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A REVIEW OF NASA'S FISCAL YEAR 2009 BUDGET REQUEST

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE, AERONAUTICS, AND RELATED SCIENCES

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

FEBRUARY 27, 2008

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A REVIEW OF NASA'S FISCAL YEAR 2009 BUDGET REQUEST

WEDNESDAY, FEBRUARY 27, 2008

U.S. SENATE,
SUBCOMMITTEE ON SPACE, AERONAUTICS, AND RELATED SCIENCES,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:30 p.m. in room SR–253, Russell Senate Office Building, Hon. Bill Nelson, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Good afternoon, and thank you for coming. Thank you for the public service that you render. As you know, what I try to do is—so we can get right to the meat of this stuff—I'm not going to make an opening statement, it will be entered in the record, and we will take your lengthy testimony, and it will also be entered in the record, and it's my understanding that the STS–120 crew is on their way, and when they get here, we will introduce them.

But, let me just welcome you and thank you for the service that you render in a very difficult time, trying to juggle innumerable balls in the air all at once. And, it's a very difficult job you have, because you don't get to decide how much that you would like—you're always, have what we used to call in the South, a governor over you. That was a device that you would put on a car, that made the car not go any faster than a certain number of miles per hour. And—so, it's a difficult task that you have and thank you for what you do.

Let me ask you—Senator Stevens, would you like to make any opening comments?

[The prepared statement of Senator Nelson follows:]

PREPARED STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Good afternoon and welcome to this hearing on NASA's 2009 budget request. We welcome NASA's Administrator, Dr. Michael Griffin as our witness today and wish to extend a special welcome to the crew of STS–120 who are visiting today.

Commander Pam Melroy, Pilot George Zamka, and Mission Specialists Scott Parazynski, Doug Wheelock, Stephanie Wilson, and Paolo Nespoli completed a spectacular mission back in November. Pam and her crew carried the Italian built Harmony module to the International Space Station and performed a series of very difficult space walks. Thank you for your part in bringing the Space Station one step

closer to completion and for showing us once again how truly resourceful and innovative NASA can be.

And before we go on, I would also like to welcome Senator Vitter in his new role as Ranking Member on the Subcommittee. As you know I believe that space exploration is a truly non-partisan endeavor. NASA and its aeronautics and space programs are some of the 'crown jewels' of our country and represent the best of what we can *all* bring forth as a nation. I look forward to working closely with you.

Dr. Griffin—I wish to express my gratitude for the difficult job you are doing. So while you are on the spot today the issue before us is not you, but rather the future of our Nation's space program. NASA has had many great achievements over the past year, and I applaud the hard work and dedication of our country's aerospace team. However I am deeply troubled by the direction our space program is heading. A countdown clock has started, but unfortunately it is not a countdown to launch, rather it is a countdown to crisis.

We are fast approaching a time where this country will not have the means to put our astronauts into space nor to access the Space Station that the American people have invested tens of billions of dollars in constructing. With the present planning, and the budgets proposed by the President, we face a gap in our human spaceflight capability of at least 5 years. And this will occur while other nations such as China are moving forward in developing their human space capability.

The President's budget requests for NASA have never provided sufficient funds for the challenge our space program faces. And this looming crisis is the direct result of this lack of support. Most American's don't realize that NASA receives well less than 1 percent of the Federal budget. And NASA needs far more resources than it receives for all that it has been tasked to do.

And so Dr. Griffin, we have invited you here to tell us about the challenges you face implementing all that you have been tasked with in this budget environment. And we also look for your thoughts on how Congress can help NASA meet these challenges. Thank you for your time today, and we look forward to hearing your testimony.

STATEMENT OF HON. TED STEVENS, U.S. SENATOR FROM ALASKA

Senator STEVENS. No, I'm pleased with your policy. I'd like to listen to Dr. Griffin, if we could.

Senator NELSON. OK, well as a courtesy to you, Senator Stevens, you're the man around here. Why don't I just relinquish the time, and let you start off the questions?

Senator STEVENS. I'd like to listen to him. You're not going to make a statement?

Senator NELSON. No, we've put his statement in the record, it's a very lengthy statement. And we're going to get right to the questions.

STATEMENT OF DR. MICHAEL D. GRIFFIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. GRIFFIN. And I will waive my oral—I will waive a brief oral statement in response to Senator Nelson's desire to get to the questions.

[The prepared statement of Dr. Griffin follows:]

PREPARED STATEMENT OF DR. MICHAEL D. GRIFFIN, ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today to discuss the President's FY 2009 budget request for NASA. The President's budget request for NASA is $17.6 billion, a 2.9 percent increase over the net budget authority enacted for 2008, along with a steady, five-year runout commensurate with inflation. This increase demonstrates the President's commitment to funding the balanced priorities he set forth for the Agency in space exploration, Earth and space science, and aeronautics research. We are making steady progress

in achieving these goals. I ask for your continued support as you consider the President's FY 2009 budget request for NASA.

When I testified before this Subcommittee last year, I spoke about the Administration's balanced priorities for our Nation's civil space and aeronautics research goals as set forth by the NASA Authorization Act of 2005 (P.L. 109–155) and the Vision for Space Exploration. NASA's mandate is clear, and the NASA Authorization Act of 2005, as well as the level of funding appropriated to NASA in FY 2008, tells me that Congress broadly endorses the balanced set of programs the Agency has put forward in this era of limited budget growth.

I have said this in other forums, but it warrants repeating here: at present funding levels, NASA's budget is sufficient to support a variety of excellent space programs, but it cannot support all of the potential programs we could execute. No plan or level of funding can fully satisfy all the many constituencies we have. Balanced choices must be made. But they cannot continually be remade and revisited if there is to be steady progress toward our common, defined objectives.

As the *Columbia* Accident Investigation Board noted, and as stakeholders acknowledged in ensuing policy debates, it would have been far worse to continue with the prior lack of strategic direction for human spaceflight, to continue dithering and debating and inevitably widening the gap between Shuttle retirement and the availability of new systems. Until and unless the Congress provides new and different authorization for NASA, the law of the land specifies that we will complete the International Space Station, retire the Shuttle, design and build a new spaceflight architecture, return to the Moon in a manner supporting a "sustained human presence," and prepare the way to Mars.

We are doing those things as quickly and efficiently as possible. System designs for the early elements have been completed, contracts have been let, and consistently solid progress is being made with a minimum of unexpected difficulty. True, the progress might be slower than all of us would prefer, but applying resources in the right direction, irrespective of pace, is always productive—and we are doing that. The Ares I Crew Launch Vehicle and the Orion Crew Exploration Vehicle, as they are presently taking form, are the building blocks for any American future beyond low Earth orbit (LEO).

Given that this endeavor will be our first step beyond LEO for crewed spacecraft since 1972, I believe that bypassing the Moon to venture directly into deep space—a proposal some have suggested revisiting—poses unacceptable risk. Returning to the Moon and consolidating the gains to be made thereby will set us properly on the path toward Mars. I believe that the NASA Authorization Act of 2005 remains the finest policy framework for United States civil space activities that I have seen in forty years. And, I thank this Subcommittee for its leadership role in crafting this legislation. I ask for your continued support and leadership as we progress toward achieving the worthy national objectives laid out in the Act.

Before I highlight key elements of NASA's FY 2009 budget request, I would like to summarize NASA's initial FY 2008 Operating Plan, submitted to the Subcommittee on February 1, 2008. The initial Operating Plan provides aggregate funding of $17.3 billion, at the level of the President's FY 2008 request. Pursuant to the rescission of $192.5 million in NASA unobligated balances in the Consolidated Appropriations Act, 2008 (P.L. 110–161), aggregate funding in NASA's FY 2007 Operating Plan is reduced by $185.2 million, and prior year balances are reduced by $7.2 million. Implementation of direction in P.L. 110–161 has resulted in a total reduction of $620.9 million in planned NASA activities, consisting of the rescission of $192.5 million, offsets for programmatic augmentations totaling $345.2 million, and site-specific Congressional interest items totaling $83.2 million. Finally, in accordance with Congressional direction, NASA has established seven Agency appropriations accounts in the FY 2009 budget request. As a result, the budgets for NASA's programs and projects are requested only in terms of direct costs, not the additional indirect costs associated with operating the Agency's field Centers, ensuring safety and mission success, and Agency management and operations. The direct budgets will continue to reflect labor, travel, and procurement costs associated with each program and project. The indirect costs are now budgeted solely within the Cross Agency Support account, and not in the NASA programs and projects. We will strive to ensure that these changes are transparent to our stakeholders.

I am appreciative of the action by the Committees on Appropriations and Congress in providing regular FY 2008 appropriations for the Agency at the level of the President's request, including essentially full funding for the Orion, the Ares I, the Space Shuttle, and the Space Station. This total FY 2008 appropriations level, with some adjustments within the total, will enable NASA to meet critical priorities in accordance with the direction from the Congress and the President.

Highlights of the NASA FY 2009 Budget Request

I am pleased to report that the FY 2009 budget represents a substantial step forward in responding to the recommendations of the National Research Council's (NRC) first Decadal Survey of Earth Science, released in January 2007. The five-year budget runout requests $910 million for priorities enumerated in the report. Funding will support development of two Decadal Survey new mission priorities—the Soil Moisture Active/Passive (SMAP) mission scheduled to launch as early as 2012, and the Ice, Clouds, land Elevation Satellite II (ICESat II) scheduled to launch in 2015—as well as formulation of three additional Decadal Survey missions.

Working closely with NOAA, we also are making significant progress toward restoring climate sensors that had been removed from the tri-agency National Polar-orbiting Operational Environmental Satellite System (NPOESS) in 2006. The FY 2009 budget request of $74 million for NOAA supports the addition of a Clouds and the Earth's Radiant Energy System (CERES) instrument onto NASA's NPOESS Preparatory Project (NPP) satellite, set to launch in 2010; instrument development and ongoing analyses to identify a suitable satellite platform for hosting the Total Solar Irradiance Sensor (TSIS); and development of climate data records. These actions, which will be implemented through close coordination between NASA and NOAA, come in addition to the inclusion of the Ozone Mapping and Profiler Suite (OMPS)-Limb sensor on the NPP satellite that was announced earlier in 2007.

The Agency's FY 2009 budget request also reflects a number of exciting developments in the space sciences, including an increase in the number of new missions, a new initiative in lunar science and initiation of plans for high priority missions in Astrophysics and Planetary Exploration. The FY 2009 request includes an increase of $344 million over 5 years for Lunar Science in order to better understand our Moon. NASA's Science Mission Directorate, with support from the Exploration Directorate is developing two small lunar landers, and the Science Mission Directorate is initiating a series of new and exciting missions headed to the Moon over the next decade. Meanwhile, we are focusing our Mars program after 2013 on a Mars sample return mission to launch by 2020, and have identified funds to initiate development of an outer planets flagship mission to be selected in October of this year for launch by 2017. The budget also significantly increases Research and Analysis funds in the space sciences to gain better value from the missions we are flying, and so too, it increases the funding and, therefore, the flight rate of our suborbital rocket and balloon research programs in the space sciences.

Our Aeronautics Research portfolio is positioned to address the challenges facing the Next Generation Air Transportation System, while also developing world-class aeronautics expertise and capabilities. Research is aligned with the National Plan for Aeronautics Research and Development and Related Infrastructure, approved by the President in December 2007. In FY 2009, we will conduct a key test to advance our understanding of aircraft aging and durability, and develop algorithms to optimize the use of crowded airspace and airports. We will continue work on blended-wing-body aircraft, which may reduce fuel consumption and emissions, as well as aircraft noise. Additionally, NASA's Aeronautics Research Mission Directorate continues to strengthen partnerships with academia, industry, and other government agencies to accomplish its strategic goals.

NASA's commitment to its exploration objectives is clearly reflected in the FY 2009 budget request. As assembly of the Space Station nears completion, NASA will increasingly focus its efforts on continuing the development of the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle. This budget request maintains Orion initial operational capability in March 2015, and full operational capability in FY 2016, though we are striving to bring this new vehicle on line sooner. In FY 2008, we will see the completion of the formulation phase for major elements of the Constellation program; both Orion and Ares I will undergo their preliminary design reviews. We will conduct the first Ares ascent development flight test with the Ares I–X in the Spring of 2009, and we will continue to conduct research and develop and test technologies through the Advanced Capabilities Human Research and Exploration Technology Development Program. The Lunar Reconnaissance Orbiter (LRO)/Lunar Crater Observation Sensing Satellite (LCROSS), an important part of NASA's lunar exploration strategy, is on track for launch at the beginning of FY 2009. The Agency is also requesting $173 million to provide incentives for entrepreneurs—from big companies or small ones—to develop commercial transport capabilities to support the International Space Station. With more than $2.6 billion in NASA funds available over the next 5 years to purchase cargo and crew services to support Space Station operations, our objective and strong preference is to use these funds to purchase these services from American commercial companies wherever possible.

While I would prefer that the United States have domestic alternatives to purchasing crew transport services from Russia, I am glad that the Russians are our partners and have such capabilities, because the consequences if they were not available are far worse. If NASA astronauts were not onboard the Space Station, our National Laboratory in space simply would not survive. If there is no Space Station, there is no market for the commercial providers we are trying to help bring into existence, and our international partnership would simply fall apart. So in order to keep these objectives viable, NASA may need to obtain additional crew and cargo transport services from our international partners if U.S. commercial services are not yet demonstrated and available.

In the area of Space Operations, NASA's FY 2009 budget request will allow us to continue to expand the Space Station, complete the supporting truss structure and solar arrays, and deliver the final component of the Japanese laboratory. This will round out the set of three space laboratories aboard the Station, with one each from the U.S., Europe, and Japan. In addition, FY 2009 will mark another milestone for the Space Station Program—for the first time, the Station will be able to support a full-time crew of six astronauts. With three major scientific facilities available to them, these larger crews will be busy as Station kicks off a new era in microgravity research aboard this National Laboratory in orbit. Critical to these achievements, the Space Shuttle is scheduled to fly five times in FY 2009. During that year, NASA also plans to launch payloads on eight expendable launch vehicles. FY 2009 will also see the consolidation of the Deep Space, Near-Earth, and Space Communications networks into a unified Space Communications and Navigation (SCaN) architecture within the Space Operations Mission Directorate.

NASA is continuing to transition from the Space Shuttle to new Exploration systems, and will need a complement of critical tools and authorities necessary for the transformed Agency to execute its mission. This transition is the largest and most daunting since the end of the Apollo program and the beginning of the Space Shuttle program. It dictates that we obtain the authorities needed to ensure sufficient support in the future. We hope to discuss the details of these legislative requests with Members of Congress in the weeks ahead.

The remainder of my testimony outlines the FY 2009 budget request for NASA in greater detail.

Science Mission Directorate

In 2007, NASA successfully launched four new orbital and planetary science missions (THEMIS, AIM, Phoenix, and Dawn), almost 20 suborbital science missions, and two major airborne Earth Science campaigns. This past year also saw the first test flights of the Stratospheric Observatory for Infrared Astronomy (SOFIA) 747 airborne infrared observatory, as well as the provision of rapid-response airborne remote sensing aid to the California wildfire emergencies. In addition, 2007 was a year of remarkable scientific discovery about the Earth, the Sun, the planets and the universe. For example, data from the Ice, Clouds, and land Elevation Satellite (ICESat), the Gravity Recovery and Climate Experiment (GRACE), and other satellites have provided dramatic new insights on ice sheet changes in Greenland and Antarctica. The Solar TErrestrial RElations Observatory (STEREO) satellites (A and B) have provided the first three dimensional images of the sun and the structures of the heliosphere. These new 3–D views, along with unprecedented observations from Hinode (Solar-B), NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission, and the Aeronomy of Ice in the Mesosphere (AIM) satellite are revolutionizing knowledge of the variable Sun and its interactions with the Earth. Also, the *Cassini* spacecraft radar imagery of Titan revealed large lakes of methane in Titan's North polar region, indicating a hydrological cycle. Finally, a new map provides the best evidence to date that normal matter, largely in the form of galaxies, accumulates along the densest concentrations of dark matter. Mapping dark matter's distribution in space and time is fundamental to understanding how galaxies grew and clustered over billions of years.

