstenmaier. Mr. Bill Gerstenmaier is here as we have mentioned, both Mr. Feeney and myself, who is the associate administrator for the Space Operations Mission Directorate at NASA.

And next to him with have Mr. Tommy Holloway, who was the Chairman for the ISS Independent Safety Task Force Report, which was completed in February of 2007.

Next to Mr. Holloway, Dr. Paul Neitzel, who is a Professor of Fluid Mechanics at the Georgia Institute of Technology.

And finally we have Ms. Cristina Chaplain, who is a Director of Acquisition and Sourcing Management at the Government Accountability Office.

Welcome to all of you. I think all of you know that spoken testimony is limited to five minutes, after each and after which the members of the Subcommittee will have five minutes each to ask questions.

We will start with Mr. Gerstenmaier.

STATEMENT OF MR. WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR, SPACE OPERATIONS MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. GERSTENMAIER. Chairman Udall, Ranking Member Feeney, thank you for inviting me here today. It is my privilege and pleasure to represent the International Space Station and Space Shuttle teams. I have attempted to answer your questions in my written statement, and I will use my opening remarks to expand slightly

on my written statement and provide kind of the latest status of where we are with both Shuttle and Station.

This is a very dynamic time in both programs. It has also been a very exciting time because the work we are doing now directly supports the future of human space exploration. Lessons we have been learning and will continue to learn as we live and work aboard the Space Station will help when we undertake our new exploration to the Moon, take our first steps on Mars, and the United States leads to the expansion of humanity's reach into the solar system beyond the current confines of low-Earth orbit. The work we are doing today clearly helps and supports those activities in the future.

Take, for example, yesterday the Space Station crew performed a seven-hour and 41 minute space walk to complete several critical tests for the continued assembly of the Space Station. Mostly likely you have heard about how the crew disposed of the early ammonia servicer device carrying 300 pounds of ammonia. It had to be removed to allow for the P–6, the truss that sits up on top, to be moved to a new location on STS–120 scheduled for launch in October.

But the thing that is important is they did many other tests as well. They changed data remote power control module, an electronic circuit breaker. This device provides power, a redundant power to the mobile transporter. That is the crane that runs up and down the truss of the Space Station. That crane needs to be in a position to install the trusses that is delivered on this next Shuttle flight. So that circuit breaker had to be changed out to allow the Shuttle flight to occur and be launched.

They also cleaned some debris off of a seal. The teams went ahead and actually took the arm earlier and looked at a seal on the outside of the Space Station. This is a pressure seal that is, allowed the modules to, when they back together, to be sealed and keep the vacuum away from the side. We noticed some debris that had accumulated on that seal. It was carried up in the Shuttle on one of the seals and got stuck there. The crew went out and cleaned that debris off so then we can move another mating adaptor there. And that activity is critical to an event that will occur later this month.

And the last thing that they did was, I think the thing that is important to see how all these are connected to the future events and future flights. They are not just related to the next flight, but they are related to a flight that may be occurring in the fall or maybe occurring in activity later this month. And that is the complexity of the Space Station. All the tasks are interrelated. There is not a single dimension. There are multiple interactions between all the different pieces.

While the Space Station team was doing the space walk, the Shuttle team was busy getting the Shuttle ready for launch down in Florida. The teams have done a good job getting that vehicle for launch on August 7. Tomorrow we will do, begin a two-day readiness review to make sure that everything is ready for that flight, but everything appears on track. The weather has been a little tough in Florida in the afternoons, so there has been a lot of thunderstorms, and the teams have been able to work around those thunderstorms as this process moves forward and things look pret-

ty good, and we will have an extensive two-day review, and we should be ready for launch on August 7.

Again, I think the teams have established a strong rhythm moving forward with assembly. We recovered from the hail damage that occurred to the tank earlier this year. That was an amazing team effort across the teams to get that tank repaired. That tank performed exactly as it was designed, did exactly what it was supposed to do. We repaired about 6,000 damages sites on that tank, and the team did a phenomenal job with that.

So, again, I think things are moving forward, and we are posed for the future. The work we are doing today postures us well for the activities in the future. And I look forward to your questions.

[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 Space Shuttle and the International Space Station (ISS). 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 Space Shuttle and ISS programs, discuss the challenges over the next five years, and share with you some of our success stories.

Only a few weeks ago, the Shuttle made an unscheduled stop at the Rick Husband Amarillo International Airport in Texas. Resting atop its modified Boeing 747 carrier, the Shuttle *Atlantis* was returning to NASA's Kennedy Space Center (KSC) in Florida following a successful mission to the ISS. While the Shuttle waited in sunny Amarillo for better weather on its planned flight to KSC, television news coverage showed hundreds of people gathering around the airport perimeter to catch a glimpse of the Shuttle. A spontaneous American pilgrimage ensued. Some drove hours and took time off work. Parents brought their children and paid homage to their space program. The children and the grownups were in awe at the sight of *Atlantis*.

Amarillo should remind all of us that the American public, in the face of challenges, even tragedy, values exploration and the contributions of the Space Shuttle and the ISS. NASA captures the imagination of Americans to reach farther, create opportunities, and live beyond the confines of our environment.

International Space Station (ISS)

With each new assembly and logistics flight, with each additional year of continuous habitation, the ISS continues to grow in both size and capability. In the second half of 2006, NASA successfully completed three Space Shuttle missions, including ISS–12A (STS–115) and ISS–12A.1 (STS–116), which continued ISS assembly with the addition of the P3, P4, and P5 truss segments. In June 2007, ISS–13A (STS–117) added the S3 and S4 truss segments, further boosting available power on the ISS to 42 kilowatts. This flight allowed for the final step in activating the permanent power and thermal systems on ISS. All of these new systems continue to operate flawlessly. As of the ISS–13A mission, the ISS is now almost 250 tons, which represents approximately 57 percent of the mass of the ISS once it is completed in 2010. The pressurized volume has grown to 14,509 cubic feet, representing approximately 45 percent of the final configuration, and ten of the twelve truss segments and three of the four U.S. solar arrays are already on-orbit.

Our state of preparedness for the upcoming missions is also very high, with the ground-based teams exercised and fully engaged as a result of the recently completed orbital assembly operations. In the second half of calendar year 2007, three more Space Shuttle missions remain on schedule to deliver the S5 truss segment, Node 2, and the first partner laboratory. The flight readiness review for the first of these missions, ISS–13A.1 (STS–118), will start tomorrow, July 25, 2007, in preparation for a launch no earlier than August 7. Together, ISS–13A.1 and the subsequent mission, ISS–10A (STS–120), will complete the major U.S. pressurized elements of the Station, after which we will turn our attention to fulfilling commitments to our international partners.

Europe, Japan and Canada are preparing for an exciting period in human space flight as their elements launch over the next year. These will include the European laboratory *Columbus,* the Japanese laboratory Kibo and its pressurized logistics

module, and the Canadian dexterous remote manipulator system Dextre. All of these elements have been delivered to KSC and are going through their final preflight checkouts and launch preparations. In addition, the European Autonomous Transfer Vehicle is scheduled for its maiden flight in early 2008.

The ISS is also proceeding well along the path towards seeing the crew size expand from three to six in 2009. The U.S.-built oxygen generation system (OGS) has been integrated in the U.S. laboratory Destiny, and successfully demonstrated its ability to produce oxygen on July 13. The water recovery system has completed development and is awaiting launch in late 2008, thus completing the regenerative environmental control and life support system.

In addition to the Space Shuttle assembly missions, we must not forget about the critical work being done on ISS every day. Since the last Space Shuttle mission, 1.8 million lines of software have been updated. This major update occurred with little fanfare but was critical to future assembly. In addition, NASA preparations for STS–118 include a spacewalk by Expedition 15 astronauts Fyodor Yurchikhin and Clay Anderson to replace a failed remote power converter and clearing the P6 for movement on STS–120 by jettisoning the early ammonia servicer. Building, servicing, and utilizing the ISS is a twenty-four hour a day, seven day a week job for the ground controllers and crews—exactly the type of training that is needed to prepare our teams and our systems for long-duration missions to the lunar surface, to Mars, and beyond.

The Congressionally-mandated ISS Independent Safety Task Force (IISTF) completed its work in February and found the program to be "robust and sound. . .with respect to safety and crew health." The Task Force made seven principal recommendations that would further strengthen the ISS program by increasing the likelihood of mission success and mitigating risks to crew safety. NASA has taken action on those principal recommendations that are within our ability to effect, such as installation of Russian-built debris panels on their service module to reduce the risk of micrometeoroid and orbital debris impacts. We continue to monitor the performance of the debris protection system through regular inspections with the ISS robotic arm, through Space Shuttle "fly arounds," and during extra-vehicular activities (EVAs) performed by the astronauts. All debris impacts seen so far are within the design capability of the ISS and are being recorded to improve our analytical debris models.

With respect to the remaining IISTF recommendations, NASA has implemented a workforce strategy to ensure the Agency retains critical skills necessary to sustain the ISS. The Agency also remains on track to support completion of the current Space Shuttle flight plan for ISS assembly. The Agency may fly up to two additional ISS logistics flights if they are deemed necessary and can be flown before the end of 2010. The IISTF recommendation to comprehensively review the European ATV logistics flight has been closed based on the review completed January 8, 2007.

We have also completed development and installed the first of two Space Station-to-Shuttle power transfer systems (SSPTS) on the orbiter *Endeavour* for testing and verification on ISS–13A.1. SSPTS allows power generated by the ISS solar arrays to be transferred to, and used by, the Space Shuttle while docked to the ISS. This capability will allow the orbiters to remain docked at the ISS an additional three to four days, thereby extending our ability to conduct planned and unplanned EVA activities during the very complex assembly operations that lie ahead.

We continue to employ the Station's unique attributes for the advancement of science and technology. During Expedition 14, there were thirty-two U.S. experiments conducted, and in Expedition 15 another twenty-one are underway. These range across the life and physical sciences, and highlight growing interest in use of the microgravity environment to advance knowledge in the fields of microbiology, genetics, bacteriology, and the metabolic nature of chronic human diseases. The upcoming ISS–13A.1 assembly mission will include research designed by Amgen, Inc., a leading Fortune 500 human therapeutics company in the biotechnology industry.

A primary focus for U.S. research on ISS is to find ways of mitigating risks associated with long-duration human exploration of the Moon and Mars. These risks include a broad range of physiological and psychological issues, including those associated with extended operations in reduced and microgravity environments (such as accelerated bone loss, adaptation to changing gravity loads, muscle loss, changes to cardiovascular functions, altered immune system responses, and drug effectiveness), guaranteeing proper nutrition and medical support while operating far from Earth, improving ergonomics and human-machine interfaces, and ensuring effective crew performance and cohesiveness. The ISS is critically important to the success of future long-duration missions specifically because it is the only facility that combines the ambient environment and research capabilities needed to understand the extent of these risks with the ability to develop and test appropriate countermeasures.

Research underway during the assembly phase is a prelude to future operation of the U.S. portion of the ISS as a National Laboratory as directed by Section 507 of the *NASA Authorization Act of 2005* (P.L. 109–155). On May 30, 2007, NASA submitted to the Subcommittee a report required by Section 507(c) which outlined the Agency's plans for operating the ISS as a National Laboratory, including progress in implementing a broad ISS applications development initiative and the prospects for productive utilization of the ISS in the post-assembly timeframe. This initiative is just beginning in anticipation of completing ISS assembly in 2010, and holds the promise for highly productive public and private partnerships in research and development—provided that needed space transportation services are available in the future.

With respect to the logistical requirements for ISS operations and utilization after the retirement of the Shuttle, on March 1, 2006, as required by Section 505 (c)(2) of the *NASA Authorization Act of 2005* (P.L. 109–155), NASA submitted to the Subcommittee a report outlining contingency plans for logistics and on-orbit capabilities for the ISS. These plans include using the Space Shuttle to preposition key spares, working with industry to demonstrate and then utilize commercial services for transporting crew and cargo to the ISS, using the Crew Exploration Vehicle to supply the ISS if commercial services are unavailable, and working with International Partners to develop additional capacities in the event they become necessary. As of today, our plans remain the same as outlined in this report,

Space Shuttle

As we reflect upon the four successful Space Shuttle missions (STS–121, –115, –116, and –117) conducted in the last 11 months and get back into the rhythm of launching every couple of months, it is important to keep in mind that flying these vehicles is neither easy nor routine.

The Space Shuttle is an extraordinarily capable transportation system, and it takes an equally extraordinary team to operate that system safely, time after time, mission after mission. When you are working on a construction site that is 200 nautical miles above the Earth's surface and that is dominated by hard vacuum and extreme temperature fluctuations, preparedness is essential for mission success. At Kennedy Space Center alone, hundreds of thousands of work-hours are needed to prepare the hardware for flight. For every hour a crew member spends outside on an EVA during a mission, seven hours are spent in the training pool at the Neutral Buoyancy Laboratory at the Johnson Space Center in Texas practicing skills and choreographing each maneuver. The contributions of thousands of highly trained people from across our Nation and around the world need to be seamlessly brought together to develop integrated mission operations plans with our international partners, to properly equip and train ground and flight crews, and to coordinate launch and mission support activities across six continents.

Our two biggest challenges over the next few years are maintaining the hard-won critical skills we need to safely fly out the Shuttle manifest and helping our workforce make a smooth transition to the post-Shuttle era. To address this concern, we have benchmarked other enterprises that have shut down major operations to implement best practices to retain our critical people. Although financial incentives can play a key role in employee retention, our best tool to retain employees is to provide meaningful and challenging work. We are doing this now through the challenging and exciting ISS assembly missions. Looking towards the future through retraining, job rotations, and other mechanisms, we are working hard to give people an opportunity to transition the skills learned flying the Shuttle to the design and operation of the next generation of vehicles.

When we fly systems as capable and as complex as the Space Shuttle and the ISS in such a dynamic environment, we have to always be prepared for the unexpected and agile enough to react quickly and effectively. For example, weather considerations often play an important role in our mission planning, and severe weather conditions can have a significant impact on our operations. Such was the case on February 26, when an intense hailstorm struck the STS–117 vehicle as it was sitting on the launch pad and caused extensive damage to the foam on the external tank.

That damage forced a roll-back to the Vehicle Assembly Building, where crews could build work platforms for controlled access to the vehicle. Within three months, NASA engineers and technicians analyzed over 6,000 discreet areas of foam damage, developed special tools and techniques and made repairs where necessary. Though the damage to the tank was extensive, our experience with various external tank foam repair techniques—combined with the powerful analytical tools developed during Return to Flight activities—enabled us to do the analysis and repairs swiftly and with a high degree of engineering confidence.

Over the coming years, NASA will need to remain agile and focused on technical excellence if the Agency is to complete the important work that is in front of us. NASA has 13 missions on the manifest over the next 38 months, including 12 assembly flights to the ISS and a servicing flight to the Hubble Space Telescope. NASA could potentially also fly up to two contingency logistics flights to the ISS to preposition spares for the post-Shuttle era if these flights are deemed necessary and can be flown before the end of 2010. Even if NASA flies both contingency flights, the pace (which equates to four or five flights a year between 2008 and 2010) would still be consistent with the Agency's recent experience in flying three Space Shuttle missions (STS–121, –115, and –116) during the last six months of 2006.

Barring further significant disruptions, NASA should be able to recover from the STS–117 launch delay and be back to plan by mid-2008. The rule that we will always follow is that, "We will fly only when we are ready to fly. As always, the safety of our crew members is our paramount consideration."

The next mission, STS–118 (ISS–13A.1), to deliver and install the S5 truss segment, is in the final stages of preparation at Launch Complex–39A at KSC. Although STS–118 is targeted to be launched on August 7, we are mindful that the Phoenix Mars Lander Mission, scheduled to be launched from Cape Canaveral on a Delta II on August 3, has a 20-day planetary launch window that, once it expires, does not return for two years. STS–118 is the first flight of *Endeavour* since the fall of 2002, and the vehicle has received sufficient structural inspections and modifications to enable it to fly through 2010 without additional major modifications. During this flight, *Endeavour* will, for the first time, use the Global Positioning System for navigation purposes and power generated by the ISS solar arrays while docked to the ISS.

Two more missions are scheduled for flight this year. During STS–120 (ISS–10A) in October, *Discovery* will carry Node 2 to the ISS. Installing Node 2 will be extremely challenging both during the Shuttle mission and afterwards, with two EVAs scheduled to reposition the node after the Shuttle departs ISS. While the next mission still may need to be moved slightly, the December launch of STS–122 (ISS–1E) will see *Atlantis* transporting the European Space Agency's *Columbus* module.

As we continue our preparations for these upcoming flights, we are also continuously improving the overall safety of the Space Shuttle system. Substantial progress has been made in preparing two important upgrades for deployment into the fleet—the Advanced Health Monitoring System (AHMS), and redesigns to the thermal protection system on the external tank. The first, AHMS, is an upgrade to the Space Shuttle main engines, one of the most complex elements of the Space Shuttle system and one of our highest areas of interest from an overall probabilistic risk perspective. Specifically, AHMS improves our ability to monitor the performance of the Space Shuttle main engines during flight and, under certain circumstances, can initiate a controlled shutdown of a suspect main engine during ascent. An AHMS controller was flown for the first time in a passive, monitoring mode on one engine for STS–116 in December, 2006, then in an active (control) mode on one engine for STS–117 in June. AHMS controllers will be installed and in active mode on all three engines starting with STS–118.

A second improvement effort has focused on continuing to reduce the debris risk posed by foam being released from the external tank during ascent. In addition to our continuous foam application process improvement efforts, we recently completed a critical design review for changes to the liquid hydrogen ice-frost ramps and liquid oxygen feedline bracket. The new ice-frost ramp design will be implemented on External Tank 120, currently scheduled to support mission STS–120 later this year. The ice-frost ramp and the feedline bracket redesigns will be flown together on External Tank 128, which will be flown before the Hubble Space Telescope servicing mission currently scheduled for September 2008.

Summary

I believe that we are living in one of the most exciting eras so far in the history of space exploration. There are challenges in front of us, to be sure, and we will have to be ready to respond to the unexpected. But no one is more prepared to confront and overcome these challenges than the international team of engineers and technicians that are flying the ISS and the Space Shuttle today. And as we look towards future flights to the Moon, Mars, and beyond (where self-sufficiency, independency and, above all, adaptability will mark the difference between success and failure), I can think of no better preparation than the work we're doing right now to complete the ISS and take best advantage of this unique research facility.

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

BIOGRAPHY FOR WILLIAM H. GERSTENMAIER

William H. Gerstenmaier is the Associate Administrator for Space Operations. In this position, Gerstenmaier directs NASA's human exploration of space. He also has programmatic oversight for the International Space Station, Space Shuttle, space communications and space launch vehicles.

Formerly Gerstenmaier was the program manager of the International Space Station Office at NASA's Johnson Space Center in Houston, and was responsible for the overall management, development, integration, and operation of the International Space Station.

In 1977, Gerstenmaier began his NASA career at the Glenn Research Center in Cleveland, Ohio, performing aeronautical research. He was involved with the wind tunnel tests that were used to develop the calibration curves for the air data probes used during entry on the Space Shuttle.

Beginning in 1988, Gerstenmaier headed the Orbital Maneuvering Vehicle (OMV) Operations Office, Systems Division at Johnson Space Center, where he was responsible for all aspects of OMV operations. Subsequently, he headed Space Shuttle/Space Station Freedom Assembly Operations Office, Operations Division and was Chief, Projects and Facilities Branch, Flight Design and Dynamics Division.

Gerstenmaier also served as Shuttle/Mir Program Operations Manager from 1995 to 1997. During this time he was the primary liaison to the Russian Space Agency for operational issues and negotiated all protocols used in support of operations during the Shuttle/Mir missions. In addition, he supported NASA 2 operations from Russia, January–September 1996.

In 1998, Gerstenmaier became manager of Space Shuttle Program Integration, where he was responsible for the overall management, integration, and operations. In December 2000, he was named deputy manager of the International Space Station Program.

Gerstenmaier received a Bachelor of Science in aeronautical engineering from Purdue University in 1977 and a Master of Science degree in mechanical engineering from the University of Toledo in 1981. In 1992 and 1993, he completed course work for a doctorate in dynamics and control with emphasis in propulsion at Purdue University.

Gerstenmaier is the recipient of numerous awards, including three NASA Certificates of Commendation, two NASA Exceptional Service Medals, a Senior NASA Outstanding Leadership Medal, and the Presidential Rank Award for Meritorious Executives. He also was honored with an Outstanding Aerospace Engineer Award from Purdue University, and additionally, twice by Aviation Week and Space for Outstanding Achievement in the Field of Space.

He is married to the former Marsha Ann Johnson. They have two children.

Chairman UDALL. Thank you, Mr. Gerstenmaier.

Mr. Holloway, the floor is yours. If you would turn on your mike, Mr. Holloway.

Mr. HOLLOWAY. Thank you.

Chairman UDALL. That is better. Thank you.

STATEMENT OF MR. TOMMY W. HOLLOWAY, CHAIRMAN, ISS INDEPENDENT SAFETY TASK FORCE

Mr. HOLLOWAY. Chairman Udall and Ranking Member Mr. Feeney, thank you for the opportunity to appear before you today. I will report on the observations and recommendations of the International Space Station Independent Safety Task Force. I will call it the task force.

As required by the *National Aeronautics and Space Administration's Authorization Act of 2005,* the task force was formed to assess the vulnerabilities of the International Space Station that could lead to is destruction, compromise the health of the crew, or necessitate its premature abandonment.

The task force offered its recommendations in the form of a final report which was submitted to NASA and the United States Congress in February of 2007. These recommendations, if followed,

should strengthen the ISS Program by increasing the likelihood of mission success and mitigating risks to crew safety or health.

I also should stress that if these, for the recommendations to be effective for the ISS to remain a robust and health program, sufficient support from the Administration and the Congress is required to ensure that the resources are provided and the safety-critical aspects of the ISS assembly and operations are enabled and maintained.

ISS is an extremely large and complex vehicle, and at the time of the task force report had a current living volume of 15,000 cubic feet and a weight of 455,000 pounds. Planned assembly will expand that to 33,125 cubic feet and 855,000 pounds. Hardware and software are developed and tested all over the world, launched in Florida and at Baikonur, and assembled on-orbit at an altitude of approximately 215 nautical miles.

Major systems including electrical power, cooling, data handling, and navigational control are distributed throughout the Station and are expanded and integrated as assembly progresses. Station assembly to date has gone exceptionally well and is a tribute to the ISS and Shuttle teams. Anomalies occur but are dealt with quickly and with outstanding results as demonstrated in December, 2006, by the solar wing retraction problem where the space walking astronauts assisted in the retraction of the jammed solar wing.

These factors plus result in a complex and a distributed program with a highly technical and distributed management system that must be staffed by highly-skilled engineers and skilled and experienced managers. Maintaining critical technical and management skills in the ISS Program as the ISS matures and NASA's exploration program staff up will be a challenge requiring proactive and continuing attention by NASA management.

The ISS on-orbit vehicle is a robust and to the extent practicable, meets a two failure-tolerance requirement to minimize the likelihood of a catastrophic event. The Russians and the U.S. systems provide robust redundancy from dissimilar hardware and designs in critical systems such as guidance, navigation, and control, environmental control and lift support, and crew/cargo transportation. For most safety-related issues, time is available to mitigate vulnerabilities by switching to redundant systems, performing maintenance repairs by the crew, or relying on consumable reserves until a future logistics flight can be launched to the Station.

Time-critical exceptions to these failure tolerances are uncontrolled fire, collision with micrometeoroid or orbital debris, toxic spills, or collision with a visiting vehicle. However, the task force found that the system's design, testing, and adherence to operational procedures provide adequate controls or that adequate mitigations are being developed by NASA for these conditions.

I will now summarize the principal observations and recommendations of the task force. First of all, the observations.

The International Space Station is currently a robust and sound program with respect to safety and crew health. Safety and crew health issues are well documented and acceptable and are either adequately controlled or mitigations are being developed to maintain acceptable risks.

The ISS program has strong and proactive crosscutting functions that, if continued, should provide adequate indications and warnings that will avoid events that might lead to destructions of the Station.

The International Space Station currently has an experienced and knowledgeable and proactive team, both internally and in institutional technical checks and balances, that provides the defense for process and management failures that might lead to a safety or health issue. This posture must be maintained to continue the Station's successful operations.

Micrometeoroid and orbital debris penetrating the living quarters or damaging critical equipment is highly, a high safety risk to the crew and the Station.