NASA's FY 2009 budget request provides $4.44 billion for the Agency's Science portfolio to study the Earth, our Sun and its heliosphere, our solar system, and the Universe. This funding enables NASA's Science Mission Directorate (SMD) to start major new missions, to increase research and analysis funding, and to operate and provide ground support for 55 operating science missions, including 13 Earth Science mission extensions. It provides support for over 3,000 current operating research and analysis grants, while continuing to develop high priority missions in Earth Science, Heliophysics, Planetary Science and Astrophysics, consistent with the priorities established by the NRC's Decadal Surveys.

Pursuant to requirements of the NASA Authorization Act of 2005 (P.L. 109–555), and consistent with the latest notification provided to the Subcommittee on February 11, 2008, NASA is in the process of producing more detailed reports on budget adjustments and schedule changes which have occurred since NASA submitted its FY 2006 and FY 2007 Baseline Reports under the Act. Detailed reports are in work and planned for submission to the Subcommittee in March 2008 on Aquarius, Glory, Herschel, Kepler, NPP, and OCO. In addition, Glory has exceeded the 30 percent cost threshold triggering additional requirements as provided in the Act. Initial notifications are now in work under the processes established by the Act for schedule changes for GLAST and SOFIA.

The FY 2009 budget request for Earth Science provides $1.37 billion to help us better understand the Earth's atmosphere, lithosphere, hydrosphere, cryosphere, and biosphere as a single connected system. In addition to 14 operating missions, the request includes funding for seven missions in development. The Landsat Data Continuity Mission and Ocean Surface Topography Mission (to launch in 2008) continue the decades-long time series of land cover change and ocean surface height data, respectively. Glory targets the impact of aerosols on climate. The National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) paves the way for the future national weather system and continues essential measurements from the NASA Earth Observing System (EOS), Aquarius, and the Orbiting Carbon Observatory (OCO), set to launch in 2008. Aquarius and OCO will make the first-ever global measurements of ocean surface salinity and atmospheric carbon dioxide, respectively. The request specifically increases funding for OCO and the Aquarius missions to maintain development schedules. The Global Precipitation Measurement (GPM) mission will extend the rainfall measurements made by the Tropical Rainfall Measurement Mission (TRMM) to the global scale. The request retains the GPM core mission launch readiness date.

The budget request responds to the Earth Science Decadal Survey by establishing a funding wedge of $910.0 million over the budget runout to initiate five new Earth Decadal Survey missions for launch by 2020, while continuing to implement seven precursor missions for launch between 2008 and 2013. NASA will continue to contribute to the President's Climate Change Research Initiative by collecting data sets and developing predictive capabilities that will enable advanced assessments of the causes and consequences of global climate change.

The Heliophysics budget request of $577.3 million will support missions to understand the Sun and its effects on Earth, the solar system, and the space environmental conditions that explorers will experience, and to demonstrate technologies that can improve future operational systems. The request increases budgets for Sounding Rockets, Research Range, and Research and Analysis to achieve a more robust level of small payload opportunities. In addition to supporting 16 currently operational missions, the request supports the Interstellar Boundary Explorer (IBEX) mission focused on the detection of the very edge of our solar system and the Coupled ion-Neural Dynamics Investigation (CINDI) "Mission of Opportunity" that will provide new insight on the Earth's ionospheric structure, both of which are planned for launch in 2008. In early FY 2009, the Solar Dynamics Observatory (SDO) to study the Sun's magnetic field is planned for launch, and the Geospace Radiation Belt Storm Probes (RBSP) mission will begin development. RBSP will improve our understanding of how the Earth's radiation belts are formed and how solar output modifies the Earth's Van Allen radiation belts. Further, the five-year budget funds a new Solar Probe mission which has long been sought by the U.S. scientific community and is recommended highly in the most recent Heliophysics Decadal Survey.

The Planetary Science budget provides $1.33 billion to advance scientific knowledge of the solar system, search for evidence of life, and to prepare for human exploration. The budget supports an array of eight currently operating spacecraft and rovers traveling to or now studying Mercury, Mars, the Asteroid Belt, Saturn, and Pluto, in addition to a series of instrument missions of opportunity. The budget request augments Lunar Science to include a series of small robotic lunar satellites to begin development in FY 2009 and initiates an outer planets flagship mission, planned for launch in 2016 or 2017. The request includes continuation of funds for all five of NASA's operating Mars missions, the development of a Mars Science Laboratory in 2009 and a Mars Scout mission in 2013. The Mars Program is redirected to focus on the Mars Sample Return mission after the Scout 2013 opportunity, while expanding U.S. participation on the ESA/ExoMars mission by selecting two instrument Missions of Opportunity for study and technology development. With the *New Horizons* spacecraft continuing on its way to Pluto, the request realigns the New Frontiers Program's Juno Mission to Jupiter to be consistent with a 2011 launch date, and funds initiation of the next New Frontiers mission. An open competitive

solicitation for the next mission is planned for release near the end of this calendar year. The request continues support for the operating *Discovery* mission and for the development of the new Gravity Recovery and Interior Laboratory (GRAIL) *Discovery* mission, the latter of which will use high-quality gravity field mapping of the Moon to determine the Moon's interior structure.

The Astrophysics budget provides $1.16 billion to search for answers to fundamental questions about how the universe works, how we got here, and whether we are alone. The request supports a restart of the Nuclear Spectroscopic Telescope Array (NuSTAR) Small Explorer with a launch date of no-earlier-than 2011, increases funding for sounding rocket payloads, balloon payloads, detector technology and theory, and initiates the Joint Dark Energy Mission (JDEM) in FY 2009. The Astrophysics suite of operating missions includes three Great Observatories (Hubble Space Telescope, Chandra X-Ray Observatory and the Spitzer Space Telescope) which have helped astronomers unravel the mysteries of the cosmos. The request will support the Gamma-ray Large Area Space Telescope (GLAST) which is now planned for launch in May 2008, to begin a five-year mission mapping the gamma-ray sky and investigating gamma-ray bursts. It also provides funding for the Kepler telescope which is planned for launch in February 2009 to detect planets in the "habitable zone" around other stars. SOFIA will begin science operations in 2009, significantly earlier than previously planned. The request supports development of the Wide-field Infrared Survey Explorer (WISE), which will conduct an all-sky survey, and the James Webb Space Telescope, which will explore the mysterious epoch when the first luminous objects in the universe came into being after the Big Bang.

Aeronautics Research Mission Directorate

In 2007, the Aeronautics Research Mission Directorate (ARMD) continued to pursue high-quality, innovative, and cutting-edge research that develops revolutionary tools, concepts, and technologies to enable a safer, more flexible, environmentally friendly, and more efficient national air transportation system. ARMD's research also plays a vital role in supporting NASA's space exploration activities. ARMD's program content and direction is consistent with the National Aeronautics Research and Development Policy, as well as the follow-on National Plan for Aeronautics Research and Development and Related Infrastructure that the President approved on December 21, 2007.

A primary goal across all of the programs in ARMD is to establish strong partnerships with industry, academia, and other government agencies in order to enable significant advancement in our Nation's aeronautical expertise. NASA has put many mechanisms in place to engage academia and industry, including industry working groups and technical interchange meetings at the program and project level, Space Act Agreements for cooperative partnerships, and the NASA Research Announcement (NRA) process that provides for full and open competition for the best and most promising research ideas.

ARMD has established over 35 Space Act Agreements with industry partners and more are in the works. We have ensured that all Space Act Agreements are negotiated so that results of collaborations will be broadly disseminated. To date, NASA has selected 346 proposals for negotiation of award through the NRA process from more than 70 different universities and 60 different companies and nonprofits. NASA investment in NRAs will increase steadily from FY 2009 ($72 million) through FY 2013 ($100 million).

We have also strengthened our partnerships with other government agencies. For example, NASA and the Joint Planning and Development Office (JPDO) have established quarterly reviews to ensure close coordination, and NASA participates in all major JPDO planning activities. In addition, NASA and the Federal Aviation Administration have developed a joint program plan for the Aviation Safety Information Analysis and Sharing (ASIAS) effort with well defined roles and responsibilities. Also, NASA and the U.S. Air Force have established an Executive Research Council that meets at least twice a year to ensure close coordination and collaboration. Last, NASA and the Army have signed a Memorandum of Understanding to coordinate research efforts on rotorcraft.

In FY 2009, the President's budget for NASA requests $446.5 million for Aeronautics Research. ARMD is directly addressing the fundamental research challenges that must be overcome in order to enable the JPDO vision for the Next Generation Air Transportation System (NextGen).

NASA's Airspace Systems Program has partnered with the JPDO to help develop concepts, capabilities and technologies that will lead to significant enhancements in the capacity, efficiency and flexibility of the National Airspace System. In FY 2009, NASA's budget request will provide $74.6 million for the Airspace Systems Program to conduct trajectory analyses for service-provider-based automated separation as-

surance with time-based metering in an environment with two to three times capacity and with delay and separation comparable to or better than that achieved today. In addition, the Airspace Systems Program will develop algorithms to generate robust, optimized solutions for airport surface traffic planning and control. These surface models will be developed as a basis for the optimized use of super-density airports, integrated airport clusters, and terminals where demand for runways is high.

NASA's Fundamental Aeronautics Program conducts research in all aeronautics disciplines that enable the design of vehicles that fly through any atmosphere at any speed. The FY 2009 budget request, amounting to $235.4 million, will enable significant advances in the Hypersonics, Supersonics, Subsonic Fixed Wing, and Subsonic Rotary Wing projects that make up the Fundamental Aeronautics Program. These projects focus on creating innovative solutions for the technical challenges of the future: increasing performance (range, speed, payload, fuel efficiency) while meeting stringent noise and emissions constraints; alleviating environmental and congestion problems through the use of new aircraft and rotorcraft concepts; and facilitating access to space and re-entry into planetary atmospheres. A wide variety of cross-cutting research topics are being pursued across the speed regimes with emphasis on physics-based multi-disciplinary analysis and design, aerothermodynamics, materials and structures, propulsion, aero-servo-elasticity, thermal protection systems, advanced control methods, and computational and experimental techniques.

The FY 2009 budget request for NASA's Aviation Safety Program is $62.6 million. The four projects within the Program (Integrated Intelligent Flight Deck, Integrated Resilient Aircraft Control, Aircraft Aging and Durability, and Integrated Vehicle Health Management) will develop cutting-edge tools, methods, and technologies with close coordination among them to improve the intrinsic safety attributes of current and future aircraft that will operate in the NextGen. In FY 2009, the Program will demonstrate aircraft engine safety and reliability improvements using advanced sensing technologies and new methods for modeling engine gas flow characteristics. In addition, ballistic tests will be used to study the effect of aging on the impact resiliency of composite fan-blade containment structures for aircraft engines.

Multiple flight and simulation tests will evaluate technologies to protect aircraft during hazardous situations. For example, simulations will evaluate technologies enabling aircraft to land safely even when flight control surfaces are partially damaged or malfunctioning, and flight tests will examine forward-looking, multi-frequency radar systems for early detection of potential hazardous icing.

Finally, NASA's Aeronautics Test Program (ATP) will continue to safeguard the strategic availability of a critical suite of aeronautics test facilities that are deemed necessary to meet Agency and national aeronautics needs. The FY 2009 budget request for the ATP is $73.9 million, which will enable strategic utilization, operations, maintenance, and investment decisions for major wind tunnel/ground test facilities at Ames Research Center in California, Glenn Research Center in Ohio, and Langley Research Center in Virginia, and will support specific aircraft and test bed aircraft at Dryden Flight Research Center, also in California. ARMD has established the National Partnership for Aeronautical Testing with the Department of Defense to pursue a coordinated approach to managing DOD–NASA aeronautical testing facilities. In FY 2009, ATP will continue to reduce the deferred maintenance associated with its facilities and will also invest in new test technologies ensuring a healthy set of facilities and the new capabilities needed for future programs. In addition, ATP plans to continue off-setting the user rates for its facilities through the funding of a portion of the indirect costs resulting in competitive prices. Simultaneously, the Program will continue to move toward a long-term strategic approach that aligns the NASA and DOD facilities to meet future requirements with the right mix of facilities and appropriate investments in facility capability.

Exploration Systems Mission Directorate

In 2007, the Exploration Systems Mission Directorate (ESMD) delivered as promised and will continue to do so in 2008. Major development work is underway; contracts are in place, and our future Exploration plan is executable. By the end of 2008, ESMD will see its first spacecraft launched from the NASA Kennedy Space Center, Florida. This Lunar Reconnaissance Orbiter (LRO) and the Lunar Crater Observation Sensing Satellite (LCROSS) will help NASA scout for potential lunar landing and outpost sites. Additionally, in 2008, NASA will continue to plan how best to transition any needed Shuttle workforce and infrastructure to the Constellation program.

The FY 2009 budget request of $3.5 billion for Exploration will support continued development of new U.S. human spaceflight capabilities and supporting research and technologies, and will enable sustained and affordable human space exploration

after the Space Shuttle is retired at the end of FY 2010. The budget request provides stable funding to allow NASA to continue developing our next-generation U.S. human spaceflight vehicles while also providing research and developing technologies for the longer-term development of a sustained human presence on the Moon. Budget stability in FY 2009 is crucial to maintaining a March 2015 Initial Operational Capability for the Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle. There is minimum flexibility through 2010, so Congressional support for budget stability is critical. Additionally, ESMD will continue to work with other nations and the commercial sector to coordinate planning, leverage investment, and identify opportunities for specific collaboration on lunar data collection and lunar surface activities.

The FY 2009 budget request for Constellation Systems Program is approximately $3.0 billion. The Constellation program includes funding for the Orion and Ares, as well as for ground operations, mission operations, and extravehicular activity projects and a dedicated in-house effort for systems engineering and integration. Last year, the Constellation program made great strides and it will continue to do so in 2008. We have tested real hardware; we have tested landing systems; and we have logged thousands of hours in wind tunnels. So far, NASA engineers have conducted almost 4,000 hours of wind tunnel testing on subscale models of the Ares I to simulate how the current vehicle design performs in flight. These wind tunnel tests, as well as NASA's first scheduled demonstration test flight for Ares I, known as Ares I–X, are scheduled for spring 2009 and will lay the ground work for maturing the Ares I final design.

Constellation has an integrated schedule and we are meeting our early milestones. In fact, all major elements of the Orion and Ares vehicles were placed under contract by the end of 2007. Currently, NASA has civil servants and contractors on board for the Constellation program serving at all ten Agency Centers, as well as in more than 20 states. In 2008, NASA will continue efforts to define the specific work the Agency's Centers will perform in order to enable astronauts to explore the Moon. Preliminary work assignments covering elements of the Altair human lunar lander and lunar surface operations, as well as the Ares V, were announced in October 2007.

During 2007, ESMD completed a series of key project review milestones, including a System Definition Review for the Orion project in August and for the Ares I project in October. During these reviews, each project examined how its proposed requirements impact engineering decisions for the functional elements of the system. The Orion and Ares I teams are currently assessing design concepts, and are moving toward finalized reference designs that meets their requirements. This reference configuration will be the starting point for the design analysis cycle that leads to Preliminary Design Reviews for the Orion and Ares I projects, in turn leading to an integrated stack review by the end of December 2008. A Preliminary Design Review is a crucial milestone, during which the overall program verifies that the preliminary design meets all requirements within acceptable risk limits and within the cost and schedule constraints.

In FY 2009, NASA is requesting $173 million for the Commercial Crew and Cargo Program and its associated projects. Full funding is essential to maintaining NASA's promised $500 million investment in this program to spur the development of U.S. commercial space transportation services to and from the Space Station, while also providing substantial savings to the taxpayer compared to NASA government-owned and operated capabilities. On February 19, 2008, NASA announced that the Agency had signed a Space Act Agreement with a new funded partner, Orbital Sciences Corporation of Dulles, Virginia. Technical progress continues to be made by our other funded partner, SpaceX of El Segundo, California, as well by as several of our unfunded partners.

The Agency's FY 2009 budget request provides $453 million for activities in ESMD's Advanced Capabilities theme, which seeks ways to reduce the risks for human explorers of the Moon and beyond by conducting research and developing and maturing new technologies. In 2008, NASA's Human Research Program will focus on the highest risks to crew health and performance during exploration missions. We also will develop and validate technologies that serve to reduce medical risks associated with human spaceflight. For example, NASA will continue its work to understand the effect of space radiation on humans and to develop effective mitigation strategies. During 2008, NASA also will continue to research ways to reduce the risks to future explorers. Research onboard Space Station will include human experiments, as well as biological and microgravity experiments. In 2009, the Advanced Capabilities Exploration Technology Development program will conduct a range of activities, including testing prototype ablative heat shield materials; throttleable Lox Hydrogen engines suitable for a human lunar lander; and light-

weight life support systems for Orion. The program also will deploy and test advanced environmental monitoring systems on the Space Station to advance the safety of crewmembers, and will continue to test in situ resource utilization technologies as well as life support and cryogenic fluid management.

In response to Congressional direction contained in the Explanatory Statement accompanying the Consolidated Appropriations Act, 2008 (P.L. 110–161), ESMD will fund in 2008 a robotic lander project managed by NASA's Marshall Space Flight Center in Alabama as a pathfinder for an anticipated network of small science landers based on requirements for NASA's expanded lunar science program. The first lander mission is planned to fly in 2013–2014. NASA's Exploration Systems and Science Mission Directorates will continue to work together combining resources to ensure that the goals of the science lander are achieved.

NASA's LRO and the LCROSS have a planned launch later this year from Kennedy Space Center. These dual-manifested spacecraft are in the assembly, integration, and test phase and are making excellent progress toward launch. The knowledge generated by these missions will enable future outpost site selection and new information about resources within the permanently shadowed craters at the lunar poles. The LRO/LCROSS missions represent NASA's first steps in returning to the Moon.

Lastly, facility, infrastructure, property, and personnel transitions from Space Shuttle to Constellation continue to be a major activity. NASA transition activities are focused on managing the evolution from current operations of the Space Shuttle to future operations of Constellation and emerging commercial services, in a safe, successful and smooth process. To date, NASA has met all of its milestones and disposition targets. This joint effort between the Space Operations Mission Directorate and ESMD includes the utilization and disposition of resources, including real and personal property, personnel, and processes, to leverage existing Shuttle and Space Station assets for NASA's future Exploration activities. Formalized Transition Boards are working to successfully achieve this outcome. An initial Human Spaceflight Transition Plan was developed in 2006. An updated NASA Transition Plan, supported by key metrics, is being refined and will be released this year.

Space Operations Mission Directorate

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

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

NASA looks forward to Space Shuttle missions and Space Station Expeditions in 2008, which will feature the delivery, docking, and activation of key scientific assets from two of our International Partners: the European Columbus laboratory, launched on February 7, 2008, aboard Shuttle *Atlantis* on STS–122, and the pressurized module of the Japanese Kibo laboratory, to be launched in May. In addition, a major contribution from Canada, the Special Purpose Dextrous Manipulator—or Dextre—will be delivered to the Station, along with the Japanese Experiment Logistics Module, in March. Dextre, the final component of the remote manipulator system provided by Canada, will act as the "hand" on the robotic arm, allowing astronauts to conduct operations and maintenance activities from inside the Space Station, rather than via spacewalks. In late summer, the crew of STS–125 will become the final Shuttle crew deployed to a non-Station orbit, as they conduct the last Hubble Space Telescope servicing mission from the Space Shuttle. This mission will

outfit the telescope with the Cosmic Origins Spectrograph and the Wide-Field Camera 3, as well as replace components to extend Hubble's operational life.

The Space Shuttle FY 2009 budget request of approximately $3.0 billion would provide for five Shuttle flights to support assembly of the Space Station. This would include the flight of the Japanese Kibo laboratory's Exposed Facility, and the delivery of the final Station truss segment.

The FY 2009 budget request includes about $2.1 billion for International Space Station activities, reflecting the presence of a permanent six-person crew and three major research facilities aboard Station.

After the Space Shuttle retires at the end of FY 2010, NASA will use alternative means to transport cargo and crew to the Space Station. The Agency's first choice for such services is domestic, commercial capability, the development of which is the focus of the Commercial Orbital Transportation Services (COTS) effort. ESMD is funding the first phase of COTS under the Commercial Crew and Cargo Program, which will demonstrate this capability via funded and unfunded Space Act Agreements. SOMD will manage the second phase of the effort, covering actual cargo—and potentially crew—delivery services to the Space Station. Until such time that operational commercial means are available for resupplying the Station, NASA will look to its international partners to provide cargo resupply capability, much of which will be provided as part of the partners' contributions to the International Space Station Program. NASA has contracted with Roscosmos to provide Soyuz and limited cargo services through the end of FY 2011, as permitted under the Iran, North Korea and Syria Nonproliferation Act of 2005 (P.L. 109–112). NASA is monitoring the progress of potential domestic commercial providers to develop cargo and crew transportation services to the Space Station, and the Orion project is on track to reach its Initial Operational Capability in March 2015. The Administration is considering options to maintain a U.S. crew presence aboard the Space Station after the retirement of the Shuttle and before the advent of Orion. Purchasing crew transportation services domestically is NASA's preferred method to meet the needs of the Space Station. Another option may be to seek relief from the provisions of the Iran, North Korea, and Syria Nonproliferation Act of 2005 for additional Soyuz services to keep a U.S. crew presence on the Space Station until either domestic commercial crew transportation services, or Orion, become available. We will keep the Congress fully informed of our plans.

NASA remains focused on, and committed to, flying out the remaining Space Shuttle missions safely and completing the assembly of the Space Station. Beyond those aims, one of the challenges NASA faces as we approach the end of the Shuttle era is the smooth disposition of personnel and infrastructure. SOMD and ESMD have been working hand-in-hand to ensure that needed skills and facilities are retained and put to productive use during the development and operational phases of the Orion, Ares I, and Ares V projects. In FY 2009, the Agency's transition milestones will include the transfer of Pad 39B and Mobile Launch Platform #1 to Constellation, after the Hubble Servicing Mission. In addition, the Space Shuttle Program is reviewing whether the Space Shuttle *Atlantis* will be retired in FY 2008 or used to conduct existing missions within the planned manifest.

The Space Flight Support Program's FY 2009 budget request of $733 million would help mitigate out-year costs associated with the Delta II launch pads. The request also reflects the consolidation of the Agency's space communications projects into the Space Communications and Navigation Program. Finally, it includes funding for the development of two satellites to replenish the Tracking and Data Relay Satellite System, planned for launch in 2012 and 2013.

Education

The FY 2009 budget request for Education totals $115.6 million and furthers NASA's commitment to Science, Technology, Engineering, and Mathematics (STEM) education. NASA's primary objectives for Education are to: (1) contribute to the development of the Nation's STEM workforce through a portfolio of initiatives for students at all levels; (2) attract and retain students in STEM disciplines while encouraging them to pursue higher education that is critical to NASA's workforce needs; and (3) engage Americans in NASA's mission through strategic partnerships with STEM education providers.

NASA is committed to ensuring that its future workforce is fully prepared to handle a variety of challenging scientific and technical careers. NASA's Office of Education encourages student interest in STEM through the Agency's missions, workforce, facilities, and innovations in research and technology. The FY 2009 budget request reflects a balanced portfolio of investments which takes into account Congressional priorities, the NASA Strategic Plan, and recommendations from the National Research Council, as well as the priorities of the education community. NASA Edu-

cation is the critical link between the Agency's scientists and engineers and the education community. NASA Education translates the Agency's missions into educational materials, services, and opportunities for students and learners of all ages. NASA strives to support the role of educational institutions, which provide the framework to unite students, their families, and educators for educational improvement.

In 2008, NASA's Office of Education will continue to collaborate with Agency mission directorates and field Centers to assist educators in promoting scientific and technical literacy while attracting and retaining students in STEM disciplines and careers. NASA Education will also continue its work with other Federal agencies engaged in educational activities, along with public and private partners to leverage the effectiveness and reach of its efforts.

Cross-Agency Support

The FY 2009 budget request for activities within Cross-Agency Support includes funding for developing and maintaining NASA's technical capability including the Agency's vital mission support functions. Cross-Agency Support provides a focus for managing technical capability and Agency mission support functions. This budget area consists of three themes: Center Management and Operations; Agency Management and Operations; and, Institutional Investments. Cross-Agency Support is not directly identified or aligned to a specific program or project requirement but is necessary to ensure the efficient and effective operation and administration of NASA.

The most significant change is in the area of Agency Management and Operations. Agency Management and Operations provides for the management and oversight of Agency missions and functions and for the performance of many Agency-wide activities. Agency Management and Operations is divided into five programs: Agency Management; Safety and Mission Success; Agency Information Technology services; Innovative Partnerships Program; and, Strategic Capabilities Assets Program.

- The FY 2009 budget request provides $414.6 million for Agency Management which sponsors and supports an executive-based, Agency-level functional and administrative management agenda. Agency Management delivers policies, controls, and oversight across a range of functional and administrative management service areas and also provides for independent technical assessments of Agency programs. It delivers strategic planning services. It assesses and evaluates NASA program and mission performance. It sponsors and directs the Institutions and Management agenda in procurement, human capital, real property and infrastructure, security and program protection, diversity, equal opportunity, and small business. Agency Management also provides for the operational costs of Headquarters as an installation, including salaries, benefits, training and travel requirements of the Headquarters workforce, as well as the resources necessary to operate the Headquarters installation.
- The FY 2009 budget request provides $163.4 million for the Agency's Safety and Mission Success support activities required to strengthen and enable the fundamental and robust cross checks applied on the execution of NASA's mission. The engineering; safety and mission assurance; and health and medical independent oversight and technical authority which are essential to NASA's success and were established in direct response to the *Challenger* and *Columbia* Shuttle Accident Board recommendations for independent funding of these efforts. The Safety and Mission Success program directly supports NASA's core values and serves to improve the likelihood for safety and mission success for NASA's programs, projects, and operations. The Safety and Mission Success program includes the corporate work managed by the offices of the Chief, Safety and Mission Assurance (including the NASA Safety Center), Chief Engineer (including the NASA Engineering and Safety Center), the Chief Health and Medical Officer, and the Director of the Independent Verification and Validation Facility.
- The FY 2009 budget request for Agency Information Technology services is $163.9 million which encompasses cross-cutting services and initiatives in IT management, applications, and infrastructure necessary to enable the NASA Mission and improve security, integration and efficiency of Agency operations. In FY 2009 significant emphasis will be placed on consolidation of networks and network management, improved security incident detection, response and management, further consolidation of desktop/laptop computer services, data center assessment for consolidation, and application portfolio management leading to consolidation. NASA is using an enterprise architecture approach to assess current assets, capabilities and costs for services and developing requirements, projects and procurements for transition to the desired consolidated state. Addi-

tionally, the underlying infrastructure and systems to instill strong authentication and access to information systems in alignment with HSPD–12 will progress significantly in FY 2009. Critical work will continue under the Integrated Enterprise Management Program to improve business processes by minimizing data redundancy, standardizing information and electronic data exchanges, and processing. Also, NASA will continue participation in several Federal E-Government initiatives and Lines of Business to improve services to citizens and gain efficiencies across the government.

- The FY 2009 budget request for Innovative Partnerships Program activities is $175.7 million. This program provides leveraged technology investments, dual-use technology-related partnerships, and technology solutions for NASA. This program also facilitates the protection of NASA's rights in its inventions and the transfer of that technology for commercial application and public benefit. In addition, the Innovative Partnerships Program implements NASA's Small Business Innovation Research and Small Business Technology Transfer Programs which seek out high-technology small businesses to address key technology needs for NASA. The program also manages a Seed Fund to address technology needs through cost-shared, joint-development partnerships. The Centennial Challenges Program, which is also managed by the Innovative Partnerships Program, consists of prize contests to stimulate innovation and competition in new technologies for solar system exploration and other NASA mission areas. NASA has already benefited from Centennial Challenge competitions, and last year awarded $450,000 in prize money for the Astronaut Glove Challenge and Personal Air Vehicle Challenge. The Innovative Partnerships Program also transfers NASA technology for public benefit, as documented in NASA's annual "Spinoff" publication. "Spinoff 2007" documented 39 new examples of how NASA innovation has been successfully transferred to the commercial marketplace and applied to areas such as health and medicine, transportation, public safety, consumer goods, homes and recreation, environmental and agricultural resources, computer technology, and industrial productivity.
- Finally, NASA is requesting $28.0 million in FY 2009 for the Strategic Capabilities Assets Program, a focused activity designed to ensure that critical Agency capabilities and assets for flight simulation, thermal vacuum testing, arc jet testing, and microgravity flight services are available to NASA missions when needed. Strategic Capabilities Assets Program assets are also used by other government agencies, industry, and academia to improve the Nation's position in the global marketplace as well as its defense capabilities. The Strategic Capabilities Assets Program budget request covers the direct and associated costs required to sustain key test capabilities and assets including operating staff, preventive maintenance, subsystem repairs, and component replacements required to keep the assets in "ready for testing" condition. Incremental costs to conduct specific tests are borne by individual programs and reimbursable customers. The Aeronautics Research Mission Directorate budget request includes $73.9 million for the Aeronautics Test Program (*e.g.,* wind tunnels and flight testing) and the Science Mission Directorate budget request includes $41.9 million for High-End Computing Capability (*e.g.,* the *Columbia* super computer), which are also managed as Strategic Capabilities Assets. Centralized management at the Agency-level allows NASA to better prioritize and make strategic investment decisions to replace, modify, or disposition these capabilities and assets.

Conclusion

NASA has a lot of hard work ahead, but the Agency continues to make steady progress in managing its challenges. We are deploying our workforce to carry out the great task before us. Last fall, the Agency assigned new leadership roles and responsibilities for exploration and science missions to NASA's ten field Centers across the country in order to help restore the core technical capabilities across the Agency as we transition from the Space Shuttle to new capabilities. I ask your continued help to ensure that this Nation maintains a human spaceflight capability.