There are significant programmatic risks associated with completing the ISS Shuttle manifest and providing robust post-Shuttle logistics capability that threaten the ability to support a viable station.

Design, development, and certification of the new COTS System capability for ISS re-supply are just beginning. If similar to other new programs, it most likely will take much longer and cost much more.

Current International Traffic in Arms Regulation restrictions on NASA are a threat to the safe and successful integration and operation of International Space Station.

Principle recommendation of the task force are the International Space Station Program should place the highest priority on options to decrease the risk of micrometeoroid and orbital debris.

NASA should develop and implement plans to maintain Station critical skills and experienced managers.

The Administration, Congress, and NASA should support the completion of the current Shuttle manifest to the International Space Station, including ULF–4 and ULF–5 to assemble a viable station and provide spares for the long-term operations.

The Administration, Congress, and NASA should support a proactive and phased post-Shuttle logistics transportation program, including adequate funding to insure that adequate logistics and spares are available to maintain a viable Station.

Department of State should grant immediate relief from the International Traffic in Arms Regulation restrictions in the form of an exception to allow NASA contractors to direct interaction with the International Space Station's International Partners and their contractor.

Other details of the principle recommendations as well as additional recommendations can be found in the body of the report, "Final Report of the IISTF Task Force."

And finally, it should be noted that NASA's support and responsiveness to the task force was excellent through the process of developing the data and material required to accomplish the charter of the task force. The program manager and his team supported the technical review meetings and provide invaluable insight and technical data on the issues associated with the task force charter.

Thank you very much.

[The prepared statement of Mr. Holloway follows:]

PREPARED STATEMENT OF TOMMY W. HOLLOWAY

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear before you today. I will report to you on the observations and recommendations of the International Space Station Independent Safety Task Force.

As required by the *National Aeronautics and Space Administration (NASA) Authorization Act of 2005* (Public Law 109–155), the International Space Station Independent Safety Task Force (IISTF) was formed to assess vulnerabilities of the International Space Station (ISS) that could lead to its destruction, compromise the health of its crew, or necessitate its premature abandonment. The Task Force offered its recommendations in the form of its final report which was submitted to NASA and the United States Congress in February of 2007. The Task Force recommendations, if followed, should strengthen the ISS Program by increasing the likelihood of mission success and mitigating risks to crew safety or health. It is important to stress that, for these recommendations to be effective and for the ISS to remain a robust and healthy Program, sufficient support from the Administration and Congress is required to ensure that resources are provided and the safety-critical aspects of ISS assembly and operations are enabled and maintained.

The ISS Program is an international partnership comprised of the United States, Russia, Canada, the members of the European Space Agency, and Japan. Some 16 countries are in the partnership or involved via bilateral agreements with a Partner in building, operating, and using the ISS. This partnership will continue throughout the operational (post-assembly) phase of the Program, where NASA will continue to be responsible for the sustaining engineering, operation of NASA's elements, and integration of the Station.

The ISS is an extremely large and complex vehicle and at the time of the IISTF report had a current living volume of 15,000 cubic feet and a weight of 455,000 pounds. Planned assembly will expand it to 33,125 cubic feet and 855,000 pounds. Hardware and software are developed and tested all over the world and are assembled and operated on orbit at an altitude of approximately 215 nautical miles. Major systems including electrical power, cooling, data handling, and navigational control are distributed throughout the Station and are expanded as assembly progresses. Station assembly to date has gone exceptionally well and is a tribute to the ISS and Shuttle teams. Anomalies occur but are dealt with quickly and with outstanding results as demonstrated in December 2006 by the solar wing retraction problem on ISS flight 12A.1/STS–116, where the spacewalking astronauts assisted in the retraction of the jammed solar array wing.

These factors result in a complex and distributed program with a highly technical and distributed management system that must be staffed by highly skilled engineers and skilled, experienced managers. Maintaining critical technical and management skills in the ISS Program as the ISS matures and NASA's exploration program staffs up will be a challenge requiring proactive and continuing attention by NASA management.

NASA depends heavily on U.S. contractors for technical support of Station integration and for vehicle operations. These contractors are the source of data and expertise that are critical in ensuring mission safety and success, and their timely participation is essential to meeting mission schedules. Due to the international nature of the ISS Program, this support requires mandatory interfaces with NASA's International Partners (IPs).

Currently the International Traffic in Arms Regulation (ITAR) restrictions and IP objections to signing what the IPs believe are redundant Technical Assistance Agreements are a threat to the safe and successful integration and operation of the Station. For example, a contractor workforce comprises a majority of the operations workforce and must be able to have a direct interface with the IP operations team to assure safe and successful operations. Their interactions and their ability to exchange and discuss technical data relevant to vehicle operations are severely hampered by the current ITAR restrictions. This is an issue across the ISS Program, but must be resolved soon to allow operations training for the first flight of the European Space Agency's Automated Transfer Vehicle (ATV) in the first part of 2008.

The ISS on-orbit vehicle is robust and, to the extent practicable, meets a two failure-tolerance requirement to minimize the likelihood of catastrophic events. The Russian and U.S. systems provide robust redundancy from dissimilar hardware and designs in critical systems such as guidance, navigation, and control; environmental control and life support; and crew/cargo transportation. For most safety-related issues, time is available to mitigate vulnerabilities by switching to redundant systems, performing maintenance/repairs by the crew, or relying on consumables reserves until a future logistics flight can be launched to the Station.

Time-critical exceptions to the failure tolerance requirements are uncontrolled fire, collision with micrometeoroid and orbital debris (MMOD) leading to a major loss of cabin pressure, toxic spills, or a collision with a visiting vehicle. However, the Task Force found that systems design, testing, and adherence to operational procedures either provide adequate controls or that adequate mitigations are being developed for these conditions. For example, the risk of MMOD penetrating the ISS in its Assembly Complete configuration is 55 percent with a nine percent risk of a catastrophic result over a 10-year period. This risk can be reduced to 29 percent and five percent respectively by implementation of changes that are available or being considered for development. It must be recognized that regardless of the efforts put forth, operating in space is, and will be for the foreseeable future, inherently risky and requires continuing discipline and diligence to maintain safe operations.

The transition from the space Shuttle to post-Shuttle system(s) for logistical support to the ISS will require careful planning and phasing of new capabilities to ensure adequate logistics and spares are provided to maintain a viable Station. Approximately 160,000 pounds of logistics and spares must be transported to the Station between 2010 and 2015 by the Russian Progress or emerging transportation systems. The Program's IP's have committed to launch 40,000 pounds of this required 160,000-pound requirement. Premature commitment to emerging logistics delivery capability—if it does not materialize—could result in the loss of logistics support to the ISS for some time. Inadequate logistics will result in a serious decrease in the utility of the Station and could result in its abandonment.

The ISS Program has excellent processes and mechanisms in place on multiple fronts to ensure proper Program execution. A major component of avoiding catastrophic problems is continued diligence in monitoring the ISS system including hardware design, software development, flight preparation, and flight operations to detect and avoid unknown problems or inadequately defined operational environments. The ISS Program must maintain its current level of diligence throughout the life of the Station, never letting previous successes lead to a compromise in the required level of support or attention to detail. NASA manages the health of ISS flight crews with intensive pre-flight medical screening, certification as "fit to fly," regular in-flight health monitoring, and a limited capability to diagnose and treat illness and injuries on board. In a worst-case scenario, a spontaneous health event may necessitate returning the crew to Earth for specialized medical attention, which would result in temporary abandonment of the ISS. Analogue environment data (i.e., Antarctica and submarine populations) and astronaut health events on the ground indicate that, with an ISS crew of six, the Program might expect a spontaneous medical event requiring medical evacuation once every four to six years.

Principal Observations

1. The International Space Station Program is currently a robust and sound program with respect to safety and crew health. Safety and crew health issues are well documented and acceptable, and are either currently adequately controlled or mitigations are being developed to maintain acceptable risk levels.
2. The International Space Station Program has strong and proactive cross-cutting functions that—if continued—should provide advance indications and warnings that will avoid events that might lead to destruction of the Station, loss of the Station crew, abandonment of the Station, or development of untoward crew health issues. The International Space Station Program's operating procedures and processes are thorough and sound.
3. The International Space Station currently has an experienced, knowledgeable, and proactive team, both internally and in its institutional technical checks and balances, that provides the defense for process and management failures that might lead to an ISS safety or major crew health issue. This posture must be maintained to continue the Station's successful operation.
4. Micrometeoroid and orbital debris penetrating the living quarters or damaging critical equipment is a high safety risk to the crew and the Station.
5. Spontaneous crew illness is a significant crew risk and may necessitate returning the crew to Earth for specialized medical attention, which would result in temporary abandonment of the Station. International Space Station medical and Program management officials are taking all reasonable precautions to minimize this risk.
6. There are significant programmatic risks associated with completing the ISS Shuttle manifest and providing robust post-Shuttle logistics capabilities that threaten the ability to support a viable Station.

7. Workforce composition is a growing concern throughout NASA because of the technical and specialized nature of most of the agency's work and the large-scale program transition now under way. The International Space Station Program is vulnerable to critical management losses, making strategic workforce planning as important as ever.
8. Design, development, and certification of the new Commercial Orbital Transportation System capability for ISS re-supply are just beginning. If similar to other new program development activities, it most likely will take much longer than expected and will cost more than anticipated.
9. The current International Traffic in Arms Regulation restrictions on NASA are a threat to the safe and successful integration and operations of the International Space Station.

Principal Recommendations

- The International Space Station Program should place the highest priority on options to decrease the risk of micrometeoroid and orbital debris.
- NASA should develop and implement plans to maintain Station critical skills and experienced managers.
- The Administration, Congress, and NASA should support the completion of the current Shuttle manifest to the International Space Station, including flights ULF–4 and ULF–5, to assemble a viable Station and provide spares for its long-term operation.
- The Administration, Congress, and NASA should support a proactive and phased post-Shuttle logistical transportation program, including adequate funding of approximately one billion dollars per year above current allocations to ensure that adequate logistics and spares are available to maintain a viable Station.
- NASA senior management should conduct a comprehensive review of the Automated Transfer Vehicle to ensure agreement on the policies, approach, and technical implementation of the safety strategy for the Automated Transfer Vehicle's demonstration.
- The Department of State should grant immediate relief from the International Traffic in Arms Regulation restrictions in the form of an exemption to allow NASA contractors direct interaction with the International Space Station's International Partners and their contractors. This must be affected no later than summer 2007 to support Automated Transfer Vehicle operations.
- The ISS Program should carefully consider implementing all IISTF recommendations to improve the overall safeguards and controls against vulnerabilities.

Further details on the principal recommendations as well as additional recommendations can be found in the body of the report "Final Report of the International Space Station Independent Safety Task Force."

It should be noted that NASA's support and responsiveness to the Task Force was excellent through the process of developing the data and material required to accomplish the charter of the IISTF. The Program Manager and his team supported the technical review meetings and provided invaluable insight and technical data on the issues associated with the IISTF's charter.

With respect to the specific questions in the letter inviting me to testify at the House Committee on Science and Technology's Subcommittee on Space and Aeronautics the following is provided. My recommendations reflect the recommendations documented in the Task Force's report.

1. What are the most significant findings and recommendations of the International Space Station Independent Safety Task Force?

The principal observations and recommendations discussed above are the most significant findings and recommendations.

2. What was NASA's response to the Task Force's findings, and are there particular areas that you think require additional attention or action by NASA?

Per the *NASA Authorization Act of 2005* (Public Law 109–155), the task force's charter expired in February, 2007. No further exchange between the NASA and the Task Force has occurred since that time. Since I am currently a private citizen, I do not have any personal insight into the status of NASA's response to these rec-

ommendations. For these reasons, I cannot comment on NASA's response to the task force recommendations.

3. The Task Forces' report indicates that the risk of a "catastrophic result" from collision with micrometeoroid and orbital debris could be reduced to five percent over a 10-year period "by implementation of changes that are available or being considered for developed." Is NASA in fact implementing all the changes you reference, and if not, would the resulting level of risk be acceptable to the Task Force? In any event, did the Task Force consider the five percent to be an acceptable level of risk?

Per the *NASA Authorization Act of 2005* (Public Law 109–155), the task force's charter expired in February, 2007. No further exchange between the NASA and the Task Force has occurred since that time. Since I am currently a private citizen, I do not have any personal insight into the status of NASA's response to these recommendations. For these reasons, I cannot comment on NASA's response to the task force recommendations.

The ISS Program's requirement of "five percent probability of no catastrophic penetration" was considered by the Task Force to be reasonable given the state-of-the-art in shielding design, the mass-to-orbit limitations and the state of the development and deployment of the ISS elements.

4. The Task Force report discusses the risk associated with post Shuttle logistics capabilities to support the ISS. What would you recommend?

I would develop and implement a fully integrated logistics support plan with off and on-ramps of available and planned capability for the logistics support for the Assembly Complete/six crew member/post-Shuttle era. The plan would include projected budget requirements for logistics support. I would recommend the Administration and the Congress support this plan.

I would not commit the ISS to an unproven logistics support system such as COTS. If a proven logistics support system is not available, I would commit to the future capability that is determined by engineering analysis to have the highest chance of success until emerging capabilities are proven.

To ensure not being forced into dependency on an unproven capability I would procure additional spare proven capability to assure a smooth transition to unproven capabilities later and to minimize transition through down periods on logistics delivery systems.

I would develop an option that ensures that the two remaining Shuttle exterior logistics flights are given the highest priority for flight, in front of Node 3, if necessary, to avoid exacerbating a problem should all planned Shuttle flights not be completed.

5. Why does the Task force consider the current International Traffic in Arms Regulations restrictions to be "a threat to safe and successful integration and operations of the International Space Station," and what would you recommend be done?

NASA depends heavily on U.S. contractors for technical support for Station integration and for operations. These contractors are the source of data and expertise that is critical in meeting schedules and performing mandatory work with the IPs. For example, the mission operations contractors comprise a majority of the operations workforce and must be able to have a direct interface with the IP operations teams to assure safe and successful operations. Currently the ITAR restrictions and the IPs' objections to signing technical assistance agreements are a threat to the safe and successful integration and operations of the Station.

Each U.S. contractor working with the European, Japanese, and Russian space agencies is required to apply for a Technical Assistance Agreement (TAA) from the State Department that governs their interactions with foreign entities for each specific relationship. U.S. aerospace and defense companies are accustomed to dealing with these TAA requirements in what has become a normal part of international business. However, when the Department of State approvals are too narrowly defined and come with many caveats, limitations, and provisos, they severely restrict Program management flexibility. The constraints imposed by the current processes result in lost time and opportunity to share critical data to enable a robust joint Program.

I would grant immediate relief in the form of an exemption to allow NASA contractors direct interaction with the IPs and their contractors to facilitate and accommodate all engineering and safety reviews, data exchanges pertaining to specific ATV/HTV hardware and software, Program management interactions, and flight operations including anomaly resolution.

BIOGRAPHY FOR TOMMY W. HOLLOWAY

Mr. Holloway retired in 2002 as Manager of the International Space Station Program for NASA's Johnson Space Center. Mr. Holloway was named Space Station manager in April 1999 after serving as Manager of the Space Shuttle Program (SSP) for nearly four years. He began his career with NASA in 1963, planning activities for Gemini and Apollo flights. He was a Flight Director in Mission Control for early Space Shuttle flights and became Chief of that office in 1985. In 1989, he was named Assistant Director for the SSP for the Mission Operations Directorate. He served as Deputy Manager for Program Integration with the SSP and Director of the Phase 1 program of Shuttle-Mir dockings before being named SSP Manager in August 1995. He served on the National Research Counsel Committee on Assessment of Options for Extending the Life of the Hubble Space Telescope (2004–2005). He received his B.S. in Mechanical Engineering from the University of Arkansas and has earned numerous honors and awards including Presidential Meritorious and Distinguished Ranks, the Robert R. Gilruth Award, and the Rotary National Space Trophy.

Chairman UDALL. Thank you, Mr. Holloway.

Dr. Neitzel, the floor is yours.

STATEMENT OF DR. G. PAUL NEITZEL, PROFESSOR OF FLUID MECHANICS, GEORGIA INSTITUTE OF TECHNOLOGY

Dr. NEITZEL. Mr. Chairman and Ranking Member Feeney and members of the Subcommittee, thank you for inviting me to testify before you today on these important matters relating to the Space Shuttle and the International Space Station.

My name is Paul Neitzel. I am a Professor of fluid mechanics and mechanical engineering at Georgia Tech. I am here today as a representative of NASA's external research community and shall do my best to communicate to you some of these, its concerns.

The International Space Station or ISS has always been justified in large part as providing an experimental platform operating in a unique environment of weightlessness or microgravity to permit research relevant to future human space exploration as well as fundamental and applied research that can increase our understanding of certain phenomena, potentially leading to enhanced terrestrial applications.

NASA through the 1990's had developed an impressive external research community in the life and physical sciences to investigate such questions. This growth was a conscious decision on the part of the agency, made both to access new ideas and to expand the ground-based research program to insure that the very best projects requiring access to microgravity could be identified and subsequently flown. This community included the best researchers in the United States in their respective fields. In the 2003 *Office of Biological and Physical Research Task Book,* more than 1,700 co-investigators and nearly 3,000 students were identified as working on roughly 1,000 tasks.

In the aftermath of the tragic loss of the *Columbia* and her crew in February, 2003, and the mission shift resulting from President Bush's 2004 *Vision for Space Exploration,* NASA made a decision to terminate all external, non-exploration research and to significantly cut back on the number of external exploration projects, effectively wiping out the community of researchers that had been assembled.

Some of NASA's rationale for doing this is understandable, given the loss of a vehicle with which to continue the assembly of the ISS

and the minimum budget plus-up of $1 billion over five years devoted to the implementation of the vision. NASA is an agency that is always being asked to accomplish too much with too little. However, it is my belief that NASA's decision to proceed in this fashion is shortsighted and inconsistent with developing the types of systems that will best allow us to return to the Moon between 2015, and 2020, and prepare for more ambitious missions.

The vast majority of fundamental and applied scientific research in this country is conducted at colleges and universities, where faculty work in conjunction with students from undergraduates to post-doctoral research fellows, to make the breakthroughs that help drive our economy. By shutting out input from this community NASA not only denies itself access to potentially groundbreaking results of relevance to its mission, it also effectively guarantees the future workers it will require will be neither motivated to work on NASA-related problems, nor even be knowledgeable of them.

In addition, the hundreds of researchers who have had their NASA research programs terminated are moving onto other pursuits and are likely to be unable, if even willing, to return to problems NASA will need to have solved in the future.

The restriction to a small number of exploration-related projects is also likely to cause NASA to lock into choices at an earlier time than it should for systems currently under development. Consistent with the President's Vision, NASA should be exploring the development of systems that will permit future missions that may be of much longer duration than a trip from here to the Moon. Such missions will require the development of new, mass-efficient, dual-use systems that will accomplish their functions both on a reduced-gravity, heavenly body as well as during the extensive period of zero gravity required to get here. ISS is the only research platform capable of investigating the latter regime.

Finally, the elimination of fundamental ground-based and microgravity research denies the agency and the country the possibility of results from curiosity-driven research that has been the hallmark of academic research throughout history. Such work may or may not have immediate application. Fundamental work done by Lord Rayleigh on the breakup of liquid jets roughly 100 year ago forms the basis of technology used in both the inkjet-printing and rapid-prototyping devices of today.

NASA's plans for the utilization of the ISS by researchers funded by other federal agencies are, in my opinion, unrealistic at this point in time given the long lead times required to develop flight hardware and the finite lifetime of the ISS. The ISS National Laboratory concept, while one I support, is but a hollow shell without dedicated funding to enable both the research to be done on ISS and the expensive costs of transporting experiments to and from it. This funding, furthermore, must be fenced off from the standard NASA budget to prevent it from being redirected by the agency to other needs.

Without a vigorous program of ground- and space-based research designed to exploit the unique environment of the ISS, we are squandering this valuable resource. We are potentially relinquishing our leadership in space-based research to other nations,

and we are dimming the spark of discovery that motivated many of the current generation of such researchers, including yours truly.

Thank you again, Mr. Chairman, for the opportunity to appear here today. I am happy to try to answer any questions the Subcommittee may have.

[The prepared statement of Dr. Neitzel follows:]

PREPARED STATEMENT OF G. PAUL NEITZEL

Mr. Chairman, Ranking Member Feeney and Members of the Subcommittee: thank you for giving me the opportunity to testify on the subject of *"NASA's Space Shuttle and International Space Station Programs: Status and Issues."* My name is Paul Neitzel and I am a professor of fluid mechanics in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology. I appear today as a member of the NASA external research community. My experience as a principal investigator (PI) on NASA-sponsored research goes back more than twenty years and I have had the occasion to serve the agency in several advisory capacities over that period of time. Of particular relevance to the subject of today's hearing is my prior service on the Space Station Utilization Advisory Subcommittee (1995–99) and on two groups (in 1999 and 2000) tasked to examine the management of research aboard the International Space Station (ISS). In my written testimony below, I shall address some of the issues I feel are important to ensure that the full promise of the ISS as a research laboratory is realized.

The International Space Station is the culmination of America's desire for a "permanent" research facility in low-Earth orbit that began with the launch of Skylab in 1973 and continued with the Shuttle-Mir program. The final incarnation of the ISS will be a facility built with the cooperation of sixteen partner nations. The ISS has always been described, among other things, as a laboratory for performing research under the weightless conditions of free-fall, both to enable further human and robotic exploration of space and to answer fundamental questions that could lead to enhanced understanding of terrestrial phenomena, such as the influence and interactions of forces that are often obscured on Earth by the presence of gravity.

NASA's research program in the life and physical sciences began modestly. The physical sciences program grew out of a program called Materials Processing in Space that sought to explore microgravity to produce materials of improved quality; at the end of the 1980's only about 70 physical science PIs were receiving funding. In this period, there was pressure on the PI community to develop flight experiments to ensure that payload spaces on the Space Shuttle were full. This pressure led to the development and flight of several (often very expensive) experiments that were either poorly conceived, did not require the weightless environment to answer the research questions, or both, leading to criticism from parts of the scientific community of the quality of NASA-sponsored science.

Beginning about 1989 and continuing through the 1990's the former Office of Life and Microgravity Science and Applications (OLMSA) made a conscious decision to greatly expand its ground-based research program. The basis for this expansion was to broaden the participating research community to access new ideas and to increase the number of investigations to allow the best, most deserving candidates for flight experiments to percolate up through the pool. This decision served to attract a much broader cross-section of the life- and physical-science research communities to NASA-related research, leading to the development of flight experiments truly worthy of the unique resources provided by the Shuttle and the ISS. At its zenith the budget of the then Office of Biological and Physical Research (OBPR is what OLMSA morphed into) had grown to approximately $1B and the FY03 OBPR Task Book (*http://peer1.nasaprs.com/search2003/metrics2003.cfm*) shows a broad research program containing roughly 1,000 tasks, supporting over 1,700 PIs and co-investigators and nearly 3,000 students, ranging from undergraduates to postdoctoral fellows. A summary from this document of the numbers of tasks, investigators and students supported is included as Table 1. In my own discipline of fluid physics, which is concerned with the behaviors of liquids and gases, I can state without hesitation that the program supported the very best researchers in the United States and had far surpassed other federal agencies as the principal supporter of fundamental and applied research in the field.

On Saturday, February 1, 2003, the Nation watched, horrified, as the Space Shuttle *Columbia* broke apart upon reentry following a successful research utilization flight to the ISS. Needless to say, the tragic loss of the crew and their vehicle, along with the time lag prior to return-to-flight caused serious slippages in both the ISS assembly sequence and the conduct of research aboard both the Shuttle and the ISS.

The progress of research was further exacerbated by the decision to limit the crew size aboard the ISS to two persons, down from three and far short of the full complement of six, further negatively impacting research during the assembly phase.

In January, 2004, President Bush put forth his *Vision for Space Exploration* (VSE, or "the Vision," for short), calling for the completion of the ISS by 2010, retirement of the Shuttle at that time and the development of a new Crew Exploration Vehicle (CEV), to be used both for sorties to the ISS and exploration of the lunar surface, returning humans to the Moon between 2015 and 2020. Lunar exploration was further mentioned as permitting astronauts to develop new technologies as necessary a stepping stone to more challenging environments, including Mars. The funding for the Vision amounted to $12B over five years, $11B of which was to come from reallocation of funds within NASA's existing budget, with a $1B plus-up.