In a short span of years, we have already taken long strides in the formulation of strategies and programs that will take us back to the Moon and on to Mars and other destinations in our solar system. Indeed, a generation from now, astronauts on Mars will be flying and living aboard hardware America is funding and designing today, and will be building in the near future. This is a heady legacy to which we can aspire as we develop the next U.S. human space exploration vehicles. The foundation of this legacy will include work we plan to carry out in FY 2009.

As I said earlier in my testimony, NASA is committed to executing the exciting programs and projects within the President's FY 2009 budget request. Having reached a steady state on a balanced set of priorities, we now have a sense of pur-

pose to make steady progress toward achieving our goals for continued leadership in space exploration, scientific discovery, and aeronautics research.

Chairman Nelson, with your support and that of this Subcommittee, we are making the right strategic choices for our Nation's space program. Again, thank you for the opportunity to appear before you today. I would be pleased to respond to any questions that you may have.

National Aeronautics and Space Administration President's FY 2009 Budget Request Summary

[Budget Authority, $ in millions]

By Appropriation Account By Theme	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
Science	*4,609.9*	*4,706.2*	*4,441.5*	*4,482.0*	*4,534.9*	*4,643.4*	*4,761.6*
Earth Science	1,198.5	1,280.3	1,367.5	1,350.7	1,250.9	1,264.4	1,290.3
Planetary Science	1,215.6	1,247.5	1,334.2	1,410.1	1,537.5	1,570.0	1,608.7
Astrophysics	1,365.0	1,337.5	1,162.5	1,122.4	1,057.1	1,067.7	1,116.0
Heliophysics	830.8	840.9	577.3*	598.9	689.4	741.2	746.6
Aeronautics	*593.8*	*511.7*	*446.5*	*447.5*	*452.4*	*456.7*	*467.7*
Exploration	*2,869.8*	*3,143.1*	*3,500.5*	*3,737.7*	*7,048.2*	*7,116.8*	*7,666.8*
Constellation Systems	2,114.7	2,471.9	3,048.2	3,252.8	6,479.5	6,521.4	7,080.5
Advanced Capabilities	755.1	671.1	452.3	484.9	568.7	595.5	586.3
Space Operations	*5,113.5*	*5,526.2*	*5,774.7*	*5,872.8*	*2,900.1*	*3,089.9*	*2,788.5*
Space Shuttle	3,315.3	3,266.7	2,981.7	2,983.7	95.7	—	—
International Space Station	1,469.0	1,813.2	2,060.2	2,277.0	2,176.4	2,448.2	2,143.1
Space and Flight Support	329.2	446.3	732.8*	612.1	628.0	641.7	645.4
Education	*115.9*	*146.8*	*115.6*	*126.1*	*123.8*	*123.8*	*123.8*
Cross-Agency Support	*2,949.9*	*3,242.9*	*3,299.9*	*3,323.9*	*3,363.7*	*3,436.1*	*3,511.3*
Center Management and Operations	1,754.9	2,013.0	2,045.6	2,046.7	2,088.0	2,155.3	2,211.6
Agency Management and Operations	971.2	830.2	945.6	945.5	939.8	950.5	961.3
Institutional Investments	223.8	319.7	308.7	331.7	335.9	330.4	338.3
Congressionally Directed Items	—	80.0	—	—	—	—	—
Inspector General	*32.2*	*32.6*	*35.5*	*36.4*	*37.3*	*38.3*	*39.2*
FY 2008 Rescission**		(192.5)					
NASA FY 2009	16,285.0	17,309.4	17,614.2	18,026.3	18,460.4	18,905.0	19,358.8
Year to Year Change		6.3%	1.8%	2.3%	2.4%	2.4%	2.4%

Budgets include all direct costs required to execute the programs. Indirect costs are now budgeted within Cross-Agency Support.
* Deep Space and Near Earth Networks Transfer $256M to SFS in FY 2009.
** FY 2008 Appropriation rescinded $192.475M in prior-year unobligated balances, effectively reducing FY 2008 authority. Not included in totals.
FY 2008 budgets are the enacted levels per the FY 2008 Appropriation as shown in the Agency's FY 2009 Budget Estimates. Totals may not add due to rounding.

Senator STEVENS. Well, my basic question would be, how are you doing, and how much—what are your problems, money-wise?

Dr. GRIFFIN. Wow. I think—I think we're doing well. And I think we have an adequate budget to accomplish the tasks that have been set before us. As Senator Nelson indicated—not as rapidly as most of us would like to see them accomplished, but I think we can do it, and I'll leave it at that, for the moment.

Senator STEVENS. It looks to us like we're sort of dependent now upon Russian, or foreign vehicles, for our launches. How long is that going to continue?

Dr. GRIFFIN. You have just asked the question that probes at my greatest concern and my greatest regret. Yes, sir, you are correct—

we are dependent, we are dependent for crew transport to the Space Station between Shuttle retirement at the end of 2010, and the expiration of our INKSNA waiver, the Iran, North Korea, Syria Nonproliferation Act waiver that we have, that expires at the end of 2011. So, for a year there, we're absolutely dependent upon Russia.

If—and I'll say if—the Congress of the United States chooses to give NASA another exemption to purchase Russian crew transport services, we will be dependent upon such service until either we deploy the Orion crew exploration vehicle at the end of—or, at the beginning of 2015, or until an independent U.S. commercial capability takes form, by one or another company.

If we do not—if we do not have a further exemption to the INKSNA provisions, then there will not be U.S. crew on the Space Station after 2011, and we will have to abrogate our commitments to our international partners, to provide transport to them after 2011.

So, in brief, sir, that is the situation, as we see it.

Senator STEVENS. Mr. Chairman, you might want to introduce the crew, I think that's true, that's STS–120 just came in, if I'm right.

Dr. GRIFFIN. I would be thrilled to take a break and recognize the STS–120 crew.

[Laughter.]

Dr. GRIFFIN. In fact, we can recognize them two or three times, and it will be a——

[Laughter.]

Senator NELSON. No, don't worry. We're getting back to you, Dr. Griffin.

[Laughter.]

Dr. GRIFFIN. Somehow I thought that might be the case.

Senator NELSON. The Commander, Pam Melroy; the Pilot, George Zamka; Mission Specialist, Scott Parazynski; the Mission Specialist, Doug Wheelock; Mission Specialist, Stephanie Wilson; and Mission Specialist from our colleagues in ESA, Paolo Nespoli.

Paolo is from Italy, and they launched an Italian-built module, called Harmony. It is now part of the Space Station and it is an important connector that other payloads will be connected to.

And this is the flight last fall that, you remember the drama when they unfurled part of the solar array and something wasn't working, and they had to send Scott out there, and if Scott made a slip, he could have been fried.

But NASA, in its usual excellence, pulled it off, working a problem real-time. We all are very proud of you all, and want to welcome you to our little Subcommittee here. And this is how we try to do the people's work, and this is how we try to keep alive America's hopes and dreams through its space program.

So, welcome to you all.

[Applause.]

Senator NELSON. You all are welcome to just sit and observe, and enjoy it until you have to go, so entirely on your own schedule, Madame Commander, whatever is your pleasure. Do you have a moment or two to wait; or do you all need to run on?

Ms. MELROY. I think we have a few moments. Thanks for inviting us.

Senator NELSON. Yes, indeed.

Senator STEVENS. Mr. Chairman, I think we can see why they sent Scott, he can outreach them all.

[Laughter.]

Senator STEVENS. Great. Great job, we all watched you very carefully, thank you.

Dr. GRIFFIN. These are the people that I'm proud to lead for the duration of my assignment as Administrator, and my primary goal is to make them proud to work with me.

So, thanks for recognizing them, Mr. Chairman.

Senator NELSON. Yes, indeed.

Senator Stevens, do you want to continue?

Senator STEVENS. Can I ask one last question?

Senator NELSON. Oh, absolutely.

Senator STEVENS. How do you plan to pay for these foreign services, if we authorize you to use them?

Dr. GRIFFIN. We do have money set aside, in the budget, to purchase crew transport services from Russia. Whether it's enough money, or not, of course depends on the outcome of negotiations that can't begin yet.

If we wish to—let me back up. Our current contract expires, and is well-understood, and expires at the end of 2011, of course, as I just said. The Russian development history and production history for Soyuz is such that, if we wish to fly at the beginning of 2012, we need to have a new contract in place by the Spring of 2009. They have a 3-year production time, lead time, for Soyuz systems.

So, over the course of the next—approximately the next year, if we wish to avail ourselves of Russian crew transportation services—as opposed to de-crewing, or taking U.S. crew of the Station—if we wish to procure Russian transportation services, we would need to—the Administration would have to formulate—or finish the formulation of—a request to Congress for a further exemption, and then we would have to negotiate a new contract with the Russians by, roughly, April of 2009.

Senator STEVENS. Could we build our own transportation in that timeframe, if we gave you the money?

Dr. GRIFFIN. No, sir. With—Senator Nelson has asked me that question previously, for the record, and I have responded. And the answer is no different today. Returning to that—I mean, there are always uncertainties—but with the best analysis we have, returning to that earlier answer, the technical limit, at this point, on deployment of a new system, would be September–October of 2013, and to achieve that would require an additional $2 billion over Fiscal Year 2009, 2010, and a little bit of Fiscal Year 2011.

At the present pace, if everything goes as we expect it to go—neither better nor worse—we will deliver new capability in March of 2015, about 18 months after that.

So, the technical limit is Fall of 2013, our expected delivery date today is the Spring of 2015.

Senator STEVENS. You've been very generous, Mr. Chairman, thank you very much.

Senator NELSON. Well, you are certainly welcome, and you all can turn off the lights, we don't need any timing on this.

And, Senator Stevens, thank you for asking that question, because naturally that's of an enormous concern to me, with the Kennedy Space Center. Because if there is a 5-year gap, from the time that we are launching humans into space, putting on my parochial hat for Florida, it affects a huge number of layoffs.

Putting on my NASA hat, we become entirely reliant on Russian vehicles. And who knows what the geo-politic of the year 2013, 2014, and 2015 is going to be about Russia. Number one, that they produce the Soyuz craft for us to get to the Space Station, or number two, what they're going to cost us. And that's an uncertainty that we have.

My colleague, who has replaced Senator Hutchison as the Ranking Member of the Committee, Senator Vitter, of Louisiana, and Senator Vitter has really jumped into this with a whole bunch of gusto, and we are all very appreciative of Senator Vitter.

Senator STEVENS. Before you go, would you permit me to put my statement in the record?

Senator NELSON. Absolutely, without objection.

[The prepared statement of Senator Stevens follows:]

PREPARED STATEMENT OF HON. TED STEVENS, U.S. SENATOR FROM ALASKA

Mr. Chairman, I want to thank you for calling this hearing to hear from Dr. Griffin about the FY 2009 Budget Request for NASA.

I am also happy that the crew of the STS–120 Shuttle mission were able to stop by the hearing. Led by Colonel Pamela Melroy as mission Commander and George Zamka as Pilot, this crew delivered the key module that enabled all three major laboratories of the Space Station to be attached and linked together. They all represent the best and brightest of our country, and the other countries they represent, as in this case, Italy, with Paolo Nespoli serving as a Mission Specialist.

Our Nation's leadership in space exploration has provided this country with many scientific and technical benefits and advantages in an increasingly competitive world, but we cannot take that leadership for granted. Other nations, such as Russia, China, and even India, either have or are developing the capability to explore space, including human exploration.

I am concerned that we still do not have a clear and reliable plan for continuing our human space exploration without an extended gap after the retirement of the Space Shuttle.

It is important to complete the International Space Station and to have the Station available for our scientists and researchers to work there—that is why we have made the investment over the years to build it. But we also need to be able to get to it and use it. I am very concerned that we might be in a situation where—for as many as five or 6 years—there is no U.S.-owned capability to launch humans into space.

I will work with NASA, the Administration and this Subcommittee to ensure this country stays in the forefront of exploration of the frontiers of space.

STATEMENT OF HON. DAVID VITTER, U.S. SENATOR FROM LOUISIANA

Senator VITTER. Well, thank you, Mr. Chairman. And I'm very excited to join the subcommittee; I'm very excited to be Ranking Member. I'm very interested in the mission of NASA as a very important part of our national vision for the future. Also, there are, of course, significant facilities in my part of the world, related to NASA, Michoud, assembly facility in the New Orleans area, which has a very proud past, and I think an even more promising future, both tied to the Shuttle, and beyond.

And Doctor, I certainly appreciate your personal recognition of the asset that Michoud constitutes, and how it should be utilized in the future. And also, Stennis—right across the line in Mississippi—is a very important asset, and probably about a third of their workforce happens to live in Louisiana, so I take a great, specific interest in that, as well.

Along with the Chairman—along with many other folks—I'm very concerned about this gap from a lot of different perspectives, not just a parochial one, but from the perspective of the future of NASA.

And I guess one of my biggest concerns is that, I think we're very good at calculating the cost of additional action, like the $2 billion you're talking about—and that's real, I'm not trivializing that.

But I think we're not very good at calculating the cost of inaction. Because there is real cost—it's tougher to calculate, it's tougher to put a number on, but that doesn't mean it's any less real, the cost of inaction. There's enormous cost in terms of loss of workforce and skills, and you just don't turn off a switch, and then turn on a switch 2 years later and, you know, the lights come on and nothing's been interrupted. Those are people with skills, they leave—many of them—they don't just hang around and wait. They can't be immediately, or easily, or cheaply replaced, in terms of those critical skills.

I think there's also real cost in terms of this dependence on Russia for transportation—and not just the cost of national prestige or any of that—but I'm talking about dollar cost. And I wanted to try to explore with you, some of those costs, which again, are not as easy to calculate as the $2 billion, but I think are nevertheless, very real.

What has NASA done to sort of put pencil to paper and understand the cost of the gap, in terms of loss of workforce and skills, and how we re-gain that on the other end of the gap? And is that cost really built into the budget, in terms of the training and the skills development we're going to need, if there is this same gap, if that plays out on the other end of it?

[The prepared statement of Senator Vitter follows:]

PREPARED STATEMENT OF HON. DAVID VITTER, U.S. SENATOR FROM LOUISIANA

Thank you, Mr. Chairman. I am delighted to be here for my first hearing on NASA-related issues since becoming the Ranking Member of the Subcommittee.

I am also happy to welcome the crew of the STS–120 Space Shuttle mission with us today. I had the opportunity to meet with them briefly just before the hearing, and they are a very impressive group of professionals. As many of you know, they delivered the Harmony connecting node to the Space Station last November, which paved the way for the delivery of the final laboratory modules for the Station, built by our partners in Japan and the European Space Agency. They also conducted an impressive spacewalk to repair a torn panel on one of the station's solar arrays. We are delighted to have them with us briefly.

Like most Americans, Mr. Chairman, I have been aware of and proud of our Nation's accomplishments in space exploration. I have also long been aware of two of NASA's key installations that are vitally important to many of my constituents—the Michoud Assembly Facility near New Orleans, where the huge Space Shuttle external tanks are manufactured, among other things, and the Stennis Space Center, just over the line in Mississippi, but with thirty percent of its workforce living in Louisiana. Together, these two facilities represent a major force in the economic well-being and technical excellence of the citizens of my state.

1 am excited about this assignment and look forward to the opportunity to work with you and our colleagues as we conduct oversight and develop legislation to help

guide our Nation's extremely important civilian space agency and its activities and programs.

We begin that effort today by hearing from Dr. Michael Griffin, NASA Administrator, as he describes the President's FY 2009 Budget Request for NASA. I met with Dr. Griffin just a few days before the budget was released and—while he was of course circumspect about the details at that point—he indicated that there would not likely be any surprises in the request, or a major departure from what had previously been projected for NASA for FY 2009.

He was correct in that characterization. However, this budget request does not, I believe, adequately address a number of very important issues of concern to me and I believe to many of my colleagues.

Perhaps first and foremost, the request provides no new funding to accelerate development of the Ares I launch vehicle and the Orion Crew Exploration Vehicle (CEV) in order to begin to narrow the gap in U.S. human spaceflight capability that will occur if the Space Shuttle program is phased out at the end of 2010, as is the Administration's plan.

I firmly believe this issue is one that is growing in concern to a great many Members—and one that will be of widespread concern to the American public when they realize its true impact on the ability of the United States to maintain its leadership in space exploration. I do not believe they will be happy with the fact that the only way we can put Americans into space is to pay the Russians to launch them. On top of that, under current law, we cannot even buy those services from Russia after 2011. Unless that law is changed—and there is no guarantee of that—the United States will be unable to fly its crew members to the Space Station for the remaining 4 years of the expected gap. In the meantime, the other fifteen nations who are our partners in building the Space Station would continue to be able to access the Station with the help of Russia, doing the kind of research our own scientists have waited so long to be able to do.

Even if the exemption is extended, I am not sure the American people will be especially thrilled that we will be paying hundreds of millions of dollars to the Russians to send American astronauts to space at the same time we are laying off or forcing into other jobs the highly qualified, experienced and dedicated Americans who have been doing that job for the country in the Space Shuttle program for the past twenty-seven years.

We should examine whether it makes more sense to spend those hundreds of millions of dollars to close the gap, rather than to pay the Russians to try to fill the gap.

This is an issue that the Administration—at least those who drafted the budget request—has seemingly chosen not to address, but it's one I believe we in this Subcommittee, and in the Congress as a whole must deal with as we consider NASA reauthorization legislation.

I have other concerns regarding the transition from the Space Shuttle to its successor, and will have some questions for Dr. Griffin to address, either today or for the record.

As I have been familiarizing myself with the wide range of issues facing NASA, not only in human spaceflight, but in the areas of Space Science, Earth Science, Aeronautics Research and Education and Advanced Technology, it is clear to me that NASA is at a crucial point in its history. Decisions being made now will dramatically impact the degree to which this Nation can maintain its long-standing leadership in the exploration and utilization of space.

I look forward to working with the Chairman, my colleagues on the Subcommittee and with NASA leadership to help ensure the right decisions are made and the support needed to carry them out is provided by the Congress.

Dr. GRIFFIN. Well, let me take the last part, first. Our budget, in terms of bringing on-board the people who are needed—through, and at the end of, the gap—does contain the necessary funds for the people we will need.

What, I think, of course, you appreciate is that people will be coming off the Shuttle program, and will be coming onto the new Constellation program—our Ares and Orion systems to start, that I mentioned a few moments ago.

And that while our budget, in constant dollars, remains approximately fixed, and therefore the number of our people remains ap-

proximately fixed, they won't necessarily be in the same physical places, and they won't be the same people doing the same things.

Additionally, some of the—many, in a sense, we are ceasing for several years, we will have a hiatus, in human spaceflight operations, as opposed to design and development—the kinds of people involved are very different, in terms of their skills.

And so, as you correctly point out, the operational skills will atrophy during those years—they will atrophy. And we will have—we will undoubtedly have—startup problems as we begin to try to operate the new systems.

I appreciate your point about the cost of inaction. The opportunity cost is always harder to calculate than direct cost, but it is nonetheless real to an economist. It matters.

We owe the Congress—and will deliver to the Congress—a report, a series of reports, the first of those is due on March 24. And every 6 months thereafter, we are obliged to provide to the Congress an assessment of workforce impacts from Shuttle retirement, and Constellation buildup, at all of the different centers. We will do that. That will be available, from this date, within less than a month.

Preliminary figures that I could give you today are very uncertain, as will be the figures I will give you in a month. And they will be updated every 6 months. But, in your area of the world, Senator Vitter, in Michoud, we expect that the NASA employments—now, this is not the total government employment—but the NASA employment will drop from about 1,900 today, to under 600. Somewhere down around 500 for a time, before coming back up.

At the Kennedy Space Center, specifically, we will see—after the Shuttle retires—a net reduction in contractor force of at least several thousand. And that will not come back up, at least in terms of launch processing, because of the fact that our new systems will require—and should require—fewer people to operate than the Shuttle, which is an expensive system. We are, after all, retiring the Shuttle.

Our goal is to work as carefully as possible to preserve the skills that we need. We are dealing with that every day. And our goal, also, will be—very specifically—to move some new roles and missions to the Kennedy Space Center to replace the specific Shuttle operations tasks, which will go away and which will not come back.

We do not, by any means, have all of the answers to these problems today. I want you to know—from my heart—that I take this seriously, the displacement of lives, the displacement of skills, as we wind down the Shuttle program and start a new program, matters to me. And it matters to my team, and we are working it. We don't have all of the answers today.

Senator VITTER. To follow up, specifically, on this atrophy of skills, you say the money is there at the other end of the gap for the people. But, do you think it fully takes into account, the increased cost per head, if you will, that may be involved because of the atrophy of skills, and the re-training required?

Dr. GRIFFIN. I take your point, I think so, but I can't know that, now. And that symptom will be manifested in our ability to sustain the schedule we want to sustain. If it takes longer to get our people

back up to speed than we anticipate, then we will not be able to hold our schedule. And that's how that symptom will show.

Let me be clear—we have a program today which is heavily focused on operations—Shuttle operations. We are, of course, not designing and building the Shuttle any more. As we reach and pass 2010, we will be out of the operations business for awhile, and into the design, development, test and evaluation side of our business—we will be developing new systems.

We will be spending, in total, the same amount of money, nationwide, on our workforce, but it will be different people in different places. And then as we close in on 2015, and begin to develop routine operations again, we will shift out of design, development, test and evaluation, and back into operations.

So, at different portions of this product life cycle, we will need different kinds of people in different kinds of places.

Senator VITTER. The other cost of inaction, specifically, that I'm concerned about is what we end up paying to the Russians. You know, buying transportation from them isn't like buying a plane ticket in a free market, where you have plenty of customers going to that airline. It's a very unique negotiation.

Dr. GRIFFIN. Yes, sir.

Senator VITTER. We're the only customer in sight that has the attributes that we have, *vis-à-vis* buying what we're trying to buy from them. So, it is a one of a kind negotiation, it's not buying something off a shelf with a clear price, fixed by the market. And I'm afraid some of our inaction—whether it's in not trying to accelerate the next generation program, or perhaps not putting more money into COTS—dramatically increases their bargaining power, dramatically increases the price we end up paying for that next contract. And we've seen, I believe, major increases in that price we've gotten from them, over several years, already.

Dr. GRIFFIN. We have.

Senator VITTER. How do you analyze that, and is there any effort within NASA to try to estimate? I realize it's impossible to predict, because it's a very unique negotiation, but to try to estimate what impact on that price our own additional expenditures could have, either in terms of accelerating our program, or putting more money into COTS, et cetera?

Dr. GRIFFIN. We do have an estimate for what we expect the cost of Russian Soyuz seats, if you will, to be after the current contract runs out. I'd rather not discuss that estimate here, I'd be happy to do that with you in private. But based on our history with the Russian program, we do have such an estimate.

I do not have an estimate for how that estimate might change as a result of more timely investment in our own capabilities—whether in COTS, or in accelerating our own Orion and Ares program. I don't have a sensitivity estimate for you, that you ask about.

Senator VITTER. Wouldn't it be reasonable to develop that, to understand the cost/benefit of spending, in terms of acceleration of our program, or acceleration of COTS; if there is some saving, in terms of the bill from the Russians?

Dr. GRIFFIN. I think it would. I'd be happy to develop that. Again, it's not something I'd like to discuss publicly——

Senator VITTER. No, I don't suggest we should publish it, for obvious reasons, because we have this negotiation with the Russians, but I do suggest we should develop it on our side.

Dr. GRIFFIN. Sure. Of course, at one extreme, if we had, by the time—if we are granted, if we, if the Administration seeks and if we are granted—an exemption to INKSNA—and Senator Nelson rightly points out that we don't know what the political environment will be after 2012, but let us assume that it continues stably today—by the time we are paying for Russian services, at one extreme, we will have expended the $2 billion I spoke of that would have been necessary to close the gap.

Now, we can't go back and redo that decision, because water has moved under the bridge. But, between the existing contract, and our anticipated expenditures in the future, we will spend in the neighborhood of $2 billion on Russian hardware.

Senator VITTER. Well, again, I'd like to specifically request that sort of analysis——

Dr. GRIFFIN. We will develop it for you.

Senator VITTER.—confidential on our side, because, you know, it's—I don't necessarily predict this, but it's possible for me to imagine—certain investments, either in accelerating the timeline of our next systems, or in COTS, that pay for themselves, or almost pay for themselves, in terms of savings to the Russians.

Dr. GRIFFIN. Yes, sir. I understand, and we'll develop that for you.

One option might be to accelerate the award of the D-phase of COTS, COTS D-phase——

Senator VITTER. Right.

Dr. GRIFFIN.—which is the human spaceflight capability, if we believe that the present agreements are going well, that's always an option.

Senator VITTER. Right.

Dr. GRIFFIN. So, yes, sir. I understand. We'll get back to you for the record on that.

[The information previously referred to follows:]

Purchasing Soyuz crew transportation and rescue services does not require up-front financing or amortization of development cost. U.S. payments to Russia are based strictly on capabilities already available and certified, and do not require any development funding or investment on NASA's part.

NASA has conducted analyses on the projected development cost, schedule, and cost per seat of a domestic commercial Capability D. These analyses were based on the NASA/Air Force Cost Model (NAFCOM), and were cross checked with commercial cost estimating tools, including Parametric Review of Information for Costing and Evaluation (PRICE) and System Evaluation and Estimation of Resources (SEER). Though the results are fairly representative of the expected development costs and schedules, the models are not able to reflect commercial market conditions and industry business models that could have an effect on the cost-per-seat analysis. Such financial considerations as the cost of capital, distribution of risk across business lines, and profit margins, were not taken into consideration. The modeling did take into consideration such traditional cost drivers as maturity of design, available funding, test approach, pre-development studies, developer experience, infrastructure maintenance, operational cost, and complexity of design.

Based on multiple modeling scenarios, the estimated development costs, including NASA investment, industry contributions, and commercial financial investments, ranged from $1.2–$4.7B. Estimated development and qualification time ranged from three to 6 years. The lower development cost and shorter development times reflect the most optimistic model settings (*e.g.,* high developer experience, readily available funds, and high maturity of design). The higher development cost and longer devel-

opment time represents less optimistic settings for cost drivers. Credible industry proposals for Capability D should take into consideration an extended development period, major financial investments, and high infrastructure costs. It has been the experience of NASA and the overall aerospace industry that the eventual cost per unit will end up reflecting the development cost and market conditions.

NASA prefers to purchase U.S. commercial crew transportation and rescue services once they have been demonstrated rather than purchase Russian Soyuz services. Nonetheless, it is NASA's opinion that it is unrealistic to expect that the price per seat for Capability D will be significantly less than the Soyuz cost, and initially it is likely to be higher as the cost will need to reflect development cost outlays. Eventually, the Capability D seat price could approach Soyuz price levels. Even if Capability D becomes operationally available during this timeframe, NASA will still need to purchase Russian Soyuz crew transportation services to fill the gap between Shuttle retirement and Capability D availability.

NASA's current investment approach is to demonstrate commercial cargo capability before investing in crew transportation capability. This approach reduces the development risk for a future Capability D by doing early demonstrations of proximity operations, rendezvous and docking, and pressurized cargo delivery and return. The experiences gained by industry in development, operations, and certification of these capabilities will significantly reduce uncertainty in the development cost and schedule for Capability D.

Senator VITTER. That's all I have right now.

Senator NELSON. Well, chime in any time.

Senator VITTER. Sure.

Senator NELSON. We'll just keep this going as a conversation here.

All right, well let me pick up right there. COTS–D, which is developing a new vehicle that would have human capability. The company, SpaceX, which you've already awarded a contract to, to develop a cargo carrier, but they just bid to also develop a human carrier. The extra money that you had left over because the second bidder on the original COTS contract left the scene, you did not give it on a COTS–D contract. But now you're raising the possibility of a COTS–D, which is the human carrier, to SpaceX?

Dr. GRIFFIN. Well, let me clarify, sir, if I might. We don't have contracts, we have technically—and I need to be careful about this—Space Act Agreements for, whereby we now have two purveyors, SpaceX and Orbital, whereby they can qualify for NASA payments by reaching certain milestones in their development process. And once there is developed capability, we may well—we hope to—put out RFPs for actual contracts.

But these are other transactional authority in government procurement language and I need to be very careful about that.

Senator NELSON. And these are for cargo?

Dr. GRIFFIN. And the milestones that we are seeking, the A milestone is for unpressurized cargo, the B milestone is for pressurized cargo, the C milestone is for—equally important—the return of cargo from the Station, processed experiments and such things. And finally, the D milestone is for the delivery and return of crew.

SpaceX has bid on all four milestones—A, B, C, and D, and at—we, of course, had desired, do desire, to recognize and award the easier milestones first. I think that's obvious.

Orbital—the recent winner of a COTS agreement, has proposed on only the first two milestones. All of those are valuable things to us.

I was mentioning the point, in response to Senator Vitter's question that it is possible, if we are willing to take a lot more risk—

and this may be a time to take, this may be a time to take more risk—it is possible to recognize progress, and make an earlier award of Phase D. That is something that could be considered, which I was offering as an answer to the Senator's question, without trying to be overly specific about when, and under what conditions, we could do it.

Senator NELSON. Especially since your policy goal is to keep U.S. astronauts on the Space Station, after you shut down the Space Shuttle.

Dr. GRIFFIN. Yes, sir.

Senator NELSON. *Ergo,* you have to have human capability to launch into space.

Dr. GRIFFIN. Yes, sir.

Senator NELSON. And without the new vehicles, Orion and Ares, coming online until 2015, unless we can accelerate that, therefore for 5 years, you've got to rely on a Russian vehicle. Number one, you do not know what it costs, and number two, you do not know with absolute certainty that it is available.

Dr. GRIFFIN. That is correct, sir. Both of those are correct.

Senator NELSON. Well, then, wouldn't it be wise for us to be planning for, number one, accelerating Ares and Orion, and/or trying to get an additional human capability?

Dr. GRIFFIN. I will review with my folks, the possibility of accelerating COTS within the funding that we already have available for it.

With regard to our Ares and Orion program, our government vehicles, the President's budget contains the funding to deliver that capability in the Spring of 2015. Now, things may go better than we expect—sometimes that happens—or they could go worse. But that's our nominal planning date, at 65 percent budgetary confidence estimate.

Senator NELSON. Well, let me just throw you another——

Dr. GRIFFIN. That's what the President's budget——

Senator NELSON. I understand.

OK, now I want to give you another realistic political monkey wrench.

Dr. GRIFFIN. Thank you?

Senator NELSON. That is very realistic. Because current law prevents NASA from purchasing flights, because of ongoing Russian support to the Iranian nuclear and missile programs. So, here we have a gap coming up, regardless of Russia saying, "Well, I'm not going to supply you the vehicle," or Russia saying, "I'm going to gouge you," by making it prohibitively expensive. But now, we've got another situation, because of current law that says that we can't do ongoing contracts with the Russians if they are supporting the Iranian missile and nuclear program, which, in fact, they are.