Although the life- and physical-science research program had begun to suffer from decreased funding in the aftermath of the *Columbia* accident, the transition to the implementation of VSE was its death knell. 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. In line with the Vision, NASA decided that future agency-supported research would be restricted to exploration needs, namely the study of "exploration requirements in human health and countermeasures as well as applied physical sciences for fire prevention, detection, and suppression; multi-phase flow for fluids such as propellant; life support; and thermal control applications," as stated in *The National Aeronautics and Space Administration (NASA) Research and Utilization Plan for the International Space Station (ISS)* published last year. The small number of projects being investigated, although relevant to exploration, is inconsistent with the conduct of a robust, safe exploration program that will send astronauts to the Moon no sooner than 2015.

During a period with limited flight opportunities and a major shift in mission focus, precisely the opposite should be occurring within NASA's research programs. I shall focus on the physical sciences for the moment. Long-duration exploration such as a 500 day mission to Mars requires new solutions to long-standing problems. A principal limitation associated with such a mission is the up-mass that can be accommodated with a given launch vehicle. For a 16-day Shuttle mission, a stay aboard the ISS with regular resupply, or even a lunar outpost permitting periodic re-supply, existing solutions to environmental and vehicle needs may suffice. For a Mars mission, however, every kilogram devoted to an environmental- or fire-control system, for example, is one kilogram less that may be used for food and water. New systems for Mars missions will also need to be "dual-use," in that they will need to be able to function for an extended period of microgravity during flight as well as in the 3/8 g Martian gravity. Hence, new, more mass-efficient solutions need to be sought for such problems and a robust program of both fundamental and applied ground-based research should be able to identify good candidates for subsequent flight testing and development as the ISS facilities become available. The current exploration research plan appears to be focused on the investigation of very limited possibilities for such solutions, and is likely to yield less-than-optimal ones. The decision to rush to development at this stage is hard to understand; in this era of incredibly fast-paced technological development, NASA owes it to itself to keep as many options open until it is absolutely necessary to start "cutting metal."

Under the 2005 *NASA Authorization Act,* NASA has been directed to devote 15 percent of its ISS research funds to non-exploration research. The figure for FY07 includes $3.1M for ISS physical science, $1.7M for ISS life science, $3.9M for research aboard free-flyer vehicles, and $3.3M for ground-based grants, for a total of $12M. This number is particularly small, in part, due to the fact that the 15 percent is mandated to come from the "ISS research" funds, which are at a depressed level due to the inability to conduct meaningful amounts of research on the vehicle during the compressed assembly sequence. As a comparison point, the $3.3M devoted to ground-based research would support, at minimal funding levels, roughly 30 PIs, a figure that can be compared with the numbers from the 2003 OBPR Task Book that were mentioned above and included in Table 1, namely, roughly 1,000 tasks supporting more than 1,700 PIs and co-investigators and nearly 3,000 students. Furthermore, the non-exploration fundamental and applied research that could be conducted aboard the ISS under a robust research program aligns perfectly with the goals of the American Competitiveness Initiative.

The recent decimation of the external research community has other consequences. First, NASA seems to regard research as a spigot that can be turned off and on at will. I would agree that it is easy to turn off the research spigot at any time, but in doing this, NASA is also shutting down the water-treatment plant that supplies the spigot. The reestablishment of an external research community will

take years, if it can be accomplished at all. My colleagues in the life and physical sciences have a variety of research interests for which funding is available through other federal agencies as well as from private industry. The very best members of the research community are moving on to other pursuits and are not likely to be able, if even willing, to reengage in microgravity-related in the future.

Second, NASA is fond of speaking of the current crop of researchers who were motivated to pursue careers in space-related research by their fascination with the Mercury, Gemini and Apollo programs that culminated in landing astronauts on the Moon. With the absence of NASA-oriented research programs in our universities, where will the next generation of these researchers come from? Those of us in the higher-education community are sensitive to the fact that it has become harder to attract, and most importantly, to retain American students to study mathematics, engineering and the sciences. With the loss of motivators such as the possibility of a career in a vibrant, active, space-research program, one more incentive for future students disappears. As mentioned already, the former OBPR research program provided opportunities for nearly 3,000 U.S. students to engage in meaningful NASA-related life- and physical-science research. Other nations, notably China, are increasing their emphasis on space research; Asian cultures, in general, embrace the study of science and engineering. As we stand by and watch jobs and technology being transferred overseas, are we as a nation prepared to relinquish our superiority in space research and in the associated discoveries that can drive new businesses and jobs?

Finally, abandonment by NASA of the ISS as a platform for fundamental and applied external research with both exploration and non-exploration applications sends an unfavorable message to the international partners who have contributed their time and money to make the ISS a reality. How can the United States, in good conscience, turn its back on these partners, not to mention the American taxpayers who have borne the bulk of these expenses? An incredible investment of both time and money has been made, both in the ISS vehicle and in discipline-specific research facilities that are to be flown aboard it. These facilities exist, have already been paid for, and are merely awaiting integration aboard the ISS to be used. We need to ensure that the ISS is fully utilized to the full term of its lifetime, currently projected for 2015. This is only five years past assembly-complete, a period we should certainly be willing to sustain.

Last year, a group of us in the life and physical sciences were asked to come up with a "keep-alive" dollar figure for the life- and physical-sciences research program. The figure we estimated that would be required for PI support was roughly $70M/year. (This is exclusive of transportation costs and NASA Center personnel salaries for flight-experiment support, but these would be minimal during the remainder of the assembly sequence.) This funding level would support a research effort roughly half the size of the research program that was in place immediately prior to the recent cutbacks. This $70M/year amounts to less than $.25/year from each American citizen and less than 0.4 percent of NASA's roughly $18B annual budget. This small cost of maintaining an active research community is one that must be borne. The cost of losing the possible accomplishments of an entire community that can likely never be reestablished is far greater.

Mr. Chairman, you have posed several questions in your invitation that you would like me to address in my testimony. I shall respond to each, in turn, although some of these responses will reiterate material covered in these opening remarks.

1. What actions does NASA need to undertake to ensure that the International Space Station (ISS) can be productively utilized for exploration-related and non-exploration-related research once it is assembled? When does NASA need to undertake the recommended actions? Which of the actions would you consider to be the most important to the effective utilization of the ISS?

The principal need to ensure productive utilization of the ISS is the existence of a broad-based research community with projects in the pipeline. In addition to candidate flight experiments, this requires a substantial commitment to a ground-based program so that the previous mistakes made by the agency described in the introduction above are not repeated. Because the process for taking a research idea from conception to flight typically requires several years, NASA is already behind in terms of a time schedule that includes a 2010 assembly-complete date for the ISS. However, given that several projects relating to both exploration and fundamental/applied research were recently active, it may be possible to resurrect some of them in an effort to jump-start the reformation of a broader research community. To reestablish such a community, NASA must commit to the long-term research utilization of ISS; those who were left at the altar by NASA this past time will be uneasy

about returning in the absence of such a commitment. Many who have moved on to other pursuits will not be able to return to NASA research due to their new commitments.

2. Does NASA have well defined objectives for utilizing the ISS, and are NASA's facilities, plans, resource allocations, and research criteria and prioritization for utilization aligned with those objectives?

NASA's utilization plan calls for a research focus for the ISS that is restricted to exploration goals in support of the VSE. The small number of investigations outlined in NASA's aforementioned ISS Research and Utilization Plan is inconsistent with an effective, safe exploration program. In the fire-safety arena alone, NASA should be exploring fundamental and applied research in a broad range of the field of combustion to guarantee that the very best techniques for fire prevention, detection and suppression are developed. As pointed out in the recent NRC report entitled, *Review of NASA Plans for the International Space Station,* the risk of a fire incident on a long-term mission such as one to Mars is high. Not only must spacecraft have the best technologies on-board for prevention, detection and suppression of fires, they must be prepared to rid the spacecraft environment of potentially harmful soot and other products of combustion in the event a fire does occur. Studies of relevance to this also have applications to microgravity dust management and its effect on both humans and equipment functionality. Earthbound applications include clean-room technology, handling of nanoparticles, the detection of nanoparticle health hazards and improved fire-detection equipment.

Mass efficiency of other types of exploration-related hardware is a general concern. For example, NASA knows how to move liquids from one location to another within the spacecraft environment, but are the most mass-efficient means for accomplishing these tasks being developed? The VSE is not limited to the exploration of the Moon, but speaks of missions beyond the Moon, *beginning* with Mars, for which the up-mass limitations are critical. Even if such post-lunar expeditions are far in the future, NASA should be preparing now by exploring the best-available technologies, and these can only be identified through a robust program of both fundamental and applied research. Lunar expeditions are to explore the possibilities of living on the lunar surface, implying the conduct of research to investigate issues such as *in situ* resource utilization. Just as mass-efficient spacecraft systems for Martian missions increase the amount of water and food that can be carried onboard, so would mass-efficient systems developed for lunar missions increase the amount of research instrumentation able to be transported, per flight, to the lunar surface.

NASA has available a total of 20 International Standard Payload Racks (ISPRs) for research purposes; 10 in the U.S. lab and five each in the JEM and Columbus facilities. Its intention is to utilize half of these ISPRs for exploration-related research and development, but it is difficult to envision that the limited number of investigations described will be sufficient to fully utilize these resources. As mentioned in my introductory remarks, the fact that we are several years away from the required selection of some enabling technologies suggests that a vigorous research program be sustained in order to seek optimal solutions.

3. Does NASA have appropriate plans, programs and resource allocations to ensure that there will be a research community in place and adequately prepared to effectively utilize the ISS once the ISS is assembled?

No. NASA has made the decision to get out of the non-exploration research business and to dramatically restrict investigations related to exploration. The external research community that existed just a few years ago is no longer in place and there are no pending NASA Research Announcements, so the prospects for at least the near future look dim. As also mentioned, this research community has moved on to other pursuits and is engaged in and committed to research that cannot be dropped to return to NASA-related work, even if the community were tempted to do so.

NASA is encouraging the use of the ISS by other federal agencies with interests in microgravity experimentation, however, those agencies are expected to cover the full cost of taking their ideas to flight, including the very expensive transportation portion. I understand that there has been some recent interest on the part of the NIH in partnering in this fashion, but find it difficult to believe that, given budget constraints, a significant amount of research from NIH or other federal agencies will materialize in the near future to enable the full utilization of the 10 ISPRs that will be available for non-exploration use aboard the ISS.

4. What microgravity research in the physical and life sciences is needed to enable future human lunar and Mars exploration missions? Are there

any advantages to or requirements for conducting such research on the ISS as opposed to a lunar outpost, on lunar sorties, or on free-flying platforms?

As described above, long-duration manned space flight will require the development of mass-efficient, dual-use hardware to accomplish tasks that are now performed in, perhaps, less-than-optimal ways. The ISS is the only platform that provides access to long-term weightlessness. The challenges in designing for the 3/8 g environment of Mars or the 1/6 g environment of the Moon are routine; for zero-g, however, the absence of buoyancy (the force that causes hot fluids to rise on Earth) provides an environment in which other forces, typically "masked" on Earth by buoyancy, are dominant and exploitable. Lunar outposts will be suitable test beds for some, but not all, technologies designed to work on the Martian surface. For example, the Moon has no atmosphere while Mars does. Therefore, heat-rejection needs in non-habitat situations on the lunar surface must rely on the heat-transfer mechanisms of radiation and conduction, while convection that transports heat due to fluid motion can play a role on the Martian surface. Lunar sorties, although of reasonably short duration, will provide some microgravity periods for experimentation, if crew time permits, but not to the extent that can be performed with a dedicated crew aboard the ISS.

In the life sciences, long-duration space flight poses well-known problems for astronauts, bone loss being a major one for which no existing countermeasures have been effective. Another major hazard, particularly for human exploration of Mars, is the exposure to radiation; the recent NRC report rules out radiation shielding as being up-mass prohibitive and cautions that the exposure experienced during a three-year Mars outpost mission, "has the potential to produce significant long-term effects that may not be limited to cancer induction." The NRC panel recommends searching for pharmacological interventions to deal with these effects. Studies on the effects of microgravity and space environments on the entire range of scales within the human organism, from whole-body to cellular levels, seem warranted. The psychological problems of coping with the isolation experienced during a 500 day Mars mission are also of concern. Finally, long-duration space flight also means that astronauts will likely be growing some of their own food, meaning further study of plant cultivation in microgravity is likely necessary for exploration purposes.

The use of free-flyers is definitely a way to get some research requiring a quiescent microgravity environment conducted. Such experiments need to have excellent telescience support in order to both control and retrieve data from the experiment. Those experiments that need human intervention, for example, to change samples, are not candidates for free-flyers. In addition, in the event of an unforeseen occurrence requiring repairs, the free-flyer experiment is typically over. Although careful thought and preparation goes into the design of every flight experiment, things often happen that cannot be anticipated.

5. What are your perspectives on the intended and potential use of the ISS as a national laboratory? What is necessary to enable ISS to be an effective laboratory?

As a member of two task groups that studied the management of research utilization aboard the ISS, I am generally supportive of the concept of operating the U.S. research facilities on board the ISS as a national laboratory. A principal benefit is the buy-in that is likely to come from the external research community to a laboratory managed by a consortium of their peers. This has certainly been the case with the Space Telescope Science Institute, although it is recognized that the degree of complexity of research management aboard the ISS is much larger.

What is disconcerting about NASA's plans for the national laboratory concept, however, is that there is virtually no funding associated with it, either to support in-house or external research or to provide for transportation of experiments to and from the ISS. Operationally, the national laboratory would serve a role not unlike that of existing NASA Centers, from the standpoint of integrating research experiments into the ISS, but very unlike a NASA Center, in that national-laboratory personnel would not have any discretionary funding to pursue research aboard the ISS without competing for funds from other agencies willing to perform research there. The types of individuals the research community would like to have assisting them with the development of their flight experiments are other researchers who are knowledgeable about the logistical *and* scientific issues associated with their work. Attracting such individuals to a national laboratory with no provision for even small-scale investigations of their own will be a difficult task. In addition to the national-laboratory funding needed for direct PI support and a modest amount of in-house research, there is a substantial amount required for the development, quali-

fication and integration of experiment-specific hardware for the ISS. These functions are currently supported, to a large degree, by the NASA Centers (which, by the way, typically have discretionary funding to support in-house research). A mechanism for seamless collaboration between the Centers and the national lab or for the transfer of responsibilities (and funding to support them) to the national lab must be worked out.

NASA is supporting the development of Commercial Orbital Transportation Services (COTS) that it hopes will provide transport of experimental equipment to the ISS following assembly-complete. To be sure, transportation to and from the ISS is the "rate-limiting" factor controlling its efficient utilization. There are a variety of payload types used for research purposes, the broad classifications for transportation purposes being pressurized and non-pressurized, with the former obviously a requirement for living systems such as plant and animal models. Certain types of research payloads, e.g., living systems, also require timely transport of payloads both to and from the ISS for the proper conduct of the experiments and analysis of results. It is a leap of faith to assume that a sufficient number of such systems will be ready to perform all the necessary functions with the required frequency at assembly-complete. The failure of COTS solutions would leave the CEV as the NASA backup, requiring the additional purchase of transportation services from Russia, and perhaps from other nations that are talking of developing such systems.

In summary, it is my belief that NASA is ill-prepared to fully utilize the research facilities of the ISS upon assembly-complete in 2010. Faced with the loss of launch capability and a new exploration mission to be funded within its existing budget, NASA has chosen to virtually eliminate its dynamic extramural research program in the life and physical sciences. This move is short-sighted and has caused the loss of a research community devoted to NASA-related issues that will be difficult to reconstitute. Without the existence of this community, there is little to support the utilization of the ISS. The successful implementation of the *Vision for Space Exploration* will require the presence of an active, diverse research program performing investigations at the cutting edge to define the technologies necessary for successful exploration while, in addition, gaining deeper understanding of fundamental scientific issues that can serve to benefit life on Earth. NASA has always been regarded as a research agency. In this rapidly changing technological world, the need for it to remain a research agency is more compelling than ever.

Thank you again, Mr. Chairman, for inviting me to speak with the Subcommittee. I am happy to answer any questions about these issues that you may have of me.

Table 1: Statistics for life- and physical-sciences research for NASA OBPR programs for FY03 (Source: OBPR Taskbook http://peer1.nasaprs.com/search2003/metrics2003.cfm)

Bioastronautics Research/Fundamental Biology

FY 2003 NASA Code UB/UF Program Research Task Summary
Overview Information and Statistics

Total Number of Principal Investigators	**354**
Total Number of Principal Investigators (excluding GSRP)	**344**
Total Number of Co-Investigators	**327**
Number of States with Funded Research	**43**
Total Number of Research Tasks	**428**
Competitive Grants	286
NASA Internal Research Tasks	24
Graduate Student Research Projects	10
NSCORT Individual Projects	20
NSBRI Projects	88
Total Number of Students Supported (excluding GSRP)	**1268**
Post-Doctorate	284
Ph.D.	233
Graduate	267
Undergraduate	484

Physical Sciences

FY2003 NASA Code UG Physical Sciences Task Summary

Overview Information and Statistics

Total Number of Principal Investigators		485
Total Number of Co-Investigators		599
Number of States with Funded Research		41
Total Number of Research Tasks		581
Biotechnology	158	
Combustion Science	86	
Fluid Physics	139	
Fundamental Physics	71	
Materials Science	127	
Other/Specialized	0	
Total Number of Students Supported		1719
Post-Doctorate	291	
Ph.D.	531	
Graduate	398	
Undergraduate	499	

BIOGRAPHY FOR G. PAUL NEITZEL

G. PAUL NEITZEL is a Professor of Fluid Mechanics in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology, where he has been on the faculty since 1990. Prior to that he spent eleven years on the faculty of Arizona State University and ten years at the U.S. Army Ballistic Research Laboratory (now Army Research Laboratory) at Aberdeen Proving Ground, MD, during which time he received his Ph.D. in fluid mechanics from The Johns Hopkins University. Dr. Neitzel's current research in the field of fluid mechanics encompasses permanent non-coalescence and non-wetting of droplets, optical droplet levitation and migration, multi-phase flow simulation, and the fluid dynamics of bioreactors used for mammalian cell culture. Dr. Neitzel has been a member of the NASA Space Station Utilization Advisory Subcommittee, the On-Orbit Evaluation Board, the Physical Sciences Advisory Subcommittee of the former NASA Office of Biological and Physical Research (OBPR), and chaired, for six years, the Fluid Physics Discipline Working Group in OBPR. He served on the 1999 NRC Task Group on Institutional Arrangements for Space Station Research and on the 2000 International Space Station Operations Architecture Study. Dr. Neitzel is a Fellow of the American Physical Society and the American Society of Mechanical Engineers, an Associate Fellow of the American Institute of Aeronautics and Astronautics and a recipient of an Alexander von Humboldt Research Fellowship.

Chairman UDALL. Thank you, Doctor. Ms. Chaplain, you now have five minutes to present your point of view.

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

Ms. CHAPLAIN. Thank you, Mr. Chairman and Ranking Minority Member Feeney. Thank you for inviting me to discuss challenges faced by NASA in completing and sustaining the International Space Station and retiring the Space Shuttle.

As you know, these endeavors are part of the broader *Vision for Space Exploration* which require careful management of investments, facilities, workforce, international partners, and suppliers. Clearly, any delays or problems in completing and sustaining the Space Station itself may well have reverberating affects on NASA's ability to ramp up exploration efforts or to support other important missions.

Today I would like to present preliminary results of our work related to the Station and the Shuttle. While they are preliminary, many have been echoed in other studies and identified by NASA itself.

First, there are significant challenges related to NASA's ability to execute its plans to use the Shuttle to complete the Station. The January, 2007, Shuttle manifest projects that NASA will launch 16 flights before retirement of the Shuttle fleet in September, 2010. One of these has already been launched. Of the 15 remaining missions one is reserved for the Hubble telescope, and two are designated as contingency missions that are slated to bring materials critical to Station sustainment.

On average when counting the contingency flights, NASA will need to launch one Shuttle every 2.7 months, an aggressive schedule when compared to recent launch timeframes. Due to vehicle traffic constraints, the minimum time required between Shuttle launches to the Station is 35 calendar days. So while the manifest is aggressive, it is achievable.

There is, however, little room for unexpected delays caused by weather damage or launch debris, which have proven to impact the Shuttle launch schedule significantly.

In addition, there are potential tradeoffs NASA can make in order to position what is needed to sustain the Station after the Shuttle's retirement, and some of these tradeoffs have already been made. However, the potential deletion of such items as Node 3 and the Cupola would have a substantial impact on the quality of life on the Station, the ability to conduct research, and in the case of the Cupola, the ability to use a robotic arm to assist in docking newer transportation vehicles.

Second, we have previously reported that there is significant challenges in insuring NASA can retain critical skills to manage the Shuttle program through its completion. NASA has made progress in implementing previous GAO recommendations on this issue. For example, it has developed an agency-wide strategic human capital plan, developed workforce analysis tools, and is mapping available skills of the Shuttle workforce with the skills it will need in the future. It is important that these actions be sustained throughout the transition and that NASA also measures its progress, identify gaps or obstacles that need to be addressed, and sustain a high degree of coordination with its centers.

There are considerable challenges with filling the gap between the Shuttle and the new NASA-developed vehicles to service the Station. For example, NASA expects that the commercial sector can develop transport vehicles that can take equipment and ultimately crew to and from the Station during the gap. However, our work has generally found that space development efforts often encounter schedule delays and technical problems, particularly when they are seeking to obtain significant advances in technologies, move forward amid unknowns, or manage without adequate oversight and insight.

Risks may be high in these partnerships given that the suppliers do not have longstanding relationships with NASA and the development of the vehicles represents totally new endeavors for them. Therefore, it is critical that NASA establish clear and consistent guidance, limit requirements changes, and insure it has visibility into the progress being made by the commercial suppliers.

NASA's options in addition to the commercial vehicles which include both the European and the Japanese vehicles, which are new, and the Legacy Russian vehicles, however, NASA's reliance on these vehicles to augment re-supply activities after 2010, assumes no further delay in development. Moreover, there are limits to what the payloads these vehicles can carry.

The Independent Safety Task Force also reported challenges involved with working through laws and regulations governing the transfer of technical knowledge, though the Station program office reported to us that immediate hurdles had been overcome with respect to the European vehicle.

In addition, continued use of the Russian vehicles will require the U.S. to renegotiate exemptions to the Iran, North Korea, and Syria Nonproliferation Act. Our review will further examine risk mitigation efforts related to the gap between the Shuttle and

NASA-developed vehicles as well as the Shuttle manifest and workforce issues.

We look forward to continuing to share the results of that work with this subcommittee.

Thank you. 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

Mr. Chairman and Members of the Subcommittee:

I am pleased to be here today to discuss the challenges faced by the National Aeronautics and Space Administration (NASA) on the International Space Station (ISS) and the Space Shuttle. NASA is in the midst of one of the most challenging periods in its history. As part of its *Vision for Space Exploration,* NASA is simultaneously developing a range of new technologies and highly complex systems to support future exploration efforts, completing assembly of the Space Station, and retiring the Space Shuttle. This is NASA's biggest transition effort since landing humans on the Moon more than three decades ago and then initiating the Space Shuttle Program a few years later. Taken together, these efforts create significant challenges in terms of managing investments, launch and other facilities, workforce, international partners, and suppliers. Clearly, any delays or problems in completing and sustaining the Space Station itself, may well have reverberating effects on NASA's ability to ramp up efforts to develop technologies needed for future exploration or to support other important missions.

GAO has undertaken a body of work related to NASA's transition efforts that include NASA's industrial supplier base, its workforce challenges, development of new crew and cargo spacecraft, and NASA's assembly and sustainment activities related to the ISS. My statement today focuses on the preliminary results of on-going efforts, as well as other GAO work completed to date. Specifically, I will address the following challenges: (1) executing plans to use the Shuttle to complete the ISS; (2) maintenance of the Shuttle workforce through retirement of the Shuttle; and (3) filling the gap between the Shuttle and new NASA-developed vehicles to service the ISS. NASA's ability to overcome these challenges will be critical to ensuring the availability of the International Space Station as a viable research entity into the future. While these results and findings are preliminary, many have been echoed in other studies and identified by NASA itself. Our work is being conducted in accordance with generally accepted government auditing standards.