So we've got to do this kabuki dance that we've done in the past, which is get a waiver of that. Have you had conversations with the White House and OMB about that issue?

Dr. GRIFFIN. Yes, sir. I'm, of course, aware of the issue, and that's why I qualified my earlier statements by saying, if the Administration seeks, and we are granted a waiver of INKSNA law, then we would be able to purchase seats. So, I am aware of that.

We have initiated, within the Administration, of the discussions of which you speak, with various staff offices in the White House. And we at NASA hope to bring that to a successful conclusion in the near future.

We realize that the Congress needs—we realize the Congress needs an ample amount of time to consider our request. I don't have such a formal request available for you today.

Senator NELSON. Have you had a discussion with Secretary Rice or her Deputy?

Dr. GRIFFIN. Yes, I have not personally I would say that I know for certain that our folks who work inter-agency and intergovernmental affairs, are working with the Department of State on this matter.

Senator NELSON. Well, at the end of the day it's going to be us, in the Congress, that are going to have to bring about this waiver.

Dr. GRIFFIN. Yes, sir.

Senator NELSON. And in order for us to consider this in a deliberate manner, we're going to have to receive a request from the White House by when, March the 14 of this year, of 2008. You think we can have that request from the White House for a waiver?

Dr. GRIFFIN. I can't commit to that date, because it's not within my authority to do so, but I will do everything I can to get you such a request at the earliest possible time.

Senator NELSON. That's only about 3 weeks away.

Dr. GRIFFIN. I know that, sir.

Senator NELSON. I want to go back to another line of questioning that Senator Vitter had mentioned. You stated that Michoud workforce was going to go from 1,900 down to 600?

Dr. GRIFFIN. Or thereabouts. I wouldn't want anyone to place too much precision to that.

Senator NELSON. You said KSC, in 2011, was going to be a several thousand reduction. Then you made another statement that, you're trying to bring in additional work. Was that several thousand reduction for the Kennedy Space Center, was that net, or was that gross, before you brought in the additional work?

Dr. GRIFFIN. The reductions I speak of in all cases are before we have any consideration of what new work might exist there. For example, the COTS operations, if they're successful, are not factored in.

Again, we will never—I hope we will never use as many people to process our new launch vehicles as we used to process the Shuttle. So, if we are to avoid a permanent downturn in the contractor workforce at the Kennedy Space Center, we would need to assign some new roles and missions to the Kennedy Space Center, so that they can do other things at that location, besides process Shuttles. It is my hope to do that.

Now, the budget to support those new roles and missions, of course, doesn't materialize until after the Shuttle is retired.

Senator NELSON. And one of those roles that is already in the works; according to the contract that you let on Orion was the assembly of Orion there——

Dr. GRIFFIN. Correct.

Senator NELSON.—in the big High Bay.

Dr. GRIFFIN. Correct. And I hope to find other similar tasks as we develop new hardware systems to return to the Moon.

As you know, Senator Nelson, better than anyone, we will need a number of new hardware systems as we mount our campaign to return to the Moon, and we—but here is our issue, with regard to employment in Kennedy Space Center. During Apollo we developed all of those systems in parallel. And the Nation simply supplied the money to do that. In Constellation, we are developing them in series, in sequence, in order to fit the confines of a, basically, flat budget, adjusted for inflation.

So, we have to develop first one thing, and then the next thing, and the next thing after that. So, as these systems come online, I am very much hoping that we can do—with later systems—as we are doing with Orion. That we will assemble them at Kennedy Space Center. That is my goal. That would be my hope.

We can't know how that will come out for a number of years, because the budget to do those new systems is done serially, rather than in parallel.

Senator NELSON. And because of that, which I am grateful for as I try to look at the finest launch team in the world and it has an excellent corporate memory that you would not like to lose, and I am grateful to that, but the key word is, serially.

Dr. GRIFFIN. Yes, sir. Yes, sir.

Senator NELSON. So, the Moon program comes on down the line. That doesn't help us in 2011, when you're shutting down, to use your words, several thousand.

Dr. GRIFFIN. It does not. We have—I've been calling attention to this matter for 3 years now. We have reached the point where there is nothing that will—to use your words—fill in the gap. We are retiring the Shuttle, after 30 years—by the time it's retired—after 30 years of service. We are retiring the Shuttle, we are moving on to new systems. We are not, immediately, replacing the Shuttle with those new systems. And when we do, it is a policy goal to have the new system use fewer people. So, we have a gap that will open up in the contractor workforce at the Kennedy Space Center, and that will not be filled.

Senator NELSON. Are the other centers going to share some of the pain?

Dr. GRIFFIN. Well——

Senator NELSON. For example, what's going to be the reduction at Johnson?

Dr. GRIFFIN. I don't have that with me at the moment.

Senator NELSON. How about at Marshall?

Dr. GRIFFIN. I don't have any of that. I really don't.

Senator NELSON. Well, last November, in our hearing I had asked for the out-year projections of all of the workforce levels at all of the NASA centers. That was last November. When do you think that this Committee will receive that information?

Dr. GRIFFIN. Absolutely by March 24, which is the legislatively required, mandated date for the workforce report that we owe you, center by center, and with updates every 6 months thereafter.

I'm not 100 percent sure I recall, but I think that was the answer I gave you last November when we talked about it. That we were working on this report, and we would have it for you in March.

Broadly speaking, I don't think we're going to have significant overall employment reductions at Marshall or Johnson.

Senator NELSON. How about Goddard?

Dr. GRIFFIN. That's—Goddard is primarily not in the manned spaceflight business, and so we're not looking at any reductions at Goddard.

Senator NELSON. Glenn?

Dr. GRIFFIN. Again, I think Glenn is—will remain healthy.

Senator NELSON. JPL?

Dr. GRIFFIN. JPL will remain healthy.

Senator NELSON. So the ones that are getting it in the neck, are first, KSC, and number two, Michoud?

Dr. GRIFFIN. That is where our contractor workforce problems are the most severe, yes, sir.

Senator NELSON. The way to get around this is to get additional money, so that we can accelerate Orion and Ares from 2015 to 2013, and therefore it's only a 3-year gap. But we went through this drill last year, having gotten a billion dollars extra, which was merely to repay you for the money that you had to spend on the recovery from the *Columbia* disaster. There was a lot of shoe leather, and a lot of sweat to get that, in the Senate, and then we couldn't get support out of the White House to keep that number in the negotiations with the House. So we lost the billion dollars. But, we did get at least the President's requested level.

Dr. GRIFFIN. Yes, sir.

Senator NELSON. But that doesn't help us with the instant problem that Senator Vitter and I have.

Dr. GRIFFIN. That's correct, sir. Because, for the next few years, after the retirement of the Shuttle, our—NASA's—human spaceflight budget is spent primarily on the development of new systems. And since that was not—and is not being, and was not planned to be primarily in parallel with the Shuttle—we go, again, as I said earlier, we go from a situation where today our program is largely about spaceflight operations. And then, for several years, our program will largely be consumed with design, development, test, and evaluation. Development of new systems—and then we will transition back to operations.

So, we are doing those things serially, rather than in parallel.

Senator NELSON. I am a Florida native, my home county is Brevard County. We don't want to go through what we went through after the shutdown of Apollo.

There were about 25,000 employees in the height of the Apollo Moon program. Within a short period of time, that employment went down to something less than 10,000. Massive economic dislocation. Dinks and danks to keep it going with a Skylab, and then Apollo-Soyuz. And then there was a 6-year gap from Apollo Soyuz in 1975, to 1981, the first flight of the Space Shuttle. And those were rough times for folks back home. Nobody wants to see that kind of economic and professional dislocation occur again.

We have talked about this, privately, for some period of time, and we have talked about additional items that we could bring in. I would like for you to be thinking about that, and I would like also now to pick up on the previous thing that we're talking about, of being totally dependent on the Russians. If we did have an addi-

tional capability, American-wise, to get humans up there, that would certainly help the space launch business down at Kennedy Space Center, and it's clearly going to lessen our dependence on the Russians. And yet, we're not to the point at which we're even thinking about the capability of developing that human capability.

Dr. GRIFFIN. On COTS, you mean?

Senator NELSON. On COTS.

Dr. GRIFFIN. Well, sir, I have thought about it. Let me give you the other side—and if wishes were free, I would have already done it. Let me give you the other side of the coin, if I might.

Our COTS agreements are predicated upon the demonstration of progress by those who hold the agreements, and, in exchange for progress, and reaching certain milestones, they qualify for certain payments.

I could—as you are indicating that I should—I could bet on the outcome, and assume that we're going to have progress, and maybe this is a time to do just that, because of the exigency in which we find ourselves.

But, in the customary stewardship of government funds that I believe that you all, here on the Hill, expect of me, I don't normally wish to put government funds, in any way at risk, without a reasonable certainly that I will get a product back.

Now, when I say those words, I sound as if I'm somehow down on SpaceX—I'm not. Or down on COTS—I'm not. I'm the originator of the COTS program. It was——

Senator NELSON. Indeed, you are, and you should be congratulated for that.

How much do you think COTS–D would cost?

Dr. GRIFFIN. I don't have that in my head right now. I just don't.

Senator NELSON. I think you'll find it to be somewhere around $300 million, to move to start to develop that capability.

Dr. GRIFFIN. Well, of course, we don't have to put that all up at once.

Senator NELSON. That's correct. So, is it worth risking that as opposed to risking $2 billion later down the road on the Russians, that we don't even know is going to work for those 5 years?

Dr. GRIFFIN. I completely understand the question, we have not done—we have not analytically fleshed out our options for accelerating COTS–D within the budget that we have, we have not done that. And I will do it, and I will get back to you on what our options might be to do so.

Senator NELSON. And in the meantime, you have awarded another COTS contract for cargo, that was about $170 million?

Dr. GRIFFIN. That's correct, sir. We need that, too. Our——

Senator NELSON. Tell us, why we need that?

Dr. GRIFFIN. Well, our objective is to have—again, the COTS agreements are for the development of commercial transportation ability, which does not today exist. The government has never put up money to sponsor such development. We have done that now. It is very difficult—we can not guarantee the success of any given provider. If we had had more money available, or thought that lesser amounts of money to any one potential provider would be a sufficient incentive, we would have had three or more contracts. I

would like to have as many commercial purveyors of this capability as I could get.

What we were able to budget, starting a few years ago, we set aside in our budget, $500 million for these COTS agreements, as you well know. And we had hoped to have two providers, and so we—we had an earlier provider, who was not able to make his milestones. We didn't spend the money, but they didn't make the milestones, so we still had the money available. We did a re-compete and selected a different second provider.

Senator NELSON. And will this——

Dr. GRIFFIN. I didn't—I didn't want to get to a place where I was funding only one provider.

Senator NELSON. All right. I'm not going to beat a dead horse.

Dr. GRIFFIN. I——

Senator NELSON.You got the message.

Dr. GRIFFIN. I understand your question.

Senator NELSON. And you got the message of what we have at risk here, and oh, by the way, on top of that, is this Iranian nuclear issue.

Dr. GRIFFIN. I—I don't know how to phrase this in such a way as to convince you that I totally understand the concern and the problem, and I share it. I share the concern, I understand the problem.

Senator NELSON. Speaking of the award that you just made on COTS, for what lift cargo weight are we talking about there? As compared to SpaceX? Give us a comparison of the two.

Dr. GRIFFIN. They're in the same payload class, many thousands of pounds, when at the end of their development cycle, thousands of pounds not tens of thousands of pounds. They're in the same general class.

Senator NELSON. Tens of thousands of pounds?

Dr. GRIFFIN. Not tens of thousands of pounds.

Senator NELSON. Not tens of thousands, just thousands.

Dr. GRIFFIN. Thousands of pounds.

Senator NELSON. Both of them?

Dr. GRIFFIN. Yes.

Senator NELSON. Even with the new SpaceX rocket that they're going to launch from Complex 20 at Cape Canaveral Air Force station?

Dr. GRIFFIN. Well, Falcon 9, when developed, has a substantial payload capacity, over 10,000 pounds, but that's not the first development. They have yet to develop the Falcon 1.

Senator NELSON. Yes, but that's out at Kwajalein. Once they develop it, they're going to strap them together when they launch from the Cape, aren't they?

Dr. GRIFFIN. The Falcon 9 design is a clustered—design of clustered engines, yes sir.

Senator NELSON. And its payload is how many pounds?

Dr. GRIFFIN. I—I'll give it to you for the record.

Senator NELSON. But you just said, somewhere——

Dr. GRIFFIN. It's over 10,000 pounds.

Senator NELSON.—over 10,000 pounds.

Dr. GRIFFIN. Yes. I don't——

Senator NELSON. My question then, to get back to it, is compare the two. If that's over 10,000 pounds, what's the payload capacity of the other one?

Dr. GRIFFIN. I'm sorry, I'll get that for you.

[The information previously referred to follows:]

SpaceX's Falcon 9 launch vehicle is designed to lift approximately nine Metric tons into the International Space Station's orbit, and carry about three Metric tons of cargo.

Senator NELSON. Does anybody in that front row back there know?

Dr. GRIFFIN. I don't.

Senator NELSON. You all just issued a contract to them, and you don't know what the payload capacity is?

Dr. GRIFFIN. No, sir. We know what it is. We have it. I just don't have it in my head. I'm sorry.

Senator NELSON. OK.

Senator VITTER. If I could follow up on a few things?

Senator NELSON. Yes, please.

Senator VITTER. This is related, if I could follow-up. First of all, Doctor, I'd echo a thought you yourself mentioned, which is analyzing COTS–D and analyzing that investment, particularly given all of these circumstances. I would completely encourage you to do that carefully.

Dr. GRIFFIN. And I have committed to doing that.

Senator VITTER. Great.

A few minutes ago you said if dreams were free, but they're not, maybe in a very limited circumstance some of them are, at least in the initial stage. And by that I mean, isn't there an option that you have to enter into certain unfunded Space Act Agreements, if a commercial entity is willing to take up a project on the risk that they'll develop a good product and we'll buy it?

And as I understand it, some major entities like Boeing are willing to look at that. For instance, for a manned capsule that could fit on a lot of these other transportation rockets.

Dr. GRIFFIN. Absolutely, and we have a number of unfunded Space Act Agreements existing today, and stand ready to do more of them.

Senator VITTER. So, you're already actively exploring that?

Dr. GRIFFIN. Absolutely, and have been for the last couple of years.

Senator VITTER. Great.

Also, going back to the Russian negotiation—let's say, for the sake of discussion, that the Administration submits a request to Congress for this INKSNA waiver, we give it, it's early 2009, and so you're negotiating with the Russians. At that point, what would the duration of the next contract with the Russians likely be, what would the term likely be? Do you know?

Dr. GRIFFIN. That's, I mean, that's a subject for negotiation. But in my own view, we would want to end that dependence with the deployment of our own capability, the Orion and Ares combination. Now—and I need to be clear on this, the first time—let us say we make our schedules with our present funding and fly with human crew—the first Ares and Orion flight to the Station in March 2015,

for the sake of argument, let's say that. That vehicle is not, at that point, necessarily qualified for 6 months duration on-orbit, to serve as a crew rescue vehicle.

I think it's a good time to point out to everyone, we've been focusing on the transportation up and back, but another service that the Russian Soyuz provides today, and will provide through at least 2015, is that of crew rescue.

Now this was an obligation that the United States initially signed up for, for ourselves and our partners. So—until and unless we have a system, whether commercial or government, and until and unless we have a system up there qualified for 6 months flight between crew rotations—we can not, we can not say that we have crew rescue capability, and we will still be dependent upon the Russians.

So, speaking as an engineer, if our first flight of Ares or Orion is in March of 2015, then it would be the end of that fiscal year, we would be into Fiscal Year 2016 before we would know that we had a system qualified for crew rescue, as well as transportation up and down. So, we're looking at a substantial period of dependency upon Russia in the Space Station partnership.

Senator VITTER. Well, the point I was driving to is that, the term of that next phase is open for discussion and negotiation?

Dr. GRIFFIN. Yes, sir.

Senator VITTER. And therefore, clearly if we would do something in addition, with either accelerating the NASA program or funding COTS–D or accelerating COTS, any of that, that can clearly have an impact on that Russian contract?

Dr. GRIFFIN. Absolutely.

Senator VITTER. And, so again, just to restate the obvious, I'd really like for you all to develop a comparison of those costs and benefits, costs and savings, because it certainly seems like there could be substantial savings, in terms of payments to the Russians for certain actions we take.

Dr. GRIFFIN. Yes, sir, I agree.

Senator VITTER. Thank you.

Senator NELSON. By the way, in our last conversation about the difference between the two COTS contracts, is there not another difference in that SpaceX has the capability of bringing down cargo in their contract, and the most recent contract does not have that capability of bringing down cargo?

Dr. GRIFFIN. That's correct, sir. The recent agreement that we concluded with Orbital, includes up-cargo, pressurized and unpressurized only, and their proposal did not offer down-cargo or human transportation.

Senator NELSON. And if you have an International Space Station, you want to bring down experiments, as well as take them up?

Dr. GRIFFIN. We do.

Senator NELSON. I would just add, as a backdrop to this whole discussion, with regard to Russia, that they're just getting ready to have an election in Russia. And it's not exactly the kind of election that we're accustomed to here, because the President is inserting his own person as the new President, in order to comply with the Constitution, but it's an open secret that he is going to be the

Prime Minister, and therefore the real power will continue in the hands of Vladimir Putin.

And, we know also, that Russia has been buying up all the pipelines that feed gas and oil to Europe, and so he is going to be in a very significant position to yank a bunch of chains of a bunch of people. And I just don't think that's a good position for the United States to be in, where he's got a major chain to yank.

Now, speaking of that, we've got a Station, we've spent billions, tens of billions of dollars, we want to do scientific research on it. What are NASA's plans for the Station beyond the year 2016?

Dr. GRIFFIN. We don't currently—the Administration does not currently have plans in place for the utilization of the Station after 2016. We have taken no action to preclude such operations, but we don't have specific plans for them as yet.

Senator NELSON. Well, one of the reasons for having the Space Station was to not only conduct scientific research and spending lots of American taxpayer money, as well as other nations' moneys—but it was also to encourage private sector partners to make investment in research projects. And so, if they don't know that there's going to be a Space Station after 2016, how are we going to give them assurance if we don't make plans for the Space Station past that year?

Dr. GRIFFIN. I understand, sir.

I will say again, I mean, certainly—well, this is a personal opinion. I do not believe that the Congress which is sitting at that time or an Administration which is in place at that time, would shut down a perfectly good Space Station. I just don't believe that. That doesn't seem to me to be a realistic possibility. But, this is 2008, and what we're doing is planning for the next 5 years, at most, and most of my emphasis is on the next couple of years. We're not, at the moment, planning for 2016 and thereafter.

Senator NELSON. So you don't think there are any steps that we need to take now in order to operate beyond 2016?

Dr. GRIFFIN. There is nothing that we need to do in a budgetary sense this year, that affects what we do in 2016.

Now, as the next year or so approaches, and we start to work up our current budget horizon—of course the President's submission goes from Fiscal Year 2009 to Fiscal Year 2013. As we go to the next budgetary submission and the one after that, we do begin to have items which we will need to pay attention to in order to continue sustaining the Station. But this year, that's not an issue.

Senator NELSON. Well, no doubt, you're clear that you want the Station to operate beyond 2016?

Dr. GRIFFIN. I do, and of course, I will not be the Administrator at that time, and there will be several changes of Congressional sessions and several Administrations between now and then. The point I was making earlier, sir, was that I just—if the Space Station, after having been the result of tens of billions of dollars worth of development, is still working fine in 2016, I personally consider it unlikely that this Congress or any Administration would shut it down.

Senator NELSON. Well I do, too. I agree with you, assuming we have access——

Dr. GRIFFIN. There is that.

Senator NELSON.—to the International Space Station. Assuming all of that, let me ask you this. Don't we have to plan ahead of time for recertification to extend the service life? And what would that recertification entail and when should we start it?

Dr. GRIFFIN. I don't know that I would call it recertification. We certainly, in the next few years, will have a chance—as we are doing now—we will have a chance to observe how the individual components and pieces on the Space Station are wearing out and how they break and why they break and what equipment needs to be put up and what equipment is lasting longer than expected. So we will have an opportunity to accumulate maintenance data, if you will, on the Station. And that will influence, without question, that will influence what we decide to do and how we decide to do it in the out-years to sustain the facility.

I mean, when it is completed, you will have here, sir, a facility that weighs almost, well 900,000 pounds, just shy of a million pounds, on-orbit. It will need care.

Senator NELSON. And for the extension of its life, is going to cost some money. So, as we get around to budgeting for that, we've got to put that in there.

Dr. GRIFFIN. And as we get closer to—as we get further out in our out-years, we will have to include some budgeting for maintenance of the Station beyond 2016, but we don't need to do that today.

Senator NELSON. All right, let me come back to this year's budget. The budget reserves for the Station and the Shuttle leave such a small margin, that any unforeseen circumstance would alter the ability to meet the Shuttle manifest and complete the Station. So, how do you account for the slim margins and the potential program risk?

Dr. GRIFFIN. As of, I think you've—I believe you've almost answered your own question. The margins are quite slim. We don't have reserves in Station and Shuttle accounts, and the successful completion of the task requires us to execute as we plan.

If things go bad, if something goes badly wrong, I mean, if we have another hurricane at the Cape or something of that ilk that causes us a lot of additional expenditure, we will have to seek the permission of the Congress to reprogram money from other accounts in order to finish this job.

I mean, if we had another Hurricane Katrina at Michoud or another hurricane, as came through a few years ago at the Cape, and tore up the vertical assembly building. Those things do happen, and if they happen, we will have to take money from somewhere else.

Senator NELSON. Not even to speak of, a continuing resolution.

Dr. GRIFFIN. If we have another continuing resolution, there will be programmatic impacts. We lost, last year, as you know, about $675 million from the manned spaceflight program because of the continuing resolution that came out of Exploration rather than the Shuttle and Station accounts. If that happens again, we will have more delay in the Exploration program.

Senator NELSON. I had the occasion, recently, to go to the floor and kind of get it off my chest, about the Alpha Magnetic Spec-

trometer and trying to find 25 percent of the cargo bay on one of the remaining Shuttle flights, so that we can get that up there.

You have indicated several times, that NASA has all the space manifested. It's a major scientific experiment, put together by 20 countries. I'm going to see it in 2 weeks, it is virtually complete, sitting on the ground ready to launch: 20 countries, 50 universities, probably inviting a couple of Nobel Prizes, because of its pushing the frontiers of knowledge. To be attached to the Space Station, which the purpose of the Space Station and Senator Kay Bailey Hutchison's designation of it as a National Laboratory, is for the purpose of scientific research.

Now, I'm trying to figure out how we can accommodate this and what you can take off in the way of smaller payloads, that are not scientific experiments, but are supplies that you can put in smaller packets, so that if either one works out, you could use a COTS vehicle. You could get it up economically with another vehicle, perhaps an expendable. You can't get AMS up without a big booster, since this thing weighs about 15,000 pounds.

So, wouldn't it make sense, what I've laid out, to take some of the Station's supplies and hardware, put it over on an ELV, particularly since you're developing some, and fly the AMS and let it start doing the science that it's supposed to do?

Dr. GRIFFIN. Sir, we've looked at that over and over again. The payloads that are manifested on the Shuttle from now until its retirement, are either crucial for Station assembly, or they are crucial for maintenance of the Station during the gap.

Now, with the expenditure of enough money, I mean, anything can be flown on anything, but these payloads are uniquely configured for the Shuttle. As is, I admit, the AMS.

In our judgment, the cruciality of sustaining the Space Station appropriately, with the tens of billions of dollars we have invested in that, outweighs the desire to fly the AMS. It's not that I don't wish to fly the AMS, it's that I have to put the Space Station at risk to do it. And I don't have other good means to get the hardware up to the Station that I need to have there. I do not have the authority to add another Shuttle flight to the manifest. So, I'm out of options.

Senator NELSON. Well, I think you have——

Dr. GRIFFIN. I'm out of options.

Senator NELSON. I don't think you are out of options, and this is what I want to suggest. You have some very smart people that work for you, throughout this NASA network we know as the NASA family. What some of these smart people have suggested, is that unpressurized logistic flights for ORUs, what does that stand for?

Male SPEAKER. Orbital Replaceable Units.

Senator NELSON. OK, Orbital Replacement Units, that could be launched after the AMS could be launched, in 25 percent of the cargo bay. You take those off, and this is how those Orbital Replacement Units could be launched.

On STS–129, in August 2009, with two EXPRESS logistics carriers—now these are unpressurized logistic flights. On STS–131, in February 2010, an Integrated Cargo Carrier, Vertical Light Deployable, and a Docking Cargo Module. And then the third one

would be on STS–133, in July 2010, with two EXPRESS logistics carriers. So, that any of those flights can be reconfigured to include AMS and still carry a number of ORUs. And the displaced ORUs could be launched on the ELVs.

Now, this is coming from your people, so, would you look into that?

Dr. GRIFFIN. Of course, and we will get you a detailed answer.

[The information previously referred to follows:]

SUPPLEMENTARY INFORMATION SUBMITTED BY DR. MICHAEL D. GRIFFIN

Introduction

Given the most recent information available, the conclusions from the February 2008 NASA report to the Congress on the Alpha Magnetic Spectrometer (AMS) still stand: the cargo capabilities of International Space Station (ISS) utilization flight (ULF) 3—and potentially ULF4 and ULF5 if schedule allows them to be flown—are likely to be fully subscribed with hardware and logistics that can not (or can not cost effectively) be carried to ISS on anything but the Space Shuttle. Although NASA has done nothing to preclude flying AMS on the Space Shuttle before the Shuttle's retirement in FY 2010, a final decision does not need to be made until approximately February 2009. NASA has the opportunity to wait and observe ISS systems' performance to make a more informed decision about the spares requirements of ISS.

The first priority of the International Space Station partnership is a robust and viable ISS that is ready to support exploration and other goals after assembly is complete and the Space Shuttle is retired in 2010. It is important that NASA not put any single experiment, no matter its promise, ahead of the significant investment and future potential of the ISS partnership without serious consideration of the risks of that action.

Shuttle Manifest and ISS Operations

There are only eight assembly and logistics flights left on the Shuttle manifest with which NASA can complete the ISS by the end of Fiscal Year 2010 and deliver cargo for the post-Shuttle era. This makes Space Shuttle cargo capability an extremely limited and valuable commodity. Even if time allows for the two additional contingency logistics flights (ULF4 and 5) before 2010 retirement, the top priority for these flights is to ensure a robust configuration post-2010. This will enable as much flexibility as possible for engineers and mission planners.

NASA and its partners are only a few years into learning how to fly, operate, and maintain the largest and most complex facility ever constructed in space. Despite NASA successes thus far, the unprecedented scale of ISS construction and utilization activities in low-Earth orbit has challenged some initial assumptions about the on-orbit performance of ISS systems. To the credit of this international team of scientists and engineers, most ISS systems are lasting longer than anticipated. Other systems—like the control moment gyroscopes (CMG), the starboard beta gimbal assembly (BGA), and the starboard solar alpha rotary joint (SARJ)—have required maintenance sooner than was expected. The BGA has been repaired, and the failed unit was returned to Earth on STS–122 for analysis. This analysis will determine if there is a generic design flaw in the BGAs or if this is an isolated event. This determination is critical for developing the sparing requirements for the BGAs, and how much payload space will be required on the remaining Shuttle manifest. It should also be noted that both the BGA and the SARJ are needed for the solar arrays to track the sun and to provide power for the ISS. AMS would be a significant consumer of ISS power, and thus both the BGA and SARJ need to be repaired before serious consideration is given to mounting AMS on the ISS.

Shuttle Payload Planning

It takes several months to baseline a Space Shuttle flight. Engineers throughout NASA and its international partner community spend that time trading off between a number of critical, interrelated variables, including Shuttle mass and volume constraints; center of gravity; sequencing of hardware to ISS; power (both within the Shuttle cargo bay and on ISS); cargo bay hard points; the capabilities and constraints of other international partner vehicles; and internal and external stowage capabilities on ISS. Individual elements of that team each approach the manifesting challenge from their own perspectives. This plurality of voices benefits all, but it must be synchronized and vetted through established engineering decision-making

processes. Taking any single position out of context may obscure the true complexity of the manifesting process.

Analysis to date indicates that manifesting AMS on a Shuttle flight would be technically very risky and would result in a significantly increased shortfall of spares to ISS. In general, while AMS may only occupy about 25 percent of the Shuttle cargo bay by *volume,* its 15,000 pounds mass would consume approximately 43 percent of the total launch capability of the Shuttle for a given flight. In addition, because AMS is a large and heavy payload, manifesting it along with other payloads would be problematic given the Shuttle's center-of-gravity requirements. This translates into a much more dramatic reduction in a mission's mass-to-orbit capability than is apparent on the surface.

From an integrated manifest standpoint, it is difficult to see how NASA would be able to manifest AMS on an existing Shuttle flight at this time. The packing of the cargo on the EXPRESS Logistics Carriers (ELC) in the Shuttle is the most launch and operationally effective way to deliver these spares to orbit. For example, multiple commercial cargo launches or three to five Japanese H–II Transfer Vehicle (HTVs) (if either is available) would be required to deliver the displaced cargo of one Shuttle ELC to the ISS. Commercial transportation is not currently available, and NASA does not plan to use HTV because it is not cost effective. As a result, the Shuttle is the only way to effectively deliver this time-critical hardware to orbit.

Following are some of the specific issues NASA has identified thus far with flying AMS on ULF3, or potentially the contingency flights ULF4 or ULF5 if schedule permits. Other challenges with flying AMS on either Shuttle or another vehicle are addressed in the AMS report delivered to Congress in February 2008.

Reconfiguring ULF3

In August 2009, ULF3 will deliver two fully populated ELCs with assembly hardware, science experiments and pre-positioned spares critical to the operation of the ISS. Each ELC is an external platform that provides mechanical mounting surfaces, electrical power, and command and data handling services for up to 9,800 pounds of unpressurized cargo, including two science payloads. It is important to recognize that the logistics carriers are more than just carriers to be used for the Shuttle flights. They are also the mounting pallets that must be used to store components (either spares or experiments) outside on the truss of the ISS.

Together, the two ELCs manifested on ULF3 will deliver eleven pre-positioned spares and two science experiments with a combined mass of approximately 18,200 pounds. Launch and stowage of the pre-positioned spares will facilitate sustaining ISS through 2015, since maintenance after Shuttle retirement must either occur using an on-orbit inventory of spare parts or commercial cargo services. Launch and activation of the ELC-based science payloads is useful to the operation of the ISS as an international facility conducting important space research. The mass of the AMS is too great compared to the total mass of these smaller science payloads to allow for a manifest change. In other words, even if all of these smaller pieces were removed, there would still not be room to fly AMS.