Background

NASA plans to finish assembling the ISS in 2010 and operate the Station until 2016. The Station is scheduled to support six-person crew capability as early as 2009. The Shuttle was to be the primary means for ISS re-supply and crew rotation. NASA's international partners were planning to augment the Shuttle's capabilities with their cargo and crew spacecraft. Following the *Columbia* disaster in 2003, the President set a new "vision" for NASA that called for the Shuttle's retirement in 2010 upon completing ISS assembly. As part of the Vision, NASA is developing new crew and cargo vehicles, currently scheduled to be available in the 2015 timeframe. One of the vehicles—the Crew Exploration Vehicle—will carry and support only crews traveling to low-Earth orbit and beyond and will also be capable of ferrying astronauts to and from the ISS. However, since these systems are not scheduled to become operational until 2015, NASA plans to rely on international partners and commercial providers to make up the five-year gap in ISS logistics and crew rotation resulting from the Shuttle retirement.

Aggressive Launch Schedule for Space Shuttle

As we have begun our review of ISS assembly, several issues related to NASA's Space Shuttle manifest have come to our attention. First, the Shuttle manifest dated January 2007 projects that NASA will launch 16 missions before retirement of the Shuttle in 2010—one of those has already been launched. Of the 15 remaining missions, one will service the Hubble Telescope and two are designated as contingency missions. Assuming the contingency flights are included, on average, NASA will need to launch one Shuttle every 2.7 months—an aggressive schedule when compared to recent launch timeframes. In the past, with three Shuttles, NASA launched a Shuttle every 3.7 months on average after the *Challenger* accident in 1986. Since the *Columbia* accident in 2003, NASA has averaged 10.8 months be-

tween launches.[1] For the remainder of calendar year 2007, NASA has three launches planned, which will total four missions for the year. Due to vehicle traffic constraints, the minimum required time between Shuttle launches to ISS is 35 calendar days, so while the manifest is aggressive, it is achievable.

Additionally, the current Shuttle manifest leaves little room for unexpected delays caused by weather damage or launch debris, which have proven to impact the Shuttle launch schedule significantly. For example, in 2007, hail damage to the external fuel tank caused an unexpected two month delay in a Shuttle launch. While there are limits to the planning NASA can do for such events, the tight schedule constraints leave little room for significant delays as a result of such occurrences.

As evidence of the increasing pressure NASA is experiencing with regard to the Shuttle manifest, the ISS program office is planning for certain cargo elements to be launched on the two final Shuttle flights even thought NASA, as an agency, still considers these flights contingency missions. NASA is also being forced to consider the possibility of canceling delivery of some portions of the ISS. Specifically, NASA determined that if the schedule slips, the Cupola observatory and the Node 3 connector built for hardware, oxygen and waste storage may be slipped to contingency flights. If that occurs and those flights do not launch, those elements may not be assembled on ISS as originally planned.

Finally, NASA officials explained that since only the Shuttle is large enough to deliver certain large Orbital Replacement Units (ORUs) to the ISS, they must be launched prior to retirement of the Shuttle. These ORUs are replacement segments for those segments operating on the ISS that fail or reach the end of their life. The officials noted that NASA originally planned to use the Shuttle to launch and retrieve certain large ORUs that are critical for ISS operations. After being brought back to Earth, the plan was to repair and refurbish the ORUs and return them to service on the ISS. However, with the Shuttle no longer available to transport those ORUs after 2010, NASA changed its strategy for providing them to ISS from a refurbishment approach to a "launch and burn" approach. They suggested that under the new strategy, NASA would build enough ORUs to cover the ISS planned mission life and use them up over time. Large ORUs that originally were to be launched and returned on the Shuttle would have to be pre-positioned on the ISS before the Shuttle retires.

There is still much to be worked out with NASA's change in strategy for positioning ORUs to cover the Space Station's planned mission life. For example, the program office is still assessing the implications of restarting production lines to produce additional spares. This involves examining whether the right equipment, materials, expertise, and data is still available—an endeavor that the ISS program office acknowledged would be challenging. We will continue to monitor changes to the Shuttle manifest as they occur.

Shuttle Workforce Challenges

The Space Shuttle workforce currently consists of approximately 2,000 civil service and 15,000 contractor personnel. NASA must maintain a workforce with necessary critical skills to manage the Shuttle program through its completion. In response to GAO recommendations, NASA has undertaken several initiatives to attempt to address its potential workforce drain.

In 2005, we reported that NASA had made limited progress toward developing a detailed strategy for sustaining a critically skilled Shuttle workforce to support Space Shuttle operations. We reported that significant delays in implementing a strategy to sustain the Shuttle workforce would likely lead to larger problems, such as funding and failure to meet NASA program schedules. Accordingly, we concluded that timely action to address workforce issues is critical given their potential impact on NASA-wide goals such as closing the gap in human space flight. At the time we performed our work several factors hampered the ability of the Space Shuttle Program to develop a detailed long-term strategy for sustaining the critically skilled workforce necessary to support safe Space Shuttle operations through retirement. For example, the program's focus was on returning the Shuttle to flight, and other efforts such as determining workforce requirements were delayed. In our report, we recommended that NASA begin identifying the Space Shuttle Program's future workforce needs based upon various future scenarios. Scenario planning could better enable NASA to develop strategies for meeting future needs. NASA concurred with our recommendation. The agency acknowledged that Shuttle workforce management and critical skills retention will be a major challenge as it progresses toward retirement of the Space Shuttle and as such has acted to respond to our recommendation.

[1] These values represent the time between the launch date of the flight that resulted in loss of the Shuttle and the launch date of the next subsequent flight.

For example, since we made our recommendation, NASA developed an agency wide strategic human capital plan and developed workforce analysis tools to assist it in identifying critical skills needs. NASA also developed a human capital plan specifically for sustaining the Shuttle workforce through the retirement and, then transitioning the workforce. According to agency officials, currently NASA is mapping the available skills of the Space Shuttle workforce with the skills it will need for future work so that it can better plan and implement workforce reassignments. NASA's senior leaders recognize the need for an effective workforce strategy in order to successfully complete ISS before retirement of the Shuttle. Clear, strong executive leadership will be needed to ensure that the risks associated with the transition of the Shuttle workforce are minimized.

Filling the Gap Between the Shuttle and New NASA–Developed Vehicles to Service the International Space Station

NASA has several options for filling the gap between the Shuttle, which will retire in 2010 and new NASA-developed vehicles that are not expected to come online until 2015. The first relies on new vehicles developed within the U.S. commercial space sector. The second relies on vehicles developed by international partners—both new and legacy systems. There are considerable challenges with all options NASA is examining.

NASA Dependence on Commercial Development

NASA is working with the commercial space sector to develop and produce transport vehicles that can take equipment and ultimately crew to and from the Space Station during the gap between the Space Shuttle and the crew launch vehicle. Rather than buy these vehicles outright, NASA plans to help fund their development and purchase transportation services or perhaps even the vehicles themselves when they are needed. This program is known as Commercial Orbital Transportation Services (COTS). Currently, NASA has seven COTS agreements—all are in the initial phases of raising private funds for the development. NASA funding has been provided to two companies, Rocketplane Kistler (RpK) and Space Exploration Technologies (SpaceX). NASA has signed five more Space Act Agreements which facilitates sharing technological information, but these agreements are unfunded.

There are two phases to the program, the first phase entails COTS technical development and demonstration and the second phase will be the competitive procurement of orbital transportation services for ISS logistical support. NASA officials noted that both RpK and SpaceX met their first milestone to demonstrate financial progress by obtaining private funding. However, RpK missed its second milestone in May 31, 2007 and had to renegotiate its Space Act Agreement milestone with NASA.

The International Space Station Independent Safety Task Force (IISTF)[2] reported in February 2007 that the design, development, and certification of the new Commercial Orbital Transportation System (COTS) capability for ISS re-supply was just beginning. IISTF stated that, "if similar to other new program development activities, it most likely will take much longer than expected and will cost more than anticipated." Our work has generally found space and other complex system development efforts—including NASA-sponsored efforts—often encounter schedule delays and technical problems when they are seeking to obtain significant advances in technologies, move forward amid changing requirements or with other unknowns, and/or are managed without adequate oversight, In our opinion, risks may be high in these partnerships, given that the suppliers do not have long-standing relationships with NASA or other government agencies and the development of the COTS vehicles represent totally new endeavors for most of these companies. As such, it will be exceedingly important for NASA to establish sound program management and oversight controls over these endeavors, establish clear and consistent guidance, limit requirements changes, and ensure it has adequate visibility into the progress being made by the COTS suppliers. Our review will examine the extent to which these measures are being taken. As you know, GAO has identified contract management as a high risk area for NASA. Actions designed to enhance program management and oversight are being implemented, but it may take years to complete them. This may make it even more difficult for NASA to successfully manage and oversee its relationship with the COTS suppliers. If NASA relies on these development efforts without adequate oversight, the programs could fall short of cost and schedule

[2] As required by the *National Aeronautics and Space Administration (NASA) Authorization Act of 2005,* Pub. L. No., 109–155 §801, the International Space Station Independent Safety Task Force was charged with assessing the vulnerabilities of the International Space Station.

estimates, result in downgraded performance, and ultimately impact overall sustainment of the ISS.

NASA Dependence on International Partners

NASA has suggested that some supply activities during the gap can be conducted by vehicles under development or currently in operation by international partners—specifically, Europe, Japan and Russia—but these vehicles have constraints. Our ongoing review will assess these constraints in greater detail.

To begin with, new vehicles being developed by the European and Japanese space agencies are very complex. Currently, the first test flight for the European vehicle is likely to happen in January 2008. The Japanese vehicle will not have its first operational flight until 2009. According to NASA officials, both the European and Japanese vehicle developments experienced technical hurdles and budgetary constraints, but both partners are committed to fulfilling their roles as partners in the ISS program. They do have confidence that the European vehicle will be available for ISS operations before retirement of the Shuttle, but they are not as confident about the Japanese vehicle being ready by that time. NASA reliance on these vehicles to augment re-supply activities after 2010 assumes that further delays in their development will not occur. NASA's expectation is that these vehicles will be developed in parallel with commercial developments. The agency's preference is to use commercially developed vehicles, rather than rely on the vehicles developed by the international partners to cover the capability gap after retirement of the Shuttle fleet.

NASA also plans to continue working with Russia to provide crew and cargo support to the ISS, but this has been facilitated through an exemption to the *Iran, North Korea and Syria Nonproliferation Act.* Russian vehicles that were already operational were used to rotate crew and supply ISS during the period after the *Columbia* accident and a Russian Soyuz vehicle remains docked to the ISS continuously. The *Iran, North Korea and Syria Nonproliferation Act* exemption expires at the end of 2011, at which time any exchanges will be subject to the restrictions of the Act. However, if commercial development does not produce a usable vehicle by that date, the only vehicle that can support crew transportation is the Russian Soyuz spacecraft. According to NASA officials, the agency is planning to request a waiver to gain further exemption beyond 2011 if this situation occurs.

Additionally, there are challenges related to sharing knowledge with international partners due to restrictions by the International Traffic in Arms Regulation (ITAR). This was highlighted by the International Space Station Independent Safety Task Force, and NASA has been working to address the concerns laid out in that study. Over the years, GAO has identified weaknesses in the efficiency and effectiveness of government programs designed to protect critical technologies while advancing U.S. interests. While each program has its own set of challenges, we found that these weaknesses are largely attributable to poor coordination within complex interagency processes, inefficiencies in program operations, and a lack of systematic evaluations for assessing program effectiveness and identifying corrective actions. However, in reviewing in the Joint Strike Fighter, another complex international system development effort, we also identified actions that could be taken early in programs to prevent delays and other problems related to ITAR. Our review going forward will assess the degree to which challenges in this area remain.

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.

DISCUSSION

Chairman UDALL. Thank you, Mr. Chaplain. Thanks again to the entire panel. This is very, very helpful, and we will now begin the first round of questions, and the Chair will recognize himself for five minutes.

LOGISTICAL SUPPORT FOR ISS AND COTS

And I want to focus in on the issue of logistical support, and Mr. Holloway, from your testimony you feel like this is the most serious issue facing the program, that is this logistical support for the Station after the Shuttle is retired. You say, for example, that inadequate logistics will result in a serious decrease in the utility of the

Station and could result in its abandonment. And then you go on to recommend that the Administration, Congress, and NASA should support a productive, I am sorry, proactive emphasized post-Shuttle logistical transportation program, including adequate funding of approximately $1 billion per year above current allocations to insure that adequate logistics and spares are available to maintain a viable station.

You recommend as well that NASA not commit the ISS to an unproven logistic support system such as COTS. However, at present NASA appears to be counting on COTS as its main post-Shuttle logistics system, and the Administration's given little indication that it is considering this billion-dollar increase per your suggestions.

How much risk is being added to the ISS Program by these actions in your opinion? And Mr. Gerstenmaier, I will give you a chance to respond as well.

Mr. HOLLOWAY. Mr. Chairman, first of all, that is a very difficult question to answer, but at the time of the conclusion of the report there was 120,000-pound shortfall in logistics capability that was dependent upon some future transportation system, either the COTS or the emerging partner capability or the Russian progress vehicle. That is a tremendous amount of logistics, and as you well know, you need food, water, oxygen, and maintenance spares to be able to operate the Station. Without that you eventually will have to abandon the Station.

The COTS Program I am sure that we all are very anxious for it to be successful, and we are looking forward to the day when commercial activities can routinely launch cargo and people into low-Earth orbit. That will be a great day for the space program.

But the building of a rocket, of course, is a difficult endeavor, but with the proper reliability and safety aspects but also building a vehicle that can approach and be attached to the Space Station is a daunting, technical challenge driven by the appropriate I must say safety requirements to, that are levied on that vehicle.

The European Space Agency has been working on that for the ATV for approximately 10 years and have worked very diligently, and I must add at least for the last six or eight years have had a very good technical team. And they are just now emerging with the opportunity to launch the first one next year.

So in the long haul, I would think it would be unlikely that the COTS will be able to provide a substantial part of the logistics program in the most critical period following the retirement of the Shuttle program. I hope I am wrong, but I expect that it will be several years after that before routine commercial activities are viable.

So I think depending totally upon COTS would be a significant risk to the long-term viability of the Station.

Chairman UDALL. Mr. Gerstenmaier, would you care to respond, and you have 45 seconds to respond.

Actually, we will come back to you for your time.

Mr. GERSTENMAIER. Okay.

Chairman UDALL. The Ranking Member has offered to provide you the additional time to respond in the length that you need to respond, please.

Mr. GERSTENMAIER. Well, first of all, we agree that one of the long-term challenges of the Space Station is logistical support. This is clearly something we need to go work on. Since the task force reviewed the program, we added in some minimal progress support to provide some logistics capability to Space Station, and what we did there is we added just the absolute minimum essentially to keep Space Station viable. We didn't add any additional spares or any additional cargo in that contract addition, and we left room for the commercial orbital transportation systems to come on line. We also have got agreements now for the Automated Transfer Vehicle, the European vehicle, and also the Japanese vehicle to provide cargo to station.

So we have an understanding of the basic transportation plan that we need in the future. We have an approach that kind of goes day by day in a sense and allows us to monitor these activities such that we can anticipate a problem that is coming and still have a chance to react to it before it becomes a major problem to us.

So the first step is we are using the Shuttle and the two logistics flights to essentially outfit Space Station with all the spares that we can before the Shuttle departs. So we anticipate with our basic failure rates we see on our components we will have two to three years of margin after the Shuttle retires that the Station will be viable with the spares that we have pre-positioned. So in other words, we put items that we anticipate may fail on-board Station ahead of time so they are there in their pre-position. So that buys us some time.

We will also know next year how well the COTS Program is progressing. We will get a chance to see, they have a demonstration flight towards the end of the year and two other flights at the first part of the year. That will give us critical information and will tell us whether COTS is viable or it looks like it is going to be delayed a little bit. That will be very important data for us.

We will also get to see the Automated Transfer Vehicle fly in January. That will provide critical data to us. So I think we have a logical and step-wise plan that we can protect for this logistic period, this logistic support period when the Shuttle retires. We have time to detect a problem that is coming to us before we have to, before we are in a situation where we cannot react, and then we have some controls to react depending on what we see.

The other big unknown is we don't know what the failure rate is going to be on these components. We have only recently activated the truss components. That is the hardware that sits out on the truss. Some components are on the inside of the Space Station and perform significantly better than our analysis had shown, so we may be better from a logistics re-supply plan or a failure rate standpoint. Again, we will know next year.

So I think next year we will be in a much better posture to see what the future looks like, to see where we are, and we still have time to react with the plan. We are working this, and we are aggressively looking forward to solve this problem.

Chairman UDALL. Mr. Gerstenmaier, thank you, and I look forward to returning to this topic in the next round.

And at this time it is my pleasure to recognize the Ranking Member, Mr. Feeney, for five minutes.

MICROMETEOROIDS AND ORBITAL DEBRIS PROTECTION FOR ISS3

Mr. FEENEY. Well, thank you, Mr. Chairman. Yeah, I want to get back to COTS at some point, too, but first I want to address another issue that the task force brought up, Mr. Holloway, and that is referred to as the micrometeoroid and orbital debris problem, and I want to make sure I understand your presentation right.

On page 2 you say that over a 10-year period the ISS has a 55 percent chance of being struck by either debris or a micrometeoroid. Is that right? With a nine percent risk of a catastrophic result?

Mr. HOLLOWAY. That is correct.

Mr. FEENEY. With implementation of changes that are available that you have recommended, that that risk can be roughly cut in half?

Mr. HOLLOWAY. That is also correct.

Mr. FEENEY. This is a reminder that despite the great successes we have had, and by the way, the most recent one was the brilliant work that the people at NASA, the United Space Alliance, and many other contractors did working in a seamless team to get us through the hail storm issue from February and get us back in a very timely manner. So it is remarkable, but this is a reminder as you testified that space exploration is inherently risky. Does anybody on the panel have an opinion about the—well, let me ask the question first this way.

Mr. Gerstenmaier, has the Space Station had to be maneuvered at all to avoid any of the debris from the Chinese ASAT Test, where they basically blew up their own——

Mr. GERSTENMAIER. No, we did not maneuver the Station for that. The problem with some of that debris is it is so small it can't be tracked very effectively.

Mr. FEENEY. Right.

Mr. GERSTENMAIER. So then you don't know how to maneuver. The good thing about the Space Station was it was at a low enough altitude that the debris cloud from that satellite destruction transited the Station orbit very quickly. So it was a fairly short-term threat to Space Station. Space station has debris panels on the outside to protect us from this small debris that was called out in the report. Since the report we have added debris panels on the Russian service module. Those were done in an EVA this summer or early this spring by the Russians, so that activity is complete. We have also got some debris wings which will shield the service module. We have had discussions with the Russians, and we are currently planning to put those on a Shuttle flight in the future to go ahead and carry those up to Space Station.

So we have implemented one near-term protection. We have plans for another one that is moving forward, and we are still looking at the recommendation of putting additional protection on the Soyuz and progress vehicles, and we are still working with our Russian partners on that.

Mr. FEENEY. Well, Chairman Udall's home state they do a remarkable job at the space wing tracking some eight or 10,000 pieces of so-called space junk or space debris. But if this is as big

a concern as the task force recommends, Mr. Holloway, one of the things we need to do is to convince the international space-faring nations, starting with the Chinese, that turning one obsolete satellite into 800 or 8,000 pieces of space junk is a risk we don't want, as nations want to put human beings into space. So this should be, and there are lots of other reasons why the Chinese should not have done what they did, but at a minimum the fact that if the Chinese and other space-faring nations want to have peaceful human exploration of space, they have to respect the fact that they just can't put missiles out there to—and so if anybody cares to comment on that, that is fine. Otherwise, just be taken as a speech.

LOGISTICAL SUPPORT FOR ISS AND COTS

Mr. Gerstenmaier, going back to COTS for a second, NASA right now acknowledges a $300 million shortfall in the ISS crew/cargo services budget based on current estimates as I understand it, with an additional $600 million shortfall held as a lien against the exploration systems mission directorate budget.

We are all anxious and hopeful that COTS is going to be successful. You talk about a number of tests the next 12 months or so. When will we have to address the issue that the task force has raised about a potential billion dollar shortfall in servicing the Station post-Shuttle if COTS and our other international partners can't achieve what they plan—when will this decision be timely?

Mr. GERSTENMAIER. Again, as I described in my earlier remarks, it is really a process. We will gain some information on what our failure rates are of the components throughout this next year. We will also get a chance to see the provider's viability and see how well this space craft will perform, which will be important to us. We will also get an idea of what the cost of that cargo and carrying capability is. Through this next budget process we are working on now for the next budget cycle, we are refining some of those estimates, taking into account this data, so probably for next year's budget activity we will be prepared to discuss with a little more certainty about where we are in terms of budget threats and things.

But, again, there is many variables here, and we are actively analyzing those and gaining data to see if we can understand better what the real threats are and the options.

Mr. LAMPSON. [Presiding] Thank you, Mr. Feeney.

Mr. Udall had to step out of the room and asked me to take the Chair for a few minutes, and seeing as how I was the next one up for questioning, I will yield myself the next five minutes.

STATUS OF AMS

Mr. Gerstenmaier, let me start with you. I have had a number of meetings in the last several months with people who have been working on the Alpha Magnetic Spectrometer, AMS, and I know that this is something that has been taken off of the manifest from what I understand, and I am at some point in time wanting to seek ways that we will be able to hopefully get it put back on.

But what was NASA's original agreement regarding the AMS? Was it—and once the, well, what was the original agreement? Let

us start with that. I have a whole series of questions on this if you don't mind.

Mr. GERSTENMAIER. I believe the original agreement was to fly a precursor mission, which we did on STS–91, and that was to look at the basic technology and the basic device. We also agreed to provide some integration activity to essentially help build up the cargo and interface it with the Shuttle for launch vehicle. We are still continuing to do that, and we are still continuing to look at it.

And originally we had agreed to try to fly to Space Station in a long-duration manner. But after the *Columbia* tragedy occurred, we immediately informed the DOE that we could no longer live up to that second commitment, and the reason there is just the discussion we have had here is that we had this critical logistic sparing needs for Space Station and then we have a limited number of Shuttle flights. So we really have no option other than we cannot fly the device without taking some critical spares off that could jeopardize the overall health of Space Station.

So as soon as we knew that, the Administrator informed the DOE and our partners we could not meet that second commitment.

Mr. LAMPSON. What is the response of the international partners to NASA for canceling the plans?

Mr. GERSTENMAIER. Our interface is primarily with the Department of Energy, and I have, we have not heard anything, I don't think, directly from the Department of Energy.

Mr. LAMPSON. Might NASA be required to pay any penalties?

Mr. GERSTENMAIER. Again, I think it was, the way the agreement was written was it was written as a best effort, and we lived up to the intent of what the best effort was.

Mr. LAMPSON. Do you think that it might jeopardize future collaborations between or among potential partner nations on other projects?

Mr. GERSTENMAIER. Again, I think our partners recognize the complexity of what we are trying to do when we had the *Columbia* tragedy. You know, we are still launching their primary laboratory modules, we are still meeting our international commitments to them to do, to provide research facilities. Still providing substantial support to all our international partners in that respect, and I think they recognize the difficult situation that we were placed in, and they recognize the rationale for the decision that we had no choice to make.

Mr. LAMPSON. Just for the record, I have met with some of the representatives of those international partners, I think five of them, and from what I understand this project was one that was to cost around $1.2 billion, and the international partners were going to pay 95 percent of the cost of the project. They have essentially completed the work that they were doing on it, and the largest part of what we were going to do, I think, was to put it on the International Space Station.

Those folks with whom I have spoken are not the happiest campers in the world right now. So there is some potential downside for this not happening.

A recent Department of Energy sponsored external review of AMS supports the scientific validity of the AMS experiment. NASA's response is that, "The review does not evaluate AMS in the

context of NASA's broader program of astrophysics research. NASA's Science Mission Directorate relies on broad reviews of science disciplines conducted by the National Research Council of the National Academies of Science to establish priorities among potential missions." Because the DOE review took place outside of this framework, it is of limited useful to NASA.

Mr. Gerstenmaier, was the review conducted with the awareness of its limited usefulness to NASA, and if so, what was its purpose?

Mr. GERSTENMAIER. I am really not in the right position to answer that. I think that would be a better question directed at the Science Mission Director.

Mr. LAMPSON. Okay.

Mr. GERSTENMAIER. I am more on the facilities side and not on the scientific research.

Mr. LAMPSON. Fair enough. Thank you.

Would any of the other witnesses care to comment on any of the—Dr. Neitzel, please.

Dr. NEITZEL. I would be happy to comment, because I think that this occurrence speaks directly to what NASA says it wants to do with respect to the implementation of the National Research Laboratory aboard the ISS. NASA claims it wants to go out and find other federal agencies willing to perform research aboard the ISS and to utilize this unique facility. And here is a perfect example of the Department of Energy stepping up to the plate and doing exactly that with the participation of all these international partners, and now NASA says it is going to remove this experiment from the Shuttle manifest.

So that doesn't provide a lot of confidence that this model of having other federal agencies do research aboard the ISS is perhaps a viable one.

Mr. LAMPSON. Thank you very much.

Mr. GERSTENMAIER. And my only comment to that is in the National Lab proposal we recognize transportation up front as one of the key critical resources that need to be addressed up front. So in the case of AMS, we were forced into this because we lost our transportation system when *Columbia* disaster occurred. In the case of the National Lab we recognize this as a weakness that needs to be addressed, and we are going to work it up front with our partners and not mislead them and assume that transportation is available. That is something that we have to work, and we are trying to provide a better expectation for what can be done with the Space Station.

Mr. LAMPSON. It is something obviously that I have a significant amount of interest in, and I hope over time we will look for some innovative ways that we might be able to find the opportunity to make this piece of equipment be able to be deployed on the International Space Station.

My time has expired, and I would recognize the gentleman from California, Mr. Rohrabacher.

Mr. ROHRABACHER. Thank you very much.

RESEARCH ON ISS

Dr. Neitzel, is there anything that you can point to that we have achieved—of great value from scientific research—Shuttle? Excuse me. On the Station?

Dr. NEITZEL. On the Station? The number of investigations that have been done so far have been somewhat limited due to the compression of the assembly sequence post-*Columbia.* I can't say I am personally aware of any experiments that I would say have led to groundbreaking research, but there are some experiments that have gotten some results that could be——

Mr. ROHRABACHER. Results but nothing near the value that we were led to believe would evolve from the Space Station.

Dr. NEITZEL. Perhaps not yet, but that is partly due to the fact that the resources are limited, and the transportation resources to carry these payloads are limited. So we have many pieces of facility class hardware that are yet to be flown to the Station and utilized.

Mr. ROHRABACHER. The, we are talking now about—is there something that we might be able to do in terms of—has NASA offered this asset properly to the private sector and to a university system or should we being doing something else that would permit us to open up that opportunity?

Dr. NEITZEL. I can't speak too much to the private sector. That would be something Mr. Gerstenmaier would be better qualified to address. However, from the standpoint of the academic community, NASA has been sending the wrong message with the decimation of that research community effectively December of 2005. There were several hundred investigators who were essentially removed from——

Mr. ROHRABACHER. Well, given budget restraints, okay, given budget restraints and people, believe me, you just say to them—pay. We are going to subsidize what you want to accomplish. Given budget restraints, is there something that we can, some way we can attract more investment from the universities or from the private sector in a way that would be—necessary bottom line for us actually to get it done?

Dr. NEITZEL. Well, there needs to be a baseline research community in place to effectively utilize the International Space Station upon assembly complete, and that community no longer exists. Now, last year several of us were asked to provide some estimates for the amount of funds it might cost to keep alive a research community in this era where we have limited opportunities for flight but could still have extensive ground-based work that could be developing flight experiments, you know, therefore, enabling their conduct aboard the ISS at assembly complete. That community came up with a figure of on the order of $70 million, which, in my budget is enormous but in the scheme of things it is not a particularly large number. And it seems to me that that kind of figure ought to be able to be found easily within the existing NASA budget or through an additional appropriation.

Mr. ROHRABACHER. I will have to say that I don't think $70 million is easily found in anybody's budget these days—and I give Administrator Griffin credit. He is trying his very best, and every time you turn around when people suggest that finding things like

$70 million is easy, that just isn't the case anymore. And I think we need some very creative approaches, and I am very, you know, I am happy that NASA is trying to bring the private sector into bringing down some of the costs.

Of course, there is a risk factor in that perhaps the private sector launch capacity that we would hope was being developed, that might not work. Do we have, is not the, are not the Russians a back up if this does not work? If this is not successful and our own private sector is not capable of achieving the goals that they have set for themselves?

Mr. GERSTENMAIER. I think our international partners, the Russians, also the automated transfer vehicle, and then the Japanese HTV transit vehicle are also, are all viable back ups for us.

We still have the *Iran and Syria Nonproliferation Act* that we need to deal with beyond 2012, and we will do that at the right time.

ENHANCED USE LEASING

Mr. ROHRABACHER. And in terms of actually utilizing the Station, what we are talking about is utilizing it more for, let the private sector go in and let them try and find some creative uses for us. That leads me to Mr. Gerstenmaier—expanding enhanced use leasing, and in 2003, NASA was granted enhanced use leasing authority to permit the agency to lease underutilized property and other consideration as a demonstration program at the Kennedy Space Center and at Ames Research Center. Now, we have expanded that or we permitted that to, sort of as an example to see what can be done. Have we learned something? Can that now, are there other facilities, other NASA facilities that can be brought into play that are now underutilized?

Mr. GERSTENMAIER. We would like to open that up to all NASA centers. We think especially as the Shuttle systems are retired we will have some facilities available to us that would be attractive potentially to the commercial sector to utilize and to lease from us, and then we would like to take the funds from that, the excess capacity, and use those for other things, promote the more-NASA direct adventures and activities. So we think that the model worked well with the two centers. We would like to expand that to all ten centers.

Mr. ROHRABACHER. Is there any estimate as to how much money might be, revenue might be generated from this?

Mr. GERSTENMAIER. I don't have an estimate with me today, but we could take that for the record and see——

[The information follows:]

NASA ESTIMATE FOR ANNUAL REVENUE FROM ENHANCED USE LEASING AGREEMENTS

NASA is able to extrapolate reasonable estimates of the total value of the annual revenue to be received from existing leases based on the prior year's total annual revenue received. As outlined in the NASA 2006 *Enhanced Use Leasing (EUL) Annual Report* submitted to the Congress on April 24, 2007, the Agency reported $1.3 million in annual revenue received. Some of this was received for common services (such as security and fire protection) provided to all entities on the Center including the tenants; other portions were for rent of the actual land or facility. However, NASA is not able to estimate the amount of revenue that will be received from EUL leases that have not yet been entered into. As part of the *FY 2008 Omnibus Appropriations Act* (P.L. 110–161), Congress provided NASA with expanded EUL author-

ity for all NASA Centers, effective December 31, 2008. Consequently, beginning in 2009, NASA expects an increase in the number of EUL leases that the Agency will enter into, and therefore an increase in the annual revenue that NASA receives. Nevertheless, even though many of the NASA Centers that currently do not have EUL authority have ideas for potential EUL leases, there is no way to develop an estimate for revenue from those potential leases until the parties to the leases have entered into discussions for the actual amount of land, or facility, or portion of a facility that will be out-leased.

Mr. ROHRABACHER. Would it be possible with this approach that we might be able to come up with $70 million that might be used someplace else, for example?

Mr. GERSTENMAIER. I think based on the limited results we have seen from the two centers, I think that is a little bit on the high side of what is available, but it sure helps, and as you described in today's tough budget environment, any funds that we can get and use is definitely advantageous to us. And then we think there will be some facilities that can definitely be a win-win for the government and also for the private sector to get use of a unique facility in a unique location.

Mr. ROHRABACHER. This isn't the old days where people can just find $70 million, so we have to make sure we use every creative idea we have, and we do have an asset in the Space Station, and we ought to see if there is some creative uses, that could possibly go on there where we could generate some more resources as well. So not just savings in terms of how we utilize the Station. Actually the generating of resources.

Thank you very much.

Mr. LAMPSON. The gentleman makes some very strong points in comparison to the cost. We paid, I think paid so far some $30 billion in its construction, $70 million does not seem like a huge amount in comparison, and I think we will spend $100 billion over the lifetime of its operation. So let us hope we get it.

STATUS OF U.S.A. STRIKE AND ITS AFFECT ON THE SHUTTLE

Switch to something that I am not, I don't want this Committee to be taking sides on, but I would like to know, Mr. Gerstenmaier, the status of contract negotiations between the striking International Association of Machinist Workers who are involved in the processing of the Space Shuttle and the United Space Alliance. Can you give me an indication of what is happening?

Mr. GERSTENMAIER. I don't have direct insight into that. Our contractors are involved in those discussions and negotiations. At this time the strike is still ongoing, and we are able to essentially continue to process with limited support from our non-union workers down in Florida, and things are—I don't have the status of the latest negotiations.

Mr. LAMPSON. Okay. Has NASA evaluated the safety concerns voiced by the striking International Association of Machinists?

Mr. GERSTENMAIER. Yes, we have. We have been very careful to make sure that we are not progressing in any unsafe manner, that we have the proper skills, training for all our workforce, that we haven't cut back on any of our certifications of any of our workers for any jobs or any tasks in light of this. So we have made sure that we are processing the vehicles in a safe manner, and so far

we have done that. If we see anything that is out of bounds, we would stop the activity and not proceed.

Mr. LAMPSON. Can you give us some of the steps that NASA has taken to insure that the Shuttle processing activities associated with the next Shuttle launch are being conducted safely during the strike?

Mr. GERSTENMAIER. Yes. We provided some additional insight and oversight during some critical activities that, to make sure that we had all the right personnel supporting the activities, especially some of the vertical assembly building processing. We brought some extra NASA safety inspectors in, some extra quality folks in to actually watch that activity to make sure that it was occurring correctly, and we also reviewed the certification and training records to make sure that the employees doing the work were adequately trained and prepared to do the jobs to which they were assigned.

Mr. LAMPSON. And then what are the implications, if any, of the strike for the Shuttle launch schedule?

Mr. GERSTENMAIER. Again, near-term we don't see an impact to the near-term launch schedule. If the strike continues, we will have to continue to evaluate and to review, and again, as I stated, if we see anything that doesn't look right, we will stop the operation and no longer proceed. But we are continuing to evaluate and so far we have been affected but not overly affected.

SHUTTLE LAUNCH SCHEDULE

Mr. LAMPSON. Thank you. Your testimony notes that, "When we fly systems as capable and as complex as the Space Shuttle and the ISS in such a dynamic environment, we always have to prepare, be prepared for the unexpected and be agile enough to react quickly and effectively."

What contingency plans does NASA have in the event that weather or some other unforeseen event delays the Shuttle launch schedule to the point that assembly of the ISS cannot be completed by 2010, the date that the Shuttle is supposed to be retired and no more flown?

Mr. GERSTENMAIER. We have put together a manifest that has some robustness in it. You can see that our last Shuttle flight ends in July of 2010, and we have until September 30 of 2010. There is some margin there. We also have the ability to optimize that manifest a little bit and move some things around to actually gain some more margin if we need to, if we have another weather event, then we can move things around.

We also have the sequence and the flights ordered in a sequence that if we have to drop a flight at the end, it is our lowest priority flight, and we would make that evaluation when the time comes to drop the appropriate flight that needs to be dropped if it falls beyond that timeframe.

And, again, so I think we have prepared as much as we can. We have robust manifests. We look at this from an overall standpoint, from, it is not a single system that can cause us to delay. It is the entire system. We are looking at it continuously. We are prepared. We have some margin to take some other weather delays. And in fact, this year we have planned three flights. We plan a flight in

August, a flight in October, and a flight in December. Quite possibly that December flight may not occur just because of vertical assembly, building scheduling, and single high bay that is available. That flight may move into January. We have already evaluated that. That can occur without any impact to the downstream flights, and we will still be okay to accomplish the missions.

POSSIBILITY FOR AN ADDITIONAL SHUTTLE FLIGHT

Mr. LAMPSON. If somehow or other Congress did miraculously find the extra money for another flight, is it possible that we have the capability of building the fuel tanks and whatever else, support to it? Or is that gone?

Mr. GERSTENMAIER. We are in the process right now of terminating a lot of contracts and subcontracts. So at this point we probably still could reasonably add another, we have enough ability to buy enough spares to potentially put together another flight. Later this year and into next year we will eventually lose that ability because we will have turned off spares and suppliers. So we are kind of in a transition period. There is not a single point in time, but it is becoming more and more difficult to actually add an additional flight.

Mr. LAMPSON. Mr. Holloway and Ms. Chaplain both, would you all care to comment on any of those, please?

Ms. CHAPLAIN. I would just add that if another flight was added, it would further compress schedule. So you are just adding a little bit more risk to that schedule that needs to be negotiated.

The other thing I understand with some of these spares is that NASA is still learning their failure rate time periods, and that learning will occur for several years forward, and it won't be known until late in the schedule, you know, do shifts need to be made, what should be on that last flight, you know. All those, there is a lot of questions that are going to be out there for the next couple of years just of the need to learn the lifespan of some of these materials that are, need to be on board.

Mr. LAMPSON. Well, what is magic about that schedule? Why couldn't a flight be added at the end or of what is presently the existing schedule?

Ms. CHAPLAIN. As I mentioned in my testimony, there is about two, you know, they need 35 days between flights, and we have estimated 2.7 months between flights right now. So it is just adding another flight further compresses that time period to turn the launches around and get ready for the next one. It is still probably achievable. It just adds more schedule risk.

Mr. LAMPSON. But no possibility of extending that schedule?

Ms. CHAPLAIN. Past 2010?

Mr. LAMPSON. Uh-huh.

Ms. CHAPLAIN. You would have to ask NASA.

Mr. LAMPSON. Okay. Well, I am trying to get your feeling of that.

Mr. Holloway.

Mr. HOLLOWAY. I believe the Space Shuttle team has a great deal of flexibility to deal with a near-term and a short-duration schedule upset such as Mr. Gerstenmaier mentioned. I think in, over the course of the next three years I think they will be able to deal with those short-term weather delays of a week or two and

so on and so forth. And in the near-term they can go much faster than they go for the long haul, if you understand what I mean by that, and can make up for lost ground.

However, I would suspect that it would be most difficult to recover from a long-term delay such as the damage to the tank that occurred.

Mr. LAMPSON. Thank you very much.

I recognize Mr. Feeney for five minutes.

Mr. FEENEY. Thank you, Mr. Chairman.

ORBITAL DEBRIS

I have one more question on the micrometeoroid debris. Mr. Holloway, in your calculations where you say we can get that over a ten-year period to, you know, five percent risk of a catastrophic event. Have you taken into account the fact that we expect to double the size of the Space Station before completion?

Mr. HOLLOWAY. Yes, sir. That was taken into consideration in the basic calculations that was provided to us by NASA.

Mr. FEENEY. Well, I don't want to be too alarmist. I live in Florida, and over the next ten years the chance my house gets hit by a catastrophic event, a hurricane or tornados, is probably at least a good five percent. So, that is something that we all ought to be aware of.

NASA AND ITAR

For Mr. Gerstenmaier, the task force has strongly recommended that the State Department should give relief from ITAR. They have done that in the short range here, but given the fact that we have, you know, reports in the last 24 hours, for example, have talked about the Chinese domestic spying for both economic and military reasons, and they seem to have enhanced capabilities and access, which is very troubling. What type of plans does NASA have as it seeks these necessary waivers so we can get cooperation with contractors that do international work and international partners. What type of plans do we have to insure that there is oversight that we do not allow critical technologies to get into the wrong hands?

Mr. GERSTENMAIER. In the case of the Space Station, you know, we are partners, are part of essentially a memorandum agreement and government agreements that are in place that insure that we don't transfer data back and forth amongst ourselves unnecessarily. So I think there is some protection already within the Space Station itself.

In the case of the Automated Transfer Vehicle, we pursued through the State Department and with our contractors all the necessary agreements, the technical agreements to get in place to ensure that we would not transfer data inappropriately, and that has worked well. We still would like to have some more restrictions removed. The things that have become problematic, for example, is if a failure occurs on the Automatic Transfer Vehicles that is approaching the Space Station, we need to have the ability to talk with our international partners about what that failure was and how it occurred to avoid that spacecraft from hitting the Space Sta-

tion or causing it damage. And so we need some relaxation in those kind of dealings in the real time environment.

So we are speaking or seeking specific changes and specific limited areas that won't overall impact the transfer of critical information.

Mr. FEENEY. Mr. Gerstenmaier, which of the task force key recommendations do you agree with, which do you disagree with, and which are you sort of undecided about?

Mr. GERSTENMAIER. I think we agree with all the recommendations, and we are aggressively moving out on them. They are going to take a significant amount of time for us to implement. In some cases multiple years. Some of them are out of our direct control. Some of them rely on State Department. Some of them rely on some potential Congressional funding, but the ones that we have control of we are moving out as fast as we can, and we would, we anticipate we will be able to satisfy all the recommendations. In fact, they were a very good set of data for us to work on.

FEASABILITY OF ADDITIONAL SHUTTLE FLIGHTS

Mr. FEENEY. Would there have been discussions about a number, a completion of a number of missions, Mr. Rohrabacher talked about one, Congressman Lampson when he was in the Chair. Other than budgetary constraints and Congress's willingness to fund it, is there any technical reason that you are aware of, and Mr. Holloway, the same thing, that if the Shuttle had to fly an extra two or three missions, it took an extra six months or a year, is there any technical reasons we are aware of that that is a practical impossibility for technical reasons or capabilities?

Mr. GERSTENMAIER. There is not a technical reason that that can occur. The problem becomes budgetary, that if that money then comes from exploration, then that takes money away from the constellation vehicles, the Orion and Ares vehicles and delays that generation of the next vehicle, because the NASA budget is essentially capped at a certain level. So that is the constraint. Technically it is viable but then programmatically it just makes a longer delay in where we are.

The other piece is that the Shuttle is really necessary for these assembly flights and that extra complexity and that extra care is warranted. We would like to migrate to a newer vehicle that is more dedicated to crew transport, that is a little simpler to operate, potentially a little bit easier to operate than the Shuttle. So we want to get to the new vehicle as soon as we can. So delaying the Shuttle because of the funding constraints delays that next vehicle, which keeps us from where we want to go in the future.

Mr. FEENEY. With permission of the Chair for a moment, the new vehicle does have a lot more flexibility and capability but not in terms of the size of the payload. And so to the extent that some of these are payload size issues, the bottom line is that if Congress and the Administration in the future decide that we need to have an extra mission or two, and it needs to last an extra six months or two, that is kind of in our hands. There is no technical reason you are aware of or Mr. Holloway is aware of that that is an impossibility?

Mr. GERSTENMAIER. No technical reason.

Chairman UDALL. Thank you, Mr. Feeney. Thank you, Mr. Gerstenmaier. That is actually a very good point to keep in mind that Ranking Member Feeney mentioned.

STATUS AND FUTURE OF ISS RESEARCH

Dr. Neitzel, if I could turn to you, there is testimony on both the status of and the outlook for the Station research. If I could, I would like to throw a few questions at you and then you can pick and choose the order in which you would answer those.

The first one would be do you think the situation is irreversible and could it be fixed, and I would then move to a follow on, which is if it isn't irreversible, what would be your highest priority recommendations for fixing it. And that would be what could Congress do, and then as a follow on to that question about Congress, what would the role of NASA and the Administration be fixing a situation that, again, you pointed out is pretty sobering.

Appreciate your thoughts on this.

Dr. NEITZEL. Well, the research community is down to next to nothing right now. There are a few non-exploration research projects sponsored in academic institutions. I am fortunate enough to have one of them, a small one. I don't think the situation is irreversible at this time, but I think if we wait too much longer, it may become irreversible. As I pointed out in my, in both my oral and written testimony, a large number of the people who were working on these NASA-related projects have now moved onto other pursuits. These people have lots of interests, and there are lots of other places to receive funding to support research and to support graduate students and undergraduate students.

However, there are probably still some experiments that had been in the planning and development stages prior to the cancellation of these projects that may be able to be taken out of the closet, dusted off, and revitalized. So they could be flown perhaps as early as 2010.

The problem is that a flight experiment used to take seven or eight years to get to to space. With the development and the very wise decision by the, by NASA in my opinion to develop these facility class payloads, that development time for experiments that could utilize those facility class hardware payloads was going to be brought down to about four years. That is the length of time that a faculty member gets interested in now because that is the length of time over which a Ph.D. student is typically trained.

So I still think there would be interest in a large fraction of the community that had been involved in NASA-related research to come back and continue with the research, if their other commitments allow it.

Your second question was if it isn't possible, the highest priority for fixing it. I think I sort of wrapped both of those answers into that, and the role of NASA is that NASA has to, and the government as a whole has to commit to a long-term support of fundamental and applied research aboard the ISS in order to get this community back to the fold. No one is going to want to come back, revitalize a piece of research, start working again on a flight experiment, only to be told a year from now that the priorities have changed again and your work isn't needed.

So I think there needs to be a long-term commitment to the science community to support research that will ultimately get done aboard the ISS.

Chairman UDALL. Would you expand a little bit more on that length of that commitment and any more specific thoughts you might have about what that commitment would involve? From, this is from NASA.

Dr. NEITZEL. Well, I believe you were out of the room when I responded to Mr. Rohrabacher that the community had come up with a keep-alive number of about $70 million per year that would be required to sustain an effort, roughly half of what it was before the December, 2005, Christmas letters that we received from NASA that canceled the research program. I think at the minimum that kind of a financial commitment needs to be made by NASA to insure that there is enough community left with experiments in the pipeline to be able to effectively utilize the facilities aboard the ISS out until its projected lifetime ends.

If we think about that pipeline requiring three or four years to get something to space, then experiments that are going to be done in 2010 had already better be started, and the ones that would start now would then go into the years beyond 2010, taking us out to 2015, or whenever the ISS ceases to be viable.

Chairman UDALL. Yes. I understand that Congressman Rohrabacher's open to further persuasion by the Ranking Member and even myself when it comes to making that additional investment.

Dr. NEITZEL. That is good to hear.

Chairman UDALL. Well, I thank you, Dr. Neitzel, for your input and your insight. I think this is a very important point you have raised. The Chair looks forward to working with you.

Dr. NEITZEL. Thank you very much.

Chairman UDALL. The Chair recognizes the gentleman from Texas for five minutes.

SHUTTLE CONTINGENCY FLIGHTS

Mr. LAMPSON. Thank you, Mr. Chairman. Mr. Gerstenmaier, in Mr. Holloway's testimony he states that the ISS Independent Safety Task Force recommended that NASA commit to carrying out two so-called contingency Shuttle flights to insure that the ISS will have the needed spares in place prior to the retirement of the Shuttle. In fact, he states in his view that NASA should, "Develop an option that insures that the two remaining Shuttle exterior flights are given the highest priority for flight in front of Node 3 if necessary to avoid exacerbating a problem should all planned Shuttle flights not be completed."

Those are pretty forceful and unambiguous statements. Do you agree that the two contingency flights should become part of the baseline?

Mr. GERSTENMAIER. Yes. Technically I think that is something we need to, we need to fly those flights for the reasons we have discussed.

Mr. LAMPSON. And then what about his personal recommendation that they be given the highest priority for flight?

Mr. GERSTENMAIER. Again, I think I would soften that a little bit just to see what our failure rate is over the next year, and I recognize we won't have perfect data, but I sure will have a lot better data after seeing how well this hardware performs in one year, and then we could, then we will make a decision on whether they are the highest priority as you described.

Mr. LAMPSON. And then when will the final status of the two contingency flights be nailed down, and who needs to make the decision on whether to include them in the Shuttle manifest?

Mr. GERSTENMAIER. They are currently in our budget right now, and we plan to seek to officially add them this summer.

Mr. LAMPSON. Mr. Holloway and Ms. Chaplain, would you please comment on that line of questioning?

Mr. HOLLOWAY. I don't have anything to add except I suspect when it plays out those two flights will be critical in maintaining the, particularly the external spares. As you know, today there is not a capability to, outside the Shuttle to launch external spares, and so NASA will be dependent upon the emerging Japanese capability or the COTS capability. And neither of those are a sure thing, at least in the short-term.

So, again, I believe as the task force recommended that getting these two flights done is extremely important to maintain the viability of the Station.

Mr. LAMPSON. Ms. Chaplain.

Ms. CHAPLAIN. I agree with Mr. Holloway, and would just add, though, that not having Node 3 go up does further hamper the ability to conduct research on the Station. So it is another tradeoff that makes research more difficult to do, but it is a tradeoff you have to make if you want to sustain the Station.

Mr. LAMPSON. Thank you very much.

Mr. Chairman and Ranking Member, I for one and probably people may start throwing things at me when I say this, but I think it would be very, very worth our while to see if we can't begin to lobby our own colleagues to find the money necessary to do more of the science. Sure it is going to cost us more money, but we chose to dream, and we chose to dream big, and now for us to back off on—doesn't make a lot of sense to me.

I will put my neck on the line and go out and start asking for support for the increased resources necessary to do these things. Science is critically important. It should be more than $70 million in my opinion, and when we begin to skimp, it just seems like we shortchange ourselves. We have gotten huge returns from what we have learned in the past, financial returns. We created significant industries, we have made, created untold numbers of jobs and put exceptionally great amounts of money into the economy. When we choose to look and play small, we, I think, give away, we give away our future.

At any rate, I am volunteering to work with you and any of the rest of us in Congress to try to make these things happen. Dream and tell us those dreams and we have the responsibility to try to make them come true.

I will yield back my time.

Chairman UDALL. The gentleman from Texas is as always courageous and well spoken, and I look forward to working with him to

make sure we make the maximum usage of this leadership in that regard.

The gentleman from Florida is recognized for five minutes.

Mr. FEENEY. Well, thanks, and I appreciate Congressman Lampson's encouragement and agree with that. I should know, my understanding is our Appropriations Committee in the House has put in plans the capability to fund the two contingency missions, which for the long-term health and resiliency and longevity of the Shuttle apparently are very important according to the task force recommendation. I don't think Mr. Gerstenmaier disagrees, and so I also think that having reestablished a regular schedule with some successes will make it easier for Congressman Lampson and the Chairman and others to encourage our colleagues that an investment in future science programs, I mean, if you weren't going to get the Shuttle back up safely on a regular basis. I can understand a lot of reticence.

So the successes that we have had, Mr. Gerstenmaier, will allow us to make credible arguments along the lines as Congressman Lampson suggested.

WORKFORCE TRANSITION

I want to leave with one last thing that is obviously a passion of mine. We have got a huge workforce at NASA in the Kennedy Space Center area and with the many contractors that service that area. We learned lessons after Apollo about the loss of workforce within a transition after Apollo. We learned lessons after the *Challenger* disaster about the irreplacability of the special capabilities and skills. Dr. Neitzel is testifying today about the problems in life sciences because we have dramatically slowed down emphasis in those areas. What does each of you recommend briefly that you can do as you complete the International Space Station and retire the Shuttle that will make the transition for employees and workforce skills as seamless as possible?

Mr. GERSTENMAIER. From our perspective we are trying to show that the work we are doing today has a real benefit to the future programs. As I described in some of my opening remarks, a lot of the systems on-board the Space Station that were up and operating, the pumps and systems that operate are real systems that will be used in future exploration systems, and we have a natural tie between those two.

So the folks that are working on the Space Station can see that their future and their work is tied, now today is tied to exploration in the future.

The same with some of the workforce down at the Kennedy Space Center. We recently, we are getting ready to stack the solid rocket motors for the October flight, and typically we stack those solid rocket motors in parallel. We stack one side, then the other side, and the stacks that then will, the external tank will hang between. What we are doing this time is we are just stacking one of those boosters, and we are doing that because we are going to fly the Ares 1–X flight in 2009. That will be the first test flight of the Aries system with dummy upper stage with just a single booster off of one of our mobile launch platforms.

So we are going to gain data on how much that launch platform deflects with just a single booster on it. We can provide that data to the exploration folks.

So, again, we are showing a real world tangible example of the Shuttle workforce is actually preparing the way for the exploration workforce to get ready. So we are showing our workers there is a future. The jobs will be different. They may not be operational type of jobs. They may be more developmental operations kind or more, they will not be operational jobs. It will be more developmental in nature, but we are showing that there is a future. We are providing them training opportunities and allowing them to be part of that future system today while they are doing their existing job.

Mr. FEENEY. Go ahead, Ms. Chaplain, or anybody else who would like to—and then I am going to yield back the balance of my time when the panel is completed.

Ms. CHAPLAIN. I just would make a couple comments on workforce because we have been doing some work in this area.

One of the things we would like to see NASA do is make sure it has good measures to track the progress of a lot of the actions they have been taking to sustain and keep the critical skills that they need. The activity of mapping skills that they have now to what they need in the future is good, but that needs to be tracked continually. And government-wide, you know, we have this issue of retaining systems engineers in-house in government agencies that all agencies are, you know, facing problems in that area and incentivizing people to stay. And at the same time knowing how to manage the contractors that you are relying on to conduct the activities and systems engineering.

So it is just another area they need to pay special attention to to make sure they don't lose that critical expertise.

Dr. NEITZEL. Might I make a comment? I certainly would worry about the ability to retain center personnel at the various NASA research centers who work and support the research payloads that go up to the Station and have been flown on the Shuttle. There is a large body of expertise there that could conceivably be lost as you pointed out in the era between Apollo and the Shuttle program. A large number, a large amount of institutional memory went away.

I also worry very much about our ability to motivate future generations of young Americans to consider careers in science, technology, engineering, and mathematics, the STEM disciplines.

We have a hard time right now retaining young people at universities who come starting to study engineering and sciences. So we need motivators to keep those kids interested and to keep them wanting to pursue careers in science and engineering. And if we take away a large thing like the space program, which is one the things that motivated me when I was a teenager growing up in Florida, we risk losing the next generation to these kinds of activities. Not just, not the whole generation just because the ISS may go away, but we really need these kinds of things to help motivate our kids to pursue careers in technological fields.

Chairman UDALL. I thank the gentleman from Florida for some terrific questions.

STATUS OF HUBBLE SERVICING MISSION

I am going to direct a final set of questions to Mr. Gerstenmaier. This is actually one of my favorite assets in the portfolio of NASA, and that is the Hubble telescope. I would like to give you, Mr. Gerstenmaier, a chance to talk a little bit about the status of the preparations for the mission and what do you consider to be the greatest challenges, including that mission successfully, and is there any chance that the '08, launch date might slip because of its accommodate assembly mission to the state?

Mr. GERSTENMAIER. We are actively in the process of working on that mission with the Science Mission Directorate, and the Science Mission Directorate is finalizing the activities that are going to occur on that flight, what specific instruments are going to be repaired. We have been busily working with them to insure that we are prepared to go do this. Again, Space Station has prepared us in a lot of ways that we were not prepared with before for the Hubble serving mission. We have gained a lot of experience in extra-vehicular activities or space walks that will be, have direct application. So I think the teams are prepared. We are ready for that mission.

Recently when we had the hail damage to the tank, the Shuttle manifest went through a slip, we actually held the Hubble mission in its position in the calendar dates, and we let some of the Station missions slide beyond the Hubble mission to hold it in the September timeframe. I think on paper we show it now maybe in the August timeframe. It will probably be in September when we actually fly the mission. So we have been able to hold the Hubble telescope even though we had some schedule threats and we let the Station flight slip around because, again, we don't often get to optimize for whatever situation we have. We have to balance between the two, so we balanced the risk of getting the Hubble serviced at the right time against the Station delays, and we made the appropriate decision, I believe, to hold the Hubble where it was. So, again, things look pretty good for the Hubble mission.

One other thing I would add is the Hubble telescope team is looking at some innovative tools to actually be able to repair potentially some devices out on the outside. They have developed a device that will hold screws that allows to essentially pop a circuit breaker out of a device that is on the outside of the Hubble Space telescope, and replace a card within that computer device.

I don't know if we will decide to do that particular task on the Hubble mission or not, but that has tremendous application to Space Station and other vehicles. We now maybe have the ability to go outside and repair a computer box without having to bring it inside, pop the card up, put a next card in. We may even be actually able to do that on the outside.

So, again, we are able to learn from the science group and what they are repairing for their repair mission and apply that to Station and apply that to exploration. So as long as we stay open and we continue to work across programs, we can maximize the benefit as we move forward.

So this mission fits well.

Chairman UDALL. Just out of curiosity since I have a little bit of time left, the procedure you just outlined, in the past has it been difficult or impossible to undertake because of zero gravity or because of the extreme conditions that are out, you find outside the body of the Space Station or the telescope?

Mr. GERSTENMAIER. The problem in this case is there is a bunch of screws, about—I think maybe ten or so screws that actually hold the circuit board in place. Those screws are not captive. So when you are in the space suit with the gloves and the tools, and you back that screw out, it typically floats away, and then you are in not such good shape.

What they have developed is a simple plastic device that sits over the top of those screws and then as the screw backs out with the device, it goes in and it is held captive in this plastic device, and then you can change the card out, put the plastic device back on and reinsert the screws back into the circuit board.

So it is a clever concept, a mechanical way to capture and hold these screws or a way to repair something that wasn't intended to be repaired that way. And I guarantee you we will take benefit of that on-board the Space Station, either on the inside or on the outside of the Space Station.

Chairman UDALL. And it also has a useful in a gravity environment as well.

Mr. GERSTENMAIER. It is not as critical in the gravity environment because gravity provides that force that holds the device or the screw where you want it to be, and in this case it is a——

Mr. FEENEY. Mr. Chairman, just out of interest, if I may, sorry to interrupt, but——

Chairman UDALL. Happy to yield.

Mr. FEENEY.—I am going to show my scientific ignorance here. That is why I was a dirt lawyer before I got to Congress. Wouldn't magnetic capabilities help?

Mr. GERSTENMAIER. That would be another option, too, but the beauty of this device is you place it on and then all ten screws are held by this device where some kind of magnetic capability, it may be a screw at a time, and then you have got the screw magnetically held to your screwdriver, and then how do you get it off with this big glove on? This way it is all held by the mechanical device, and it is a very elegant solution to a fairly simple problem but a problem that we face in zero gravity.

Chairman UDALL. With that I thank the gentleman from Florida for his question. At this point I want to bring the hearing to a close. I want to thank all of the witnesses for testifying before the Subcommittee today on these very important topics that deal with the future of the space program, our competitiveness agenda, and whether we are going to be the innovator of the world in this regard.

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.

The hearing is now adjourned.

[Whereupon, at 11:40 a.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Mr. William H. Gerstenmaier, Associate Administrator, Space Operations Mission Directorate, National Aeronautics and Space Administration

Questions submitted by Chairman Mark Udall

Q1. Given the European Automated Transfer Vehicle has taken approximately 10 years to develop, according to Mr. Holloway's testimony, what evidence, technical or otherwise, does NASA have to indicate that COTS systems will be available within the timeframe NASA needs them to support International Space Station (ISS) logistics?

A1. Modern commercial development practices employed by the Commercial Orbital Transportation Services (COTS) partners are expected to accelerate the development schedules for these systems. Also, the technology employed by vehicles to fly cargo or crew to the ISS is well within today's state-of-the-art. The ISS integration of the European Space Agency (ESA) Automated Transfer Vehicle (ATV) and the Japanese Aerospace Exploration Agency (JAXA) H–II Transfer Vehicle (HTV) has provided valuable pathfinders that make the subsequent integration of new visiting vehicles much easier. Although one COTS partner has encountered issues with financing, the other participant has successfully completed six milestones on schedule and their vehicle is still on track for a final demonstration flight to the ISS in late 2009.

Q2. Has NASA assessed the technical status of non-U.S. vehicles such as the Japanese HTV and European Automated Transfer Vehicle (ATV) that are intended to provide cargo services to the ISS once the Shuttle has been retired?

A2. NASA maintains an on-going integration and oversight role of the HTV and ATV. Major Design Reviews and Technical Interchange Meetings (TIM) are regularly conducted to confirm technical progress with the International Partner visiting vehicles. A representative set of key events for HTV include:

- Critical Design Review 2 in April 2006;
- Proximity Operations Preliminary Qualification Review (PROX PQR) in July 2007; Launch Package TIM in June 2007; and,
- HTV Joint Operations Panel (HJOP) in June 2007.

A representative set of key events for ATV include:

- ISS Independent Safety Task Force ATV Review in October 2006;
- NASA Headquarters ATV Review in January 2007;
- PQR in June–Sept. 2007; and,
- Program Manager's Review in September 2007.

Q2a. What back-up cargo transport has NASA established should COTS and the non-U.S. vehicles be unavailable to meet NASA's logistics schedule for ISS?

A2a. NASA has developed a plan for flying multiple cargo transportation vehicles with multiple development timelines to support the ISS. This is a strategy that does not depend solely on one vehicle's success to ensure ISS viability. NASA closely monitors development of the COTS vehicles and has strategies to react within the appropriate timeframes if the development does not proceed per schedule.

The Shuttle manifest calls for 10 assembly flights to the ISS and one to service the Hubble Space Telescope. In addition, NASA may fly up to two additional ISS logistics flights if they are deemed necessary and can be safely flown before the end of 2010. As a part of ISS assembly, NASA will continue to use the Space Shuttle to preposition spares on orbit. This will provide some schedule margin for new visiting vehicles.

Q2b. If NASA begins to use COTS systems and a COTS launch failure occurs, what back-ups would be available to support the ISS?

A2b. NASA hopes to have multiple U.S. providers available for services and will structure the ISS re-supply services contract in a way that will enable multiple provider support. However, if a U.S. provider fails and an alternate U.S. provider is not available, the ISS would utilize alternate transportation capabilities provided by the International Partners.

Q2c. How far in advance must NASA procure additional Progress, ATV or HTV vehicles?

A2c. The lead time is about two years for Progress manufacturing. However, there is a concern as to whether the infrastructure can support the build, processing and launch of additional Progress vehicles above the current level planned for ISS. For ATV and HTV, the lead time is about three years.

Q3a. Mr. Holloway's testimony refers to "160,000 pounds of logistics and spares that must be transported to the Station between 2010 and 2015."

Does that mass include logistics needed to support ISS research as well as ISS research experiments? If so, how much of the total is for each?

A3a. The mass does include logistics to support ISS research. Utilization demand comprises about 39,000 pounds of the 160,000 pounds of total ISS demand from 2010–2015.

Q3b. How much of the 160,000 pound logistics requirement can be satisfied at present?

A3b. As stated in the ISS Safety Task Force Report, about 40,000 pounds will be delivered by International Partner vehicles to offset their CSOC obligations. The remaining 120,000 pounds (or 54.4 MT) will be delivered on COTS vehicles.

Q3c. What are NASA's plans for securing transportation for the remaining logistics requirements?

A3c. As stated above, COTS vehicles will deliver the remaining 120,000 pounds of cargo.

Q3d. What logistics support (upmass and downmass) on COTS vehicles, Progress or Japanese HTV vehicles will be allocated to ISS utilization?

A3d. Given this set of launch vehicles (including ATV), 100 percent or 39,000 pounds of the utilization demand will be delivered in the 2010–2015 timeframe.

Q4. With respect to ensuring U.S. access to the ISS,

Q4a. What is the plan for getting U.S. astronauts to and from the ISS after the current exemption from the ISS-related payments provisions of the Iran and Syria Nonproliferation Act *expires at the end of 2011?*

A4a. Once the Space Shuttle retires and until COTS Capability D or Orion becomes available, the Russian Soyuz represents the only crew transfer vehicle that can support ISS crew exchanges and rescue services.

Q4b. Does NASA plan to seek legislative relief to allow payments to Russia for continued ISS related crew transfer and crew rescue services after 2011? If so, when will that occur?

A4b. NASA is monitoring the progress of potential domestic commercial providers to develop cargo and crew transportation services to the International Space Station (ISS), and the Orion project is on track to reach its Initial Operational Capability in March 2015. Purchasing cargo and crew transportation services domestically is NASA's preferred method to meet the needs of the ISS. The Administration is considering options to maintain a U.S. crew presence aboard the ISS. This may include relief from the provisions of *Iran, North Korea and Syria Non-Proliferation Act* (P.L. 106–178, as amended) ("INKSNA") for additional Soyuz services to keep a U.S. crew presence on the ISS until either domestic commercial crew transportation services, or Orion, become available. We will keep the Congress fully informed of our plans.

Q4c. What is the earliest credible date that a commercial crew transfer service might be available, and what is your estimate of the most likely date?

A4c. The currently funded Space Act Agreements (SAA) with our COTS partners include milestones for both a cargo and a crew transportation demonstration, with only the cargo demo milestones currently funded. If the crew transportation demonstration option is exercised and funded by NASA upon the successful conclusion of the cargo demonstrations, the proposed option's milestone schedule could support testing and demonstration of COTS crew transfer capabilities as early as 2011 or 2012, after cargo is successfully flown on multiple flights and the reliability of the new system is established. One of the Agency's funded COTS partners has completed all six performance milestones on schedule to date, however significant technical challenges remain for completing the remaining milestones. NASA will have the ability to more accurately estimate the COTS Capability D availability window after additional partner milestones are attempted and met over the next year.

Q4d. What will you do if neither commercial nor Russian options for crew transfer are available to NASA after 2011?

A4d. NASA anticipates that the Russian Soyuz vehicle will be the only option for crew transfer and emergency crew return capability for post-2011 until Orion or COTS Capability D are available.

Q5. Ms. Chaplain's testimony discussed the risks of the COTS program given the new relationships that NASA is developing with potential COTS providers and the fact that new vehicles are being developed. Her testimony also noted that "it is critical that NASA establish clear and consistent guidance, limit requirements changes, and ensure that it has visibility into the progress being made by the commercial suppliers." What, in specific terms, is NASA doing to address these issues and risks?

A5. The COTS model is a different approach from standard government contracting, and the approach to the development of new vehicles is also different. The COTS partners are not developing a system to be operated by the government or its contractors, but are demonstrating a capability that NASA can later utilize as a commercial service. While these companies develop vehicles that they intend to use commercially, they will assume most of the financial and programmatic risk.

The Agency's COTS strategy established high-level performance goals to encourage innovation. The Agency's commercial partners are responsible for developing their own detailed design requirements. Only in the area of ISS, visiting-vehicle integration and human rating were firm requirements imposed—and these were open to negotiation.

NASA's COTS strategy has much less day-to-day oversight of the commercial partners than in standard government contracting; however, insight is maintained by a team of civil servants that work with the partners on a day-to-day basis providing assistance and monitoring progress. This approach was taken to encourage process innovation and to not externally impose existing processes on the partners.

This risk of a partner not successfully demonstrating its capabilities is mitigated by working with multiple commercial partners to maximize the probability of one or more partners succeeding. NASA assists the commercial partner's efforts by providing a network of Agency technical experts across all discipline areas known as the COTS Advisory Team (CAT). Extensive NASA technical and facility resources are also available to the commercial partners through reimbursable SAAs.

The Government's financial risk is limited by paying partners only upon the successful completion of a pre-negotiated set of performance milestones. If NASA determines that a partner has succeeded in a milestone based on objective success criteria, the partner is paid; if not, no payment is made. These milestones typically occur every three or four months for each commercial partner until the conclusion of the COTS Demonstrations project in 2010. These milestone certifications provide clear evidence of the progress being made by each of the partners.

Q6. What is the status of NASA's discussions with the Department of State regarding International Traffic in Arms Regulations (ITAR) issues and NASA's ability to use contractors versus civil servants to support the European ATV launch to the ISS?

Q6a. What are the issues under review?

Q6b. The Space Station program has been in existence as an international partnership for about two decades. Why is ITAR now being raised as an issue for contractors that are integrating and operating the ISS?

A6a,b. NASA's discussions with the Department of State regarding ITAR impacts have addressed several topics, including: restrictive provisos (i.e., conditions) on Technical Assistance Agreements (TAAs) regarding anomaly resolution and dual-nationals/third-country nationals; and a possible limited ITAR exemption for NASA contractors implementing NASA international programs. The State Department has been working with NASA, the European Space Agency, and the Canadian Space Agency to address the subject of restrictive provisos, and the State Department has indicated that it will publish guidance on its website in the near future to facilitate progress on activities covered by TAAs in certain cases.

For the longer-term, NASA has also been engaged with the State Department regarding the potential development of a tightly-circumscribed ITAR exemption to allow NASA to authorize certain exports and technical assistance by contractors implementing NASA's international Government-to-Government agreements. From the NASA perspective, this proposal is based upon already-existing authority in the ITAR enjoyed by the Department of Defense (DOD) in effecting Foreign Military

Sales and includes comprehensive review and reporting requirements, to ensure that NASA contractors' ITAR-controlled activities are consistent with NASA's international agreements, and that the State Department is apprised of those activities in a timely manner. The current NASA proposal is compatible with previous guidance provided by the State Department as part of prior efforts to work with NASA and DOD on the creation of additional, reasonable discretion under the ITAR in overseeing major NASA programs. The details and overall feasibility of this proposal remain under discussion between NASA and the State Department.

The ITAR issues under discussion with the Department of State are not new. NASA has been engaged with the State Department for over seven years in efforts to explore solutions to various ITAR challenges confronting its contractors. Those activities have included closer coordination with the State Department on NASA contractors' license applications, efforts to revise unduly restrictive license conditions, and the proposed development of the limited ITAR exemption referenced above to facilitate NASA's international cooperative activities involving the Space Shuttle program, the International Space Station program, and major science missions.

Q7. In its 2006 report, the Congressionally-established Aerospace Safety Advisory Panel [ASAP] "observed that launch decisions are too regularly elevated to the Administrator level, and the Panel noted the lack of an analytical risk-assessment process that is standardized, comprehensive, and well understood throughout the agency."

Q7a. What is your response to ASAP's findings? Do you agree with them, and if so, what do you plan to do differently?

A7a. This question addresses two different but related issues: (1) flight risk issues elevated to the NASA Administrator level (2) analytical risk assessment capabilities at NASA. NASA's response to each aspect of the question is provided below:

Flight Risk Issues Elevated to the NASA Administrator Level

The decision of the NASA Administrator to become technically involved in the Flight Readiness Review (FRR) process is based on his personal choice to do so. There are currently no NASA or Shuttle Program requirements or expectations for the Administrator to participate in this capacity.

Under the revised Governance model, any safety of flight risk characterized as unacceptable by the Program Manager, Engineering Technical Authority, Safety and Mission Assurance (S&MA) Technical authority, or Health and Medical Technical Authority, must be elevated to the next higher level (typically the appropriate Mission Directorate Associate Administrator). Since the Shuttle Return to Flight, only one Shuttle flight risk issue that has been elevated to the Headquarters level for decision. This case involved the risk associated with debris liberation from the External Tank ice/frost ramp (IFR) and the potential for catastrophic Orbiter Thermal Protection System (TPS) damage. This is the only situation when the Administrator was formally requested by the Space Shuttle Program (SSP) to participate in the FRR decision process.

Analytical Risk Assessment Capabilities at NASA

In relation to this issue, in its 2006 Third Quarterly Report of September 26, 2006, ASAP made a specific recommendation to NASA. This recommendation is identified as Recommendation #4 (2006–03–02) on Page 57 of ASAP Annual Report for 2006. It reads:

> "The ASAP recommends that a comprehensive risk assessment, communication and acceptance process be implemented to ensure that overall launch risk is considered in an integrated and consistent manner. The process should be sound, mature, consistently implemented to yield high confidence and consistent results that are generally accepted by the majority of the community."

NASA accepted this recommendation and is in the process of implementing it. NASA's implementation approach is documented on pages 58 and 59 of ASAP Annual Report for 2006.

Q8. In an April 16, 2007 Wall Street Journal *article on preparations for extending ISS operations past 2016, NASA Administrator Griffin is quoted as saying "We're discussing all of that right now." And the article states that Administrator Griffin added that he would be "very surprised if the U.S. decides to end its participation" in the Station by 2016.*

Q8a. What is the status of those discussions on extending ISS operations past 2016?

A8a. No funding for the ISS is in the budget after 2016. Work to reduce Space Station operations and transportation costs is underway. (Transportation costs are expected to be roughly 40 percent of the ISS long-term costs.) Affordability and utility would need to be weighed within the larger context of the Nation's space program in any decision on whether the ISS's life should be extended beyond 2016. A decision to extend the life of the ISS beyond 2016 could be made as late as 2010 without significant cost impacts.

Q8b. Have any of the ISS International Partners expressed views on the matter?

A8b. All of the International Partners are considering the prospects of operating the ISS beyond 2016. Once the European and Japanese Laboratories are installed and operational aboard ISS, all partners will be in a better position to fully evaluate future returns on their national investments to solidify their position regarding how long to maintain their ISS operations.

Q8c. When do you expect a decision to be made, and what will be the criteria for deciding?

A8c. A decision to extend U.S. participation in the ISS beyond 2016 would depend on whether the benefits to the Nation of continued operations are justifiable, and a determination on where the ISS fits into the larger perspective of the Nation's space program after 2016.

Q9. Has NASA prepared a Space Station Utilization Plan that includes a schedule, specific milestones, a list of prioritized experiments and resources (crew, logistics, funding) required to implement the plan? If not, why not? If so, please provide it for the record.

A9. NASA manages NASA Exploration and non-Exploration science on the International Space Station (ISS) through the *ISS Exploration and Non-Exploration Research Project Plan* and the *Human Research Program Utilization Plan for the International Space Station.* Plans for the multi-agency utilization of the U.S. segment of ISS as a National Laboratory are being aggressively pursued to maximize U.S. investments and reflect U.S. priorities. NASA and the ISS International Partners are developing an updated *Consolidated Operations and Utilization Plan* (COUP) for the ISS. The COUP includes a schedule, specific milestones, a list of prioritized experiments and resources (crew, logistics, funding) required implementing the plan.

All three documents—the COUP, the *ISS Exploration and Non-Exploration Research Project Plan,* and the *Human Research Program Utilization Plan for the International Space Station*—will be available in December 2007, and NASA will provide a copy of these documents to the Subcommittee at that time. In June 2006, pursuant to section 506 of the *NASA Authorization Act of 2005* (P.L. 109–155), NASA submitted a report to the Space and Aeronautics Subcommittee outlining a research plan for the NASA utilization of the ISS. At that juncture in time, the Shuttle manifest and all the upmass requirements were still being formulated after the return to flight activity following the *Columbia* accident.

Consolidated Operations and Utilization Plan

Inputs from all International Partners are consolidated annually into a *Consolidated Operations and Utilization Plan* (COUP) that is specified in the ISS Memoranda of Understanding between NASA and each of its International Partners. The COUP includes all available on-orbit resources and all proposed uses for each International Partner's allocation of Space Station user accommodations and utilization resources. The COUP is developed multilaterally and approved by a multilateral coordination board which is comprised of one representative from each International Partner. Once released, the COUP is used to plan supporting launch transportation services, return transportation services, on-orbit resource allocations, and payload accommodation sites on the ISS. Once complete, a final utilization schedule is developed and executed. Other strategic plans that inform the COUP update are the *ISS Exploration and Non-Exploration Research Project Plan,* and the *Human Research Program Utilization Plan for the International Space Station.*

ISS Exploration and Non-Exploration Research Project Plan

This project plan describes ISS experiments to be conducted on the CIR, FIR, MSRR, MSG and EXPRESS racks that directly support both NASA's Exploration and Non-Exploration research activities. This research focuses on reduced gravity investigations in applied technology and physical science fields such as combustion science, fluid physics and materials science. Descriptions of the experiment content and budgets for proposed experiments are included. The existing ISS utilization traffic models for the subject facilities forecast the currently planned usage from the

present to the 2011 time frame. Some of the currently baselined experiments are described in this document to present a complete picture of the facility utilization, but the proposed new experiments described herein would be conducted after 2010.

Human Research Program Utilization Plan for the International Space Station

This plan entails the assumption and approach used by the Human Research Program, to utilize the ISS to retire 17 of the 33 health risks to astronauts baselined by the program and most appropriately studied on ISS. This plan also takes into account factors such as available crew time, number of available subjects, upmass and downmass capabilities and potential follow-on research that would be required to retire a risk and validate appropriate countermeasures.

Q9a. A 2006 National Academies report recommends that NASA schedule periodic reviews of the ISS utilization plan. Have any such reviews taken place? If so, when?

A9a. Consolidated Operations and Utilization Plan

NASA recognizes the importance of having a consolidated plan for the operation and utilization of the International Space Station at assembly complete. To this end, the Agency, in cooperation with the ISS partners, has been developing an updated *Consolidated Operations and Utilization Plan* (COUP), which is projected to be available in December 2007. This plan is updated annually by the ISS partnership. The U.S. portion of this plan will also be reviewed annually as part of the NASA annual budget formulation process.

ISS Exploration and Non-Exploration Research Project Plan and the Human Research Program Utilization Plan for the International Space Station

The plans cited above are elements of the Exploration Technology Development Program and the Human Research Program of the Exploration Systems Mission Directorate (ESMD). Both programs are subject to internal and external reviews for research and development proposals prior to implementation and for implemented proposals, annual reviews are held until completion. The external component of these reviews may involve external advisory groups such as the National Research Council (NRC). Additional annual reviews are completed as part of NASA's budget formulation and review cycle and technical reviews are held in accordance with 7120.8. Currently, ESMD's Exploration Technology Development Program and its ISS Exploration and Non-Exploration Research project are being reviewed by an NRC panel, per Congressional directive and Agency policy. In June of 2008, the Human Research Program intends to hold a Program Implementation Review (PIR). This bi-yearly review will cover the HRP management processes, and alignment of the HRP technical content, schedule and budget.

Q10. NASA's ISS National Laboratory report notes that one of the criteria for evaluating how long NASA will operate the ISS is whether the "benefits to the Nation are justifiable." How will NASA determine whether the benefits are justifiable?

A10. NASA will measure the overall benefits and costs in economic and strategic terms. Once ISS assembly is complete, that evaluation will be an ongoing effort conducted in an environment open to, and in collaboration with, all domestic and international stakeholders.

Q11. Could you please describe the status of any discussions between NASA and the National Institutes of Health (NIH) on NIH's potential use of the ISS National Laboratory?

A11. As stated in the NASA/NIH Memorandum of Understanding (MOU) signed on September 12, 2007:

The designation as a National Laboratory underscores the significance and importance that the U.S. 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.

Q11a. What is the commitment of the NIH and does NIH have a budget to support future research to be conducted on the ISS?

A11a. To date, the NIH has not shared their specific implementation strategies with NASA.

Q12. NASA's report on the ISS National Laboratory states that "In the case of the ISS, affordable space transportation services remains the single greatest barrier to fielding a productive public sector program in research." At what point would the cost of space transportation be considered "affordable" enough to encourage expanded use of the ISS?

A12. The affordability of space transportation can only be determined in the context of the economic value of the benefits as perceived by specific users, i.e., it will be a case-by-case determination. NASA is working to ensure a better future economic balance in those areas by engaging a large percentage of public and private entities to reach potential users with innovative ideas, while, at the same time, actively working to lower the overall costs through the creation of new, low-cost commercial space launch capabilities.

Q12a. How does NASA plan to handle negotiations on transportation with potential non-NASA users?

A12a. NASA is still exploring workable solutions to secure commercial services for non-NASA users for the delivery of cargo to the ISS. NASA is committed to finding approaches that will maximize the accessibility of the ISS to external users while ensuring maximum value to the government.

Q12b. Will NASA provide any technical support on launch services and ISS utilization to potential users?

A12b. Yes, NASA is committed to ensure the successful execution of all joint ventures. NASA has already established an approach to assist the efforts of commercial partners by providing a network of Agency technical experts across all discipline areas. For COTS, NASA has established the COTS Advisory Team (CAT). Additionally, extensive NASA technical and facility resources can be made available to the commercial partners through reimbursable Space Act Agreements.

Questions submitted by Representative Tom Feeney

Q1. The ISS Independent Safety Task Force recommends that the State Department should grant immediate relief from the ITAR restrictions no later than summer of this year to support European Automated Transfer Vehicle operations. Would you please explain the consequences to NASA and our European partners if such an exception is not granted? Has NASA sought an exemption from the State Department and if so what is the status? If not, why not?

A1. As the overall integrator for the International Space Station (ISS), NASA has the responsibility to ensure that the European Space Agency's (ESA's) Automated Transfer Vehicle (ATV) is technically and operationally compatible with the ISS and poses no safety risk. In order to complete this responsibility, NASA and its contractors are required to conduct technical interchanges to review the ATV design, development, and testing in order to verify that the ATV meets program requirements and will work as expected. However, the efforts of our contractors have been impeded by requirements pertaining to certain export licenses, known as Technical Assistance Agreements (TAAs). The International Traffic in Arms Regulations (ITAR) requires that TAAs be signed by ESA (and other International Partners) before NASA's contractors can provide necessary technical assistance and services. Due to specific concerns about restrictions in the TAAs, and more general objections to signing TAAs with U.S. contractors in the first place, ESA and other partners have been reluctant to sign the TAAs necessary for the completion of the tasks that are required to ensure the safe and successful completion and operation of the ISS. NASA, ESA, and the State Department have been working to resolve the TAA issue. In addition, due to certain ITAR authorities exclusive to U.S. Government agencies, NASA can perform tasks that would otherwise be done by its contractors, if the TAA problem persists. It is not an efficient work-around, but it can be employed, as necessary.

For several years, NASA has engaged with the State Department regarding the potential development of a tightly-circumscribed ITAR exemption to allow NASA to authorize certain exports and technical assistance by contractors implementing NASA's international Government-to-Government agreements. From the NASA perspective, this proposal is based upon already-existing authority in the ITAR afforded

to the Department of Defense (DOD) in effecting Foreign Military Sales, and includes comprehensive review and reporting requirements to ensure that NASA contractors' ITAR-controlled activities are consistent with NASA's international agreements, and that the State Department is apprised of those activities in a timely manner. The current NASA proposal is compatible with previous guidance provided by the State Department as part of prior efforts to work with NASA and DOD on the creation of additional, reasonable discretion under the ITAR in overseeing major NASA programs. The details and overall feasibility of this proposal remain under discussion between NASA and the State Department.

Although no State Department exemption has been granted, ESA did sign a TAA with NASA's contractor, permitting technical exchanges to proceed. ESA did so reluctantly in view of the points noted above, but this allowed both sides to proceed in the near-term to ready ATV for its upcoming initial flight. While this resolved the immediate issue, it does not resolve the broader issues for future cooperation.

Q2. The ISS Independent Safety Task Force recommends that the Administration, Congress and NASA should support the completion of the current Shuttle manifest including the two contingency flights (STS–131 and STS–133). NASA has told us the flights are in the budget but they have not been cleared through OMB. What factors determine whether the two contingency logistics flights will be accomplished? Does NASA require anything from Congress to allow the flights to take place? What is NASA planning to do with these flights in the event of a major delay in completing the ISS assembly missions?

A2. The primary rationale for the two contingency flights is the need to preposition unpressurized components that are required to ensure the viability of a safe and operational ISS in the post-Shuttle environment. Other factors include International Partner commitments to launch modules and large unpressurized elements, and the Shuttle's unique capability to launch large unpressurized elements that are not able to be accommodated on any other current or planned vehicle.

All the necessary Space Shuttle Program and ISS funding and resources are in place to execute the contingency flights. However, the contingency flights will only be flown if they can be done safely before the end of 2010.

In the event of a major delay in the assembly of the ISS, NASA would discuss with its International Partners the implications to the ISS configuration and viability based on retirement of the Shuttle in 2010. NASA would also work with its stakeholders to develop a strategy that will meet the interest and policy objectives of the U.S.

Q3. How serious is the risk that a lack of critical spare parts could lead to losses of a critical station function for an extended period, which could ultimately force NASA to abandon the station?

A3. NASA has developed a plan that uses multiple cargo transportation vehicles to support the ISS. A key element of the plan is to preposition critical spares prior to Shuttle retirement to ensure continued ISS system functionality. This provides an on-orbit inventory of spares to reduce the risk resulting from launch delays for visiting vehicles, which ensures that ISS viability is not dependent on the success of any one vehicle.

Q3a. What is NASA's contingency planning in the event the COTS is delayed?

A3a. NASA is closely monitoring development of the COTS vehicles and has strategies to react within the appropriate timeframes if development does not proceed according to schedule.

The Shuttle flight manifest calls for 10 assembly flights to the ISS and one to service the Hubble Space Telescope. NASA also hopes to fly up to two additional ISS logistics flights if they are deemed necessary and can be safely flown before the end of 2010. In addition to prepositioning of spares on orbit with the Space Shuttle, NASA is closely monitoring development of the COTS vehicles and is developing strategies to react within the appropriate timeframes if development does not proceed according to schedule.

Q4. Would you please give some specific examples of actions NASA has taken to help workers gain skills that can be transitioned to Exploration Systems?

A4. Expanded workforce skills can occur in a variety of ways under Space Shuttle contracts. In some cases, Constellation tasks are added to Shuttle contracts and Shuttle workers are able to broaden their skills applicability to Constellation work by performing actual contract tasks.

NASA is providing the tools, training and time for workers to gain experience and skills on new processes we know we will implement for Orion/Ares. NASA is apply-

ing these new processes required for Constellation into Shuttle processing now, to provide skill and experience that the workforce will need to do the future job on Constellation. This will be real, hands-on experience and familiarity, which will qualify workers for future work. Examples include:

- The United Space Alliance (USA) Space Programs Operation Contract (SPOC) workforce is being used by Constellation to process the Ares I–X vehicle for the first Constellation test flight scheduled for April 2009. The first Constellation flight of Ares will be conducted by the Space Shuttle workforce.
- On STS–118, a single Solid Rocket Booster (SRB) was stacked at a time to gather engineering information on the Mobile Launch Platform for Ares I–X. The existing Space Shuttle workforce performed this work for the Constellation Program.
- On STS–118, Endeavour was powered up using a new "paperless" process as a test of future procedures for the Orion spacecraft. The Shuttle workers gained both a new tool for the remaining Space Shuttle missions, and were able to preview and critique a new procedure which is planned to be used for Constellation.

In cases where additional training is useful, the contract cost principles in the Federal Acquisition Regulation allow, with certain exceptions, charging contracts for the costs of training and education that are related to the field in which an employee is working or may reasonably be expected to work. Depending on the specific kind of training, the employee's job, and company accounting practices, training costs might be direct contract costs or overhead expenses. It is up to the company to determine the training needs for their workforce to ensure successful contract performance. As with any other contract expense, training costs need to be managed as part of total contract cost to avoid contract cost overruns.

Specific examples of retraining and crossover job assignments to gain experience for Constellation include:

- NASA Civil Servants: For Fuel Cell engineers at KSC, after analyzing the skill sets and positions descriptions, KSC identified several likely positions for these individuals to transition to within Constellation in support of Cryogenic Systems or Environment and Crew Life Support Systems (ECLSS). Currently, the KSC training and development office is in the process of creating training plans that will identify the precise pathway for these individuals to transition to one of these other positions.
- Pratt & Whitney-Rocketdyne (PWR) Personnel: Space Shuttle Main Engine employees across all sites spend approximately 20 percent of their time on other programs. Some examples of areas where this is occurring are combustion devices engineering, manufacturing engineering, electrical engineering, software engineering and business operations.
- United Space Alliance (USA) Personnel: USA is beginning to retrain employees and share staff between the Space Shuttle and Constellation Programs. Examples include:
    - Technicians and engineers supporting Shuttle Flight Software are providing matrix support to Constellation.
    - Technicians and engineers supporting Shuttle Ground Operations are providing matrix support to Constellation for shipping and receiving logistics, hardware storage, tooling, and maintenance of ground support equipment.
    - Technicians and engineers that install Orbital Maneuvering System (OMS) and Main Engine tubing, tanks, valves, thrusters and engines on the Orbiter can be trained to install the same types of components in the Orion Crew Module and Service Module Propulsion Systems.
    - Technicians that currently bend and weld tubing, manufacture and apply thermal protection, solder electrical components, and fabricate cables for the Orbiter and Solid Rocket Booster can be trained to perform these functions in the assembly of the Orion Crew Module and Service Module.
    - Technicians and engineers that install electrical harnesses, avionics boxes, cable trays, batteries and instrumentation in the Orbiter and Solid Rocket Booster can be trained to install these components on the Orion Crew Module and Service Module.
    - Technicians and engineers that refurbish and install the Orbiter Landing Drag Parachute and the Solid Rocket Booster Recovery Parachutes can be trained to install the Crew Module Recovery System.

- Technicians and engineers that install pyrotechnics on the Orbiter and Solid Rocket Booster can be trained to install these components on the Orion Crew Module and Service Module.
- Technicians and engineers that fabricate and install closeout panels on the Orbiter and Solid Rocket Booster can be trained to install the Backshell, Heatshield and access panels on the Crew Module and Service Module.
- Technicians and engineers that conduct component and system testing for the Orbiter, Solid Rocket Booster and assembled Shuttle Vehicle can be trained to perform component, subsystem, major assembly and integrated vehicle testing on the Orion Crew Module and Service Module.
- Technicians and engineers that install Environmental Control and Life Support System components on the Orbiter can be trained to install similar hardware on the Orion Crew Module.

- In addition, USA Flight Operations received NASA approval of a number of initiatives to apply their skilled work force to performing trade studies and evaluations on various aspects of the Constellation Program, using lessons learned and expertise attained over the past 25 plus years. These teams have performed, or are currently performing, tasks associated with the following disciplines outlined below.
  - Flight Design and Dynamics—Conducting trade studies for Navigation Analysis and Design to assess Constellation integrated performance management plans, navigation tracking accuracy, navigation standards, space vehicle environments, identifying existing models applicable for future trajectory simulations.
  - Spaceflight Operations—Assessing existing NASA flight planning tools and techniques and identifying recommended enhancements or modifications to adapt existing resources for use on Constellation.
  - Flight Management—Performing assessments of NASA's existing production process reference networks for reuse on the Constellation program for accurately estimating component task durations and required resource profiles.

Q5. What agencies or other groups have expressed interest in using the ISS as a National Laboratory? What will NASA do with the unused capacity and capabilities of the ISS if other agencies decide not to make significant use of it?

A5. Seven federal agencies, listed below, have actively engaged in discussions regarding research opportunities on the ISS in its potential new role as a National Laboratory. Discussions on ISS National Laboratory opportunities have been held with representatives of the National Institutes of Health (NIH), National Science Foundation (NSF), Food and Drug Administration (FDA), National Institute of Standards and Technology (NIST), the U.S. Department of Agriculture (USDA), U.S. Department of Energy (DOE) and the Department of Defense (DOD). As a sign of progress resulting from these efforts, on September 12, 2007, NASA and NIH signed a Memorandum of Understanding (MOU) that provides a framework for NIH to encourage use of the ISS as a National Laboratory for research in related space and terrestrial physiology such as bone, muscle and immunology.

NASA is also engaging the private sector to solicit additional ideas and further opportunities for ISS utilization. This is taking place in the context of the August 14, 2007, NASA announcement of Opportunity for the Use of the ISS by Non-Government Entities for Research and Development and Industrial Processing Purposes. Responses to this announcement were due September 28, 2007. In the past, private firms have demonstrated interest and participated in space research across topics as diverse as molecular biology, tissue culturing, bone demineralization, antibiotics production, plant genetics, combustion synthesis, and ultra-high vacuum and microgravity processing of materials. NASA also continues to encounter the potential for agreements with private sector firms that involve use of ISS accommodations and resources as testbeds for engineering research. Identification of new ventures resulting from these efforts will maximize ISS utilization once assembly is complete.

Q6. NASA has requested that Congress expand the Enhanced Use Leasing authority to include all NASA centers. Why is it important to expand NASA's existing Enhanced Use Leasing authority, and specifically how will it benefit Shuttle transition? Can you give us some specific examples of how expanded EUL authority might ease the workforce transition at each of the Human Space Flight Centers, including Stennis Space Center and Michoud Assembly Facility?

A6. Expanded Enhanced Use Leasing (EUL) authority is needed now for all NASA Centers and is critically important as NASA moves forward to retire the Space Shuttle and transition to the new human space flight systems. NASA's proposed expanded and modified EUL authority was included in S. 1745, the FY 2008 Commerce, Justice, Science, and Related Agencies appropriations bill, as reported, and the Agency is seeking Congressional support for inclusion of this provision in the Conference agreement on the FY 2008 appropriations bill.

With the retirement of the Space Shuttle, NASA will have even more under-utilized facilities as part of the Agency's institutional management responsibilities. Space Shuttle facilities alone have been valued at approximately $5.7 billion. The proposed expanded and modified EUL authority will allow NASA to recover asset values, reduce operating costs, improve facility conditions, and improve mission effectiveness. Other federal agencies, such as the Department of Defense, have even broader authority than the legislative authority proposed by NASA.

NASA has conducted a successful five-year demonstration of EUL at the Ames Research Center (ARC) and Kennedy Space Center (KSC) pursuant to authority included in the FY 2003 *Consolidated Appropriations Act* (P.L. 108–7). Using this authority, ARC and KSC have leased under-utilized property, consistent with the Agency mission, to companies and universities, retaining proceeds to cover the full costs to NASA in connection with the leases and using the balance of funds for maintenance, capital revitalization, and improvements to real property assets.

The expanded and modified EUL authority will enable Centers with facilities and infrastructure associated with the Space Shuttle program and mission to potentially out-lease those facilities to others. Through a tenant base, the added Centers will be better able to control their operations and maintenance burden for under-utilized facilities that have no current program or use. Expansion of NASA's EUL authority has the potential to further NASA mission in science as the leased facilities can provide a platform for development of private sector research and development activities which can further NASA's mission in space related research. Having tenants on-site can alleviate some of the impact of completion of the Space Shuttle program on the communities and the personnel associated with that program.

Expanded EUL authority could benefit all NASA Centers, however the facilities outlined below could benefit substantially from the ability to enter into EUL agreements.

Kennedy Space Center (KSC): KSC is planning for a substantial facility and workforce realignment in the transition era from Space Shuttle to Constellation, and is investigating a number of new potential EUL partnerships. KSC can use EUL to grow the private sector's role in the Nation's civil space activities and expand KSC's institutional user base to more fully utilize existing spaceport assets. Future Potential Enhanced Use Lease Options under Consideration by KSC include an "Exploration Park" the 320-acre site outside the spaceport's controlled access area; Public and Commercial Space Access at the Shuttle Landing Facility (SLF); a Public Outreach Venue for tourism growth and demand for hotel/conference facilities in region; and an Academic and Commercial Test Facility by providing the site for a test facility to support clean energy development (currently there is no such U.S.-based facility).

Marshall Space Flight Center—Michoud Assembly Facility (MAF): MAF will manufacture the Boeing Ares I Upper Stage, Ares V Boost Stage, and Ares Earth Departure Stage, so there could be a significant incentive for private entities to locate on the site when EUL authority is available. Commercial use of the space, by tier 2, 3, or 4 Space program suppliers is expected. The proximity of suppliers can increase the suppliers' understanding of NASA program requirements and ease product delivery, expanding the skill base and workforce pool needed to execute NASA's next generation of vehicles. EUL authority would allow MAF to reduce its facilities overhead burden and to develop revenue streams for sustaining its facilities and infrastructure. MAF currently hosts the U.S. Coast Guard and the U.S. Department of Agriculture as tenants on the site. MAF was one of the few sites in that part of Louisiana that was not inundated by the Hurricane Katrina storm surge and flooding. EUL authority would allow MAF to expand the existing tenant base on the green space within the 836 acres to accelerate hurricane recovery in Louisiana. NASA MAF has already met with other Federal entities, such as the Department of Energy Oak Ridge National Laboratory to discuss their business model for developing their science and technology park. MAF has specific unusual capabilities which can be utilized or expanded by EUL partners. These capabilities include extensive infrastructure for design, manufacturing, and testing of extremely large aerospace structures; their transportation and handling including a deepwater port; and the specialized environmental permits, wastewater treatment capability, and compliance management for large launch vehicle manufacturing. MAF already hosts

the National Center for Advanced Manufacturing (NCAM), a federal, State, and university sponsored partnership. The NCAM currently includes the friction stir weld (FSW) universal weld system, environmentally enclosed state-of-the-art advanced fiber placement machines, and advanced Non-Destructive Evaluation and high speed machining systems.

Stennis Space Center (SSC): The Army, under the BRAC 2005, will soon transfer the Mississippi Army Ammunition Plant to SSC, offering significant EUL potential with the transfer of 1.5 million square feet of plant space and 4,500 acres of land. Some of the under-utilized property can be available for out-leasing. These potential leases could help bring jobs and growth to an area devastated by Hurricane Katrina.

Glenn Research Center (GRC): GRC has under-utilized land outside the campus gates that has a high potential for out-leasing due to its proximity to the airport, interstate highways, and to GRC. Additionally, Plum Brook Station has an under-utilized water intake capacity (Rye Beach) from Lake Erie in which the surrounding communities and farms have expressed interest. Other parts of Plum Brook Station may also be available for out-leasing.

Goddard Space Flight Center (GSFC): GSFC has identified several EUL candidates, including a Science Exploration and Education Center, to provide public knowledge and engagement related to Earth and Space Science and buildings and land where collocation of scientific research or technology partners could strengthen NASA's ability to attract and retain talent and foster collaboration with industry and academia. The Wallops Flight Facility has several aircraft facilities where EUL authority could maximize the economic benefit and flexibility to pursue additional commercial opportunities to sustain facility infrastructure and promote economic development on the Eastern Shore.

Langley Research Center (LaRC): As part of its Master Plan for New Town, LaRC has identified up to 400 acres in the northern portion of the Center for leasing or collaborative use opportunities with outside entities, which could be a candidate for use of EUL authority.

Q7. The current Shuttle flight rate between now and 2010 is optimistic. What is NASA's contingency plan if the actual Shuttle flight rate turns out to be insufficient to complete all the planned ISS assembly and logistics flights by the end of 2010? How would a major delay impact on ISS utilization and operations?

A7. There is sufficient schedule margin in 2010 such that, if a flight had to slip out of 2008 or 2009, it could still be flown before the end of 2010. If there is an unforeseen event that leads to insufficient schedule margin remaining in which to conduct any planned missions, NASA will discuss the impacts with the International Partners and develop a revised transportation plan.

NASA has no plans to fly the Shuttle after 2010, and indeed the Shuttle cannot fly after 2010 without causing major disruptions to the Exploration Program. These plans support ISS utilization and operations.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Tommy W. Holloway, Chairman, ISS Independent Safety Task Force

Questions submitted by Chairman Mark Udall

Q1. Your testimony refers to the need for "sufficient support from the Administration and Congress. . .to ensure that the resources are provided and the safety-critical aspects of the ISS assembly and operations are enabled and maintained."

Q1a. Did the task force comment on whether the current level of resources is sufficient or not?

A1a. With the exception of funding for logistics transportation after Shuttle retirement, the Task Force believes the current level of funding for the ISS is adequate.

Q1b. What level of resources would be considered sufficient?

A1b. The ISS budget should be augmented to support the logistics transportation requirements. Care should be taken in future core budget (budget for other than logistics transportation) reductions to avoid deletion of critical engineering skills to maintain the current level of attention to safety-critical aspects of ISS operations.

Q1c. What, if any, are the safety and other implications to the ISS if additional resources are not found for the program?

A1c. The major safety implications are the loss of the skills to detect and correct emerging safety issues before they become a problem. It is critical that critical skills be maintained in all disciplines and experienced and highly skilled managers be maintained to avoid safety implications becoming a reality.

Q2. If NASA had to return the ISS crew to Earth for whatever reason, could the ISS survive in an un-crewed mode, and if so, for how long?

A2. In the opinion of the Task Force Chairman, the ISS survival in a un-crewed mode depends on the reason the ISS was un-crewed and the type and number of future failures. The Mission Control Center (MCC) can operate the ISS without a crew but, of course, the MCC cannot perform maintenance and repair tasks to repair or replace failed components. For some failures the ISS could not survive in the un-crewed mode and for many others the ISS could survive for months and perhaps years depending on future failures.

Q3. You testified that "I think it would be unlikely that the COTS will be able to provide a substantial part of the logistics program in the most critical period following the retirement of the Shuttle program." *What actions do you believe NASA should take to ensure a robust logistics supply capability for the ISS in the post-Shuttle period? What should NASA be doing to ensure a crew transfer and crew rescue capability for U.S. astronauts after 2010?*

A3. Currently there are only three systems operating or being developed that could provide post-Shuttle logistics support. They are:

a. The Shuttle
b. COTS
c. ISS partner logistics vehicles (Russian Progress, ESA ATV and Japanese HTV

The Task Force made the following recommendation relative to the post-Shuttle logistics transportation (*Final Report of the International Space Station Independent Safety Task Force,* page 59):

5.2.1 The ISS Program should develop a fully integrated logistics support plan with off and on ramps of available and planned capability for the logistics support for the Assembly Complete/six crew member/post-Shuttle era. The plan should include projected budget requirements for logistics support.

a. The Program should not be required to commit the ISS to an unproven logistics support system such as COTS. If a proven logistics support system is not available, the Program should commit to the future capability that is determined to have the highest chance of success until emerging capabilities are proven. The Administration and the Congress should support this position.
b. To ensure that it is not forced into dependency on an unproven capability, the Program should procure additional spare proven capability to assure a

smooth transition to unproven capabilities later and to minimize transition through down periods on logistics delivery systems.

5.2.2 The ISS Program should develop an option that ensures that the two remaining exterior logistics flights are given the highest priority for flight, in front of Node 3 if necessary, to avoid exacerbating a problem should all planned Shuttle flights not be completed (ref. Shuttle Manifest Considerations).

5.2.3 NASA should develop roles, responsibilities, and critical review mechanisms for COTS and other future non-NASA systems that will fully support ISS requirements. The ISS Program should be responsible for managing and conducting the NASA review and approval of hazard analyses and participating in the required design reviews to ensure safety requirements are being meet.

5.2.4 In early 2009, NASA should seek legislation for an extension of the 2005 amendment to the Iran Non-Proliferation Amendments Act.

This means procure enough proven capability to support logistics until the systems under development is proven. Since production and therefore procurement of flight systems will take two to three years, careful phasing of procurement of new systems with backup capability from proven systems should be employed. Practically, this means buy enough Russian Progresses to ensure adequate ISS logistics transportation until the next system is operational. Then sequence the emerging systems based on the capability required and procurement considerations.

Questions submitted by Representative Tom Feeney

Q1. The ISS Independent Safety Task Force was very concerned about the adequacy of the ISS's post-Shuttle logistics support. According to NASA, there is a $300 million shortfall in the ISS-Crew-Cargo Services budget based on current estimates, with an additional $600 million shortfall held as a lien against the Exploration Systems Mission Directorate budget. What critical decision milestones should Congress and NASA focus on as COTS is being developed? Can you recommend any early indicators that Congress and NASA might use to predict whether COTS is progressing as advertised?

A1. The Task Force Chairman cannot recommend any reliable early indicators to predict whether COTS is progressing as advertised. It is not possible to make an early determination that a new major development program with daunting crew safety requirements is going to meet technical requirements and be on schedule. As reported in the "Final Report of the International Space Station Independent Safety Task Force," (page 58) the following summarizes the NASA safety requirements for approaching and being attached to the ISS:

The IISTF considers the design and development of a new support vehicle and logistical system to dock with the ISS to be a formable technical challenge. The significant safety requirements to be able to safely rendezvous and berth or dock to the ISS include:

- the system must be two failure tolerant (i.e., can sustain two failures without causing a catastrophic ISS hazard).
- the system must have on-board fault detection, isolation, and reconfiguration capability for low-level redundancy management.
- the system must have vehicle self-monitoring of critical capabilities and functions and auto-corrective actions, including hold, retreat, or escape maneuvers.
- the vehicle must have an independent collision avoidance maneuver function.
- the system must support ISS crew and ground monitoring and abort capability.
- the flight system must have robustness against failed capture capabilities (if the vehicle is captured by the RMS) or failed docking (if the vehicle is actively docked to the ISS) while ensuring a safe recovery or separation from the ISS.

Considering the above, it is critical that the ISS Program performs a series of safety reviews and approves Hazard Reports to ensure that all of the safety requirements are adequately implemented. The ISS Program must also participate in major design reviews to ensure that the design is implementing the necessary safety requirements.

It is the Task Force Chairman's opinion that early in a development program it is very difficult to determine if a program such as COTS will successfully meet its technical requirements and stay on schedule. Monitoring by personnel who are expe-

rienced in development programs and are accountable for safety requirements can determine that a program is failing to meet technical requirements or is behind on its schedule; but, conversely, it is not possible to judge that the program will meet future technical and schedule expectations. As the program progresses through Preliminary Design Review, Critical Design Review (CDR), and a flight certification review the ability to determine technical readiness and schedule integrity increases. The final test is a flight test program to demonstrate the requirements are met and the system performs as advertised.

It is the opinion of the Chairman of the Task Force that procurement commitments for an emerging ISS logistics transportation system should not be made until the system is proven by flight test or, if an emerging capability is mandatory earlier than that schedule would provide, no earlier than CDR.

It is also the opinion of the task force Chairman that the most difficult development challenge will be the development of the spacecraft that rendezvous and docks with the ISS rather than the launch rocket.

The difficulties and schedule delays that ESA has had in developing the Automated Transfer Vehicle (ATV) should be a measure of the technical challenge. There are no reasons to expect others will be more successful in the foreseeable future.

ANSWERS TO POST-HEARING QUESTIONS

Responses by G. Paul Neitzel, Professor of Fluid Mechanics, Georgia Institute of Technology

Questions submitted by Chairman Mark Udall

Q1. You testified that NASA's plans for ISS utilization are "shortsighted and inconsistent with the types of systems that will best allow us to return to the Moon between 2015, and 2020, and prepare for more ambitious systems." *Could you please discuss specific examples of the systems that are needed and for which R&D is not currently included in NASA's ISS utilization plans?*

A1. Although the President's *Vision for Space Exploration* does not specifically call for a manned mission to Mars, it seems "shortsighted" to be developing new systems to take us to the Moon that will not employ the best possible solutions to long-standing needs, such as management of liquids (propellants, cooling agents, waste, etc.,), heat rejection, fire detection/suppression, and operation of life-support systems. I have characterized in my original written testimony the challenges of designing fluid systems capable of operating on the lunar or Martian surface as "routine," but we must recognize that long-duration stays aboard either surface will require the development of new technologies for the efficient utilization of available resources that cannot be fully validated prior to their implementation. Many of the systems that are likely to be necessary will involve the handling of multi-phase flows (e.g., of bubbly liquids or dusty gases) that can operate differently in a partial-gravity environment. A substantial investment in research on the behavior of fluid systems in zero-to-partial gravity is required so that the engineering of any eventually needed technologies is well-grounded scientifically to ensure highest performance and reliability.

The principal limitation for any launch vehicle is up-mass. A 500- to 1000-day manned mission to Mars with limited re-supply requires the development of *mass-efficient* systems to satisfy these needs to permit maximum transport of food, water and materials and supplies to be used on the planetary surface. Missions to the Moon that aim to establish laboratories and habitats will likewise require the transport of materials and supplies to enable effective lunar research, exploration, *in situ* resource utilization, and habitat construction. These new, mass-efficient systems will need to be *dual-use,* i.e., capable of functioning both in a reduced-gravity (1/6 lunar and 3/8 Martian) environment as well as in the microgravity environment experienced during the journey itself. Existing systems developed for the Shuttle era are more than a quarter-century old and do not incorporate results of the incredible amount of research and development done over the last 25 years.

NASA's ISS utilization plan indeed includes projects that will evaluate systems chosen as candidates for addressing some of the issues raised above. However, NASA has decided to focus on projects considered to be at mid-to-high Technology Readiness Levels (TRL), i.e., ready for implementation. In some instances, a *single* system is being investigated as a *potential* solution to a given problem. This eliminates considerations of trade-offs between candidate systems and between systems designed to accomplish other tasks, reducing the likelihood of arriving at an optimal configuration. Given that the earliest possible launch date is nearly eight years away, does it make sense to be selecting new solutions to long-standing issues at such an early date, particularly in light of the rapid technological progress being made in such areas as micro- and nano-scale systems?

Q2. In your testimony, you evaluate NASA's planned ISS research and state that "The small number of projects being investigated, although relevant to exploration, is inconsistent with the conduct of a robust, safe exploration program that will send astronauts to the Moon no later than 2015." *Could you please elaborate on why you think the number of research investigations is inconsistent with the conduct of a robust and safe exploration program?*

A2. As mentioned in response to the first question above, NASA has seemingly restricted its attention to focus on a very small number of systems at mid-to-high TRLs for more efficiently solving some of the long-standing problems associated with space travel. The rapid pace of scientific and technological development within the last decade or so, particularly in the areas of computational capability and micro- and nano-scale systems suggests that there are several avenues that could be explored to ensure that the *best* and *most reliable* solutions (and in some cases the only solutions) to these problems are found. The ISS is the only test bed available for the conduct of long-duration experimentation under true microgravity conditions.

Additionally, for research at small length scales, terrestrial experiments, numerical simulation and theory can go a long way in narrowing down candidates to the subset likely to hold the most promise for exploration applications and, therefore, worthy of further testing/validation aboard the ISS.

Q2a. What should be done to correct the situation?

A2a. The tremendous expertise available within the external (to NASA) research community should be drawn upon to seek the best, most reliable solutions to the aforementioned problems. NASA should immediately reinstitute a vigorous external research program in both fundamental and applied science so that the required systems can be envisioned and tested in a timely manner for ultimate implementation aboard the next generation of space flight vehicles.

Q3. Could you please describe, in specific terms, the type of logistics support that might be needed for meaningful research on the ISS?

A3. The ISS U.S. laboratory was intended to simplify access by experimenters to space. Some hardware, designated as "facility class," was designed to accommodate roughly 80 person of the experiments envisioned to be conducted within their respective disciplines. One example of this is the Fluids and Combustion Facility consisting of the Fluids Integrated Rack and the Combustion Integrated Rack. These facilities provide power, standard instrumentation, video capability, etc., necessary to support many of the common experimental tasks, while also providing the outer levels of containment required for safety. Thus, the experiment-specific hardware to be developed for each investigation is simplified, streamlining the path to flight. It is important to the conduct of "meaningful research" that these facilities be transported to and properly integrated with the ISS.

A critical component limiting meaningful research is crew time. At its present size, a permanent crew of three is able to do little more than keep the ISS flying and tend to "housekeeping" tasks. Those ISS research investigations that have been conducted to-date have been chosen because of their minimal resource (in terms of both hardware and crew) requirements. Research necessary for the development of new, innovative systems to permit lunar and Martian exploration will require experiments that are more complex than those currently possible. According to Mr. Gerstenmaier's written testimony, NASA plans to increase crew size to six members in 2009. This will permit more crew-intensive research to be conducted, such as those investigations requiring the use of facility-class hardware mentioned in the previous paragraph. In addition to crew time, ISS Experiments require significant ground support, including training astronauts to conduct experiments and provisions for in-flight communication between investigators and astronauts. These costs must be properly funded, in addition to the more direct research costs.

*Q4. Mr. Gerstenmaier's testimony notes that "*The ISS is critically important to the success of future long-duration missions. . .because it is the only facility that combines the ambient environment and research capabilities needed to understand the extent of these risks [associated with long duration human exploration] with the ability to develop and test appropriate countermeasures." *Could you please comment on NASA's plans to address these risks?*

A4. It is my understanding that NASA has a plan to use the ISS until roughly 2019 as a platform for research on risks to health associated with long-duration human exploration and the development of appropriate countermeasures. This seems to be a prudent course of action.

Q5. The ISS safety task force found that systems design, testing, and procedures and mitigation approaches to respond to potential uncontrolled fire or toxic spills, for example, were adequate. Based on your expertise, are risks associated with uncontrolled fire or the behavior of toxic spills in microgravity well understood? If not, what further aspects of potential uncontrolled fire or toxic spills need to be understood to ensure robust mitigation approaches and response procedures?

A5. It is not clear that we are adequately prepared to handle major incidents such as an uncontrolled fire or toxic spill in a microgravity environment. NASA's principal approach to fire safety has been to focus on prevention. However, as ISS systems age and the amount of material on-orbit grows, the likelihood of a fire incident increases; the same holds true for toxic spills. We know that fires burn and spread differently in microgravity and the transport and effectiveness of suppressants is also affected by the absence of body force. Liquid and solid toxic spills likewise behave differently in microgravity than in a gravitational environment and differently from one another.

Surprisingly, despite the known toxicity of certain flammable materials that must be used on spacecraft and despite the risk of fire, the cleanup of spacecraft following a fire is currently not a NASA priority, according to the 2000 National Research Council report, *Microgravity Research in Support of Technologies for the Human Exploration and Development of Space and Planetary Bodies.* Hazard-mitigation and cleanup strategies need to account for the differences in dispersal and deposition characteristics for particles and liquid droplets in microgravity. During the Shuttle era, the plan, in the event of such an accident, was to refurbish the spacecraft following its return to Earth, something not possible with the ISS or a lunar habitat and not practical for a spacecraft traveling to Mars.

To ensure the safest possible spacecraft environment, NASA must be prepared to deal with accidents such as uncontrolled fire and toxic spills. A well-coordinated program of ground-based research and microgravity experiments should be in place to address these issues, but none exists, at least within the external research community.

Questions submitted by Representative Tom Feeney

Q1. What specifically should NASA do within their current budget to ensure the most productive utilization of the ISS after the Shuttle is retired?

A1. Presently, there is no guarantee that the ISS will be utilized productively following he retirement of the Shuttle in 2010. The ISS National Laboratory Plan intends to rely upon other federal agencies and commercial ventures to make use of this facility, bearing the significant transportation costs from their own budgets. Transportation to and from the ISS is to be provided by COTS being developed presently. Thus, there are many things that have to come together in order for the present ISS National Laboratory Plan to be viable.

It is, in my opinion, unlikely that sufficient interest on the part of other federal agencies and commercial ventures will arise to fully utilize the research facilities of the ISS at assembly complete. On the other hand, this platform provides a research capability that is central to the solution of problems associated with activities to be pursued under the President's *Vision for Space Exploration.* In addition, the ISS is the only facility capable of supporting non-exploration research requiring access to long-duration microgravity. NASA needs to pursue aggressively lines of investigation of both fundamental and applied natures and both exploration and non-exploration relevance that are suitable for study aboard the ISS and that would benefit from its unique microgravity environment. The former NASA external research community was effectively abolished and there are few flight experiments "waiting in the wings." For a relatively modest investment by NASA from its current budget—say $70–$100M per year—a reasonably healthy research program (of roughly half the size it was immediately prior to its cancellation) could be restarted and maintained, ensuring the productive utilization of this significant facility in the post-Shuttle era.

Q2. In your testimony, you outline the risks associated with the reduced levels of research funding, and note that NASA sometimes regards research as a spigot that can be turned off and on at will. Given the reductions and the loss of researchers in the pipeline that has already taken place, what can NASA do now to ensure an appropriate level of exploration-related research is available when needed in the 2015 timeframe?

A2. NASA needs to reinvest immediately in its *external* research program with a commitment to funding such research out to the expected lifetime of the ISS. The importance of advanced training at the graduate level for supplying future researchers in the microgravity life and physical sciences central to NASA's mission and the motivation provided by space-based research for American youth to pursue careers in the STEM disciplines cannot be overstated. With a long-term commitment of research support from NASA, some of those principal investigators from NASA's former external research community would likely be willing to return to the program to enable their research to be completed and new investigators would be stimulated to think about microgravity-related problems. The first stage of exploration-related research should be oriented to improving our depth of understanding of fluid and combustion phenomena and material handling in microgravity, fundamental research that could be underway now in ground-based facilities if NASA were funding it.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Cristina T. Chaplain, Director, Acquisition and Sourcing Management, Government Accountability Office

Question submitted by Chairman Mark Udall

Q1. Your testimony refers to risks related to the newness of both NASA's relationships with the Commercial Orbital Transportation System (COTS) suppliers and the COTS vehicles being developed. What contingencies do you think NASA should consider given these risks?

A1. Current contingency plans available to NASA in the event that the COTS program does not meet cost, schedule and performance thresholds are limited and problematic at best. NASA has focused primarily on one major contingency to COTS and that is the use of international partner vehicles—those existing and those currently in development—if COTS vehicles are not ready at the time of Shuttle retirement. NASA has stated its preference for the use of COTS, but acknowledges that reliance on partners may be necessary. However, NASA must acknowledge several constraints associated with reliance on international partners. First, all of the international partner vehicles—Russian, European and Japanese—have payload limitations and only one can carry crew. Second, the new European and Japanese vehicles are still under development. The European vehicle is slated to make its first test launch in early 2008 and the Japanese vehicle is scheduled for its first operational flight in 2009. These tests must go smoothly in order for NASA to be able to transition to use of these vehicles at the time when the Shuttle is retired. Third, NASA may face restriction in its use of Russian vehicles because of the expiration at the end of 2011 of an exception under the *Iran, North Korea, and Syria Non-Proliferation Act.* Finally, NASA may need to resolve potential export controls challenges in working with the international partners to ensure inter-operability with the International Space Station before those vehicles can begin logistics operations.

A NASA official stated publicly that the agency could also consider additional Shuttle flights past the currently set 2010 retirement date. While this may be an additional contingency plan to COTS, there are challenges associated with extending the Shuttle flights. First, if NASA has already begun to shutdown both the suppliers and workforce necessary for Shuttle operations by the time it makes the decision to extend the Shuttle retirement date, the agency will have to overcome shortfalls in both workforce and equipment as a result of those closures. Our previous work has noted that production restarts when some suppliers are let go but found to be needed later, can lead to funding gaps. Supplier viability presents another challenge. Over the years, the Shuttle Program has experienced many instances of suppliers dropping off unpredictably, making supply chain management more difficult and costly.

NASA also faces the prospect of continuing to experience delays because of weather and launch debris as it has with previous missions. As recently as the Endeavor, NASA stated it has had design problems that plague the program and require unanticipated additional resources, which can potentially impact the current flight schedule.

Finally, according to NASA, adding Shuttle flights will increase the costs of Shuttle operations. NASA officials said that they plan to rely on funding from the Constellation program in order to fund additional Shuttle flights after 2010. By pushing the retirement of the Shuttle back, NASA would again have to reassess its cost estimates and funding options for COTS and the Constellation program. Our previous work has found that developing cost estimates is a complex task for a transition of this magnitude. Although NASA has identified funding needs through fiscal year 2010 for transition activities relating to the retirement of the Shuttle and the ramping up of the Constellation program, those total costs are currently being developed. Additionally, many transition and retirement activities will occur after the retirement date, and according to NASA officials, such efforts could last through 2020. Our previous work has also noted that NASA does not yet know the extent of the Shuttle Program's environmental liabilities. Paying for such liabilities later may complicate NASA's future fiscal landscape, especially when there will be other competing demands, such as Constellation's crew exploration vehicle, the crew launch vehicle, and other new exploration activities.

Questions submitted by Representative Tom Feeney

Q1. The ISS Independent Safety Task Force was very concerned about the adequacy of the ISS's post-Shuttle logistics support. According to NASA, there is a $300 million shortfall in the ISS Crew-Cargo Services budget based on current estimates, with an additional $600 million shortfall held as a lien against the Exploration Systems Mission Directorate budget. What critical decision milestones should Congress and NASA focus on as COTS is being developed? Can you recommend any early indicators that Congress and NASA might use to predict whether COTS is progressing as advertised?

A1. NASA is relying on the availability of COTS vehicles after retiring the Shuttle in 2010 to provide logistics support and re-supply to the ISS. The COTS services currently under development for demonstration to NASA have received funding for cargo services only. Crew capabilities are an option written into the agreements between NASA and its primary COTS developers that will require NASA to provide further funding at a later date.

GAO has performed extensive work in determining important milestones that indicate progress for development of new systems. Currently, one of NASA's COTS developers is entering Critical Design Review, which is the final review of system drawings before fabrication of their system.[1] For this milestone, GAO has found that completing 90 percent of drawings portends successful fabrication. In addition, all technologies should have been fully matured and tested in a relevant environment. Each critical component should also exhibit "form, fit and function" characteristics at this point. Congress should closely consider these indicators of how well the proposed vehicles meet requirements and what the delivery time frames will actually be. If the technologies needed to meet requirements are not mature, design and production maturity will be delayed. Critical Design Review can provide a clear and realistic indication of the schedule for delivery of the capability.

While the COTS vehicles are in some measure based on existing systems, they are nonetheless being developed for new purposes. The four capabilities—unpressurized cargo delivery, pressurized cargo delivery, pressurized cargo delivery, and return and crew transport—are due to be delivered in a staggered schedule, rather than all on a single date. As such, testing events will also be very important to informing both NASA and the Congress on the progress of the COTS vehicles. If a vehicle fails a test, the program could face schedule delays. Furthermore, the COTS vehicle tests require berthing with the ISS. A NASA deputy program manager for the ISS stated that the new European vehicle will be ready for test launch to the ISS shortly, but because of ISS's scheduling windows, that vehicle cannot make that test flight until late January 2008. Similar constraints will be put upon COTS vehicle tests, so the success of those tests will be critical to NASA's assessment of when those capabilities will be available.

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[1] The second primary COTS developer has not completed the previous phase, as described in the agreement with NASA, which required the company to secure sufficient funding for the development program by February 2007. NASA officials told us that they extended the deadline for that developer, but as of September 2007 the company still had not accomplished the financial requirement necessary to proceed to Critical Design Review.