Although the ULF3 flight could potentially be reconfigured to deliver just one ELC and AMS, it would be at the expense of losing or delaying the delivery of approximately 10,700 pounds of cargo that supports ISS viability after Shuttle retirement. Only the Space Shuttle currently has the capacity to effectively transport an ELC to the ISS; failure to launch an ELC on the ULF3 Shuttle flight could result in a permanent loss of external stowage and experiment capacity for the ISS.

Co-manifesting AMS and an ELC on the same Shuttle flight would require AMS to be placed in the aft portion of the payload bay due to the need to maintain proper weight and center of gravity. The maximum total weight for the companion ELC would be reduced to approximately 12,000 pounds, decreasing the maximum cargo capability from 9,800 pounds to 7,500 pounds. This is significantly less than the manifest planned for the carriers on ULF3. Therefore, the total impact of launching AMS on ULF3 is the loss of an entire ELC worth of cargo, plus the loss of approximately 1,100 pounds from the remaining ELC. This reduction of pre-positioned spares delivered on ULF3 further increases NASA's reliance on limited or yet-to-be demonstrated non-Shuttle launch opportunities. The loss of an ELC and the external platform it provides for unpressurized science experiments would pose challenges to ISS operations and capability to support other important planned space research.

Using a Contingency Flight

ULF4 and 5 are the Shuttle contingency flights that will only be flown if they can be completed before the end of 2010.

ULF4

If approved, ULF4 would deliver an Integrated Cargo Carrier—Vertical Light Deployable (ICC–VLD) and the Docking Cargo Module (DCM) in February of 2010. The ICC–VLD is an external platform used to ferry up to 6,560 pounds of unpressurized cargo to and from the ISS; the ICC–VLD returns with the Space Shuttle and does not become a permanent part of the ISS. The ICC–VLD would deliver maintenance and assembly hardware, as well as a pre-positioned spare, with a combined mass of approximately 5,900 pounds. Six power system batteries would be replaced during the ULF4 mission to allow ISS operations through 2015. The Enhanced Orbital Replacement Unit (ORU) Temporary Platform would increase the efficiency of robotics operations, and delivery would augment on-orbit inventory of spares in order to maintain ISS through 2015.

The DCM is a pressurized module built by the Russian Space Agency, Roscosmos, which would deliver 3,086 pounds of United States On-orbit Segment (USOS) internal cargo, as well as approximately 3,400 pounds of cargo as part of the U.S. contribution to the ISS partnership. The DCM would become a permanent part of the ISS, providing a docking port, additional habitable volume, and external stowage for Russian Segment outfitting.

ULF4 could potentially be reconfigured to deliver the ICC–VLD and AMS, but at the risk of losing the DCM and its associated accommodations. NASA would undergo significant technical challenges in potentially reconfiguring an ELC on ULF5 to deliver and stow the external outfitting for the Russian Segment, reducing pre-positioned spares and science experiments by approximately 8,500 pounds. In addition, the loss of 3,086 pounds of USOS internal cargo would force NASA to rely on limited pressurized resupply opportunities.

Alternately, ULF4 could be reconfigured to deliver the DCM and AMS, at the expense of losing or delaying approximately 5,900 pounds of cargo. However, due to the substantial weight of each element, significant technical challenges would exist in accommodating the DCM and AMS on the same Shuttle flight. In this configuration the AMS would have to be flown in the forward position of the payload bay. Considerable structural and loads issues are expected regarding the placement of the approximately 15,100-pound AMS in the forward position of the payload bay. For this reason, this configuration does not now appear to be supportable from a Shuttle payload bay loads standpoint.

Even assuming the Shuttle can physically support AMS in this configuration, the Shuttle would still run a negative mass margin (approximately 4,000 pounds) unless other items were de-manifested from ULF4.

ULF5

If ULF5 is approved, the impacts of flying the AMS on this contingency flight are very similar to the impacts described on ULF3. The weight impact of flying AMS on ULF5 is slightly less, but this flight would require removal of spares that are best flown on the Shuttle. For example, accommodating AMS on ULF5 would remove EXPRESS Logistics Carrier number 4. This carrier would carry a fourth high pressure oxygen tank to support ISS space walks, a battery charge discharge unit, an S-Band antenna support assembly and a spare robot arm for Dextre. The high pressure O_2 tank does not fit on another launch vehicle without major redesign, and is critical to ISS basic operations.

Summary

NASA has done an exhaustive look at flying AMS on the Space Shuttle. NASA has carefully evaluated all suggestions and has looked creatively for any options to fly AMS on the remaining eight assembly and logistics flights, or potentially the two contingency logistics flights, before 2010 retirement. Until engineers better understand the performance of ISS systems and gain experience in operating the new systems on ISS, however, replacing critical hardware with the AMS poses risks to ISS operations.

Flying and operating ISS is one of the most complicated tasks that NASA has ever attempted, and therefore requires margin in order to be successful. NASA will continue to evaluate the hardware performance on ISS. If the observed performance of ISS systems proves to be better than predicted, NASA may reevaluate the option of replacing spares with AMS before a final decision is necessary in February 2009. Making a decision to fly AMS before then, only to find that the ISS has not been properly outfitted to support long-duration science experiments or power requirements, is not prudent.

Dr. GRIFFIN. I think some of my folks may be stepping a bit out of line. When you talk about 25 percent of a cargo bay, you're talk-

ing about by volume. And yes, the AMS uses 25 percent of a cargo bay by volume, but it uses almost half of a cargo bay by weight. So, in order to displace a number of small components, I have to actually displace more than—I can't displace 25 percent by volume of ORUs and replace it with the AMS, because I actually have to account for the weight as well as the volume, and that's going to eat into another one.

So, the manifesting challenges for what is on the Space Shuttle today are not trivial, and everything that's on there was—is on there as a result of a very severe winnowing process. But I understand your question. I will not—I will not be cavalier with it, I will take it for the record and we will give you a detailed answer as to how—as to how we might manifest these other things, if it is possible, on other flights. But we have looked at that.

Senator NELSON. Well, I'm sure you have, but again, this is coming from your very smart people.

Dr. GRIFFIN. Everything is easy——

Senator NELSON. Let that ingenuity bubble up, let that creativity bubble up. I want to give you two examples, and this isn't my thinking, this is folks that are these creative geniuses.

One flight would be reconfigured to include the AMS and an ICC–VLD, which is the Integrated Cargo Carrier Vertical—Light Deployable. This would allow the Space Shuttle to launch 8,800 pounds of ORUs plus the ICC–VLD to the Space Station on the same flight as the AMS. That's one example.

A second example is, reconfigure one of the existing flights to include AMS and an EXPRESS Logistics Carrier. The ELC would have to be loaded only with ORUs that do not require power in the Shuttle. Now, if you'll take that as creativity and see if it's possible.

Dr. GRIFFIN. I, of course, will do that. I would remind you that everything is easy for those people that don't have to do it. We have—we have explored these questions throughout NASA over and over again, and we've not been able to converge it, but I will try again.

Senator NELSON. My rejoinder to you is, you lead the agency that is capable of miracles. It happened on Apollo 13, and it happened, to a degree just last October, when that crew that we just announced went up there and figured out how to get that solar array unfurled. And, my hat's off to the ingenuity in NASA.

Dr. GRIFFIN. I'll give you the best answer I can get.

Senator NELSON. Well, I want you to do that without, you're a good Administrator because you're hard-headed, and that's a good quality, and I appreciate that, and I just hope that you will look at this.

Senator Vitter?

I need to ask you about Earth Sciences. I know that you have had a difficult time sometimes with NOAA, and also with the Department of Defense on NPOESS, with the significant cost and schedule overruns, and then the Nunn-McCurdy review came in 2006, and the sensor ended up being delayed by another 8 months. How is this delay going to affect NASA's launch schedule for the replacement, for NPP, before the next NPOESS? And what are the cost implications associated with the delay?

Dr. GRIFFIN. The sensor of which you speak is the VIIRS sensor, currently scheduled for delivery, I think, at the end of March next year. We are now to a point where if that sensor slips any further, we're a day-for-day slip on the launch. So that sensor is on the critical path for NPP, and the VIIRS sensor, of course, is the number one priority sensor aboard NPOESS itself. NPP is the NPOESS Preparatory Program. So, the VIIRS sensor is critical, is on critical path for everything that we're doing on NPP and NPOESS.

I will get for you, for the record, the consequential damages of a launch delay. I don't, again, I don't have those in my head. I'm sorry.

[The information previously referred to follows:]

The delay in the launch readiness date of the National Polar-orbiting Operational Satellite System (NPOESS) Preparatory Project (NPP) satellite is driven entirely by delays in the delivery of the Visible Infrared Imager Radiometer Suite (VIIRS) instrument. The delay now totals 3 years and 9 months, and the most recent delay is 8 months. NPP is currently planned for launch in June 2010. For NASA, the NPP satellite is a bridge mission to continue a subset of measurements of land, ocean and atmosphere currently recorded by NASA's Earth Observing System (EOS) Aura, Aqua and Terra satellites. The first NPOESS satellite is set to launch in January 2013, when the EOS satellites, if they continue to operate, will be well beyond their design life. The NPP launch delay increases the risk of a potential data gap in key climate data sets provided by these NASA EOS satellites.

The additional cost to NASA associated with an 8-month delay is an average of $2.75M per month, or a total of $22M. The additional amount covers costs for the technical support workforce and infrastructure required to maintain the instruments, equipment and facilities for 8 months to be available at launch. The major NASA-provided items are the spacecraft; the Advanced Technology Microwave Sounder (ATMS) instrument; the Science Data Segment (SDS) Product Evaluation and Analysis Tool Elements (PEATES) for the atmosphere, ocean, land, ozone, and sounder; the launch vehicle; and the management for the NPP mission. The ATMS has already been integrated into the spacecraft and the PEATES are ready to perform their tasks.

Dr. GRIFFIN. But, there will be a substantial cost increase to the NPP program if the VIIRS instrument doesn't show up. Now, I don't even remotely want to be seen to making excuses, but the VIIRS instrument is not a NASA development. We are a customer for it, we are waiting for it to show up, but it is not an instrument over whose development we have had any influence in the past.

Senator NELSON. How about NASA's Glory, the climate monitoring satellite? It seems like it might be heading toward a similar fate to NPOESS, with cost overruns and delays?

Dr. GRIFFIN. It is, there is another instrument—there is an instrument on the Glory spacecraft that—possibly not coincidentally—is being supplied by the same vendor, and that instrument is late and has caused substantial consequential damages to the Glory schedule. About 90 percent of the Glory cost overrun is due to this instrument or its consequential damages.

Senator NELSON. And that's Raytheon Space and Airborne Systems. How is NASA improving the oversight of this contract?

Dr. GRIFFIN. Well, our oversight of them has been careful and consistent. Their response has been less so. We—I met with the Chief Executive Officer of Raytheon 2 weeks ago, and they have pledged to remedy their—remedy the disparities between their promises and performance. We continue to work with them. At this point, I really don't have other positive options to offer you. The

progress has been slower than planned, the instruments are late, and that does have ripple affects.

Senator NELSON. And so, since it's rippled far over budget, there's no way of getting this program back on cost and on schedule?

Dr. GRIFFIN. At this point, no. The best we can do is to contain the damage, and make as much progress toward the launch date as we can.

Senator NELSON. Do you want to share with the Committee about the Next Generation Air Transportation System? What R&D projects does NASA currently have underway that will support this?

Dr. GRIFFIN. Yes, sir, quite a few.

NGATS, of course, is the centerpiece of FAA development of a new air traffic management system, and NASA is a partner on that. We are conducting research on statistical air traffic management to improve the traffic density that we can safely fly. We're conducting research on higher efficiency engines, lower noise, lower emission engines, aircraft configurations that are more efficient. We're doing a host of activities in support of the FAA and in collaboration with the FAA on NGATS, and we are—we are meeting our budgetary commitments to the FAA for it.

Senator NELSON. Is this to take existing technology and apply it? Or are you focused more on basic research?

Dr. GRIFFIN. For NASA, we focus more on basic research. We're not, in our aeronautics programs, we're not primarily in the business of taking existing technology and applying it.

Senator NELSON. Has NASA completed an MOU with the Joint Planning and Development Office that outlines the Agency's role in this next generation effort?

Dr. GRIFFIN. I don't know that we have. I can check on that for you. We certainly have a good relationship with the FAA and the JPDO, but whether the MOU is signed or not, I don't know.

Senator NELSON. Is whatever the arrangement is reflected in the 2009 budget that you have?

Dr. GRIFFIN. The 2009 budget and the out-years budget for aeronautics fully supports our commitments to the FAA on NGATS. That has been a priority for me.

Senator NELSON. We'll ask for the record, questions about the U.S. national wind tunnel facilities, and we will also ask questions about the American COMPETES Program.

[The information previously referred to follows:]

NASA has signed a Memorandum of Understanding between member agencies of the Joint Planning and Development Office (JPDO) to implement the Congressionally-mandated Next Generation Air Transportation System Joint Planning and Development Office.

Dr. GRIFFIN. OK, and I will answer as expeditiously as possible.

Senator NELSON. OK.

I don't want any misunderstanding in the term that I used earlier, hard-headed, because I use that and I explained as an attribute of admirable quality that you, as an Administrator, have and have to have. So I just want to make sure that that was not, in any way, taken as a derisive term, rather an admirable term.

And what I am trying to get out is, that this Agency has so much creativity. If there's a chance of solving this problem with the Alpha Magnetic Spectrometer, it's well worth it for us to look at different things.

Dr. GRIFFIN. Well, sir, I took no offense and I do agree. I think, there seems to be among your staff a perception that I don't want to fly the AMS. In fact, that's false. I do want to fly the AMS. I yield to none in my belief that the United States should keep its international commitments, commitments made to international partners. I've said that on the record multiple times, and I mean it.

We have looked carefully—and in detail—at options to fly the AMS within the exiting manifest, and I've not found them. If people have clever ideas and they have not put them forth, then we will investigate again and we will listen to those clever ideas and let them put those ideas forth. I would like to find an option to fly AMS. Far from stiff-arming it, I would like to do it. But I will not—I will not do it in such a way that would cause, in my judgment, harm to the Station.

Senator NELSON. Well, I certainly understand that, but at the same time, I've got to remind everybody, what's the purpose of the Space Station? And what's the purpose of the expenditure of tens of billions of American taxpayer dollars? And that was, not only to have a facility where we could learn about the adaptation of humans to space, but that we would have a scientific facility for experimentation. And this is just one project, but to move that over to an expendable, which it's going to be delayed 5 to 7 years, at considerable additional cost.

Dr. GRIFFIN. And we don't recommend that.

Senator NELSON. And that's what I'm trying to find a solution for.

This has nothing to do with the State of Florida. In some minimal amount it may, with regard to the 50 universities that are involved in this thing, I think there is one university in Florida that's involved, but that's beside the point. This is an experiment that's ready on the ground, to analyze these cosmic rays and to see what's out there and what's the origin and so forth.

So, thank you very much.

Senator Vitter, anything further?

Senator VITTER. No, thank you very much.

Dr. GRIFFIN. Thank you both, and I will do everything in my power to answer your questions about remanifesting cargo to fly AMS. We will look at it and give you the most honest answer that we can do. I will spend time on it personally.

Senator NELSON. Thank you, Dr. Griffin.

And the meeting is adjourned.

Dr. GRIFFIN. Thank you, sir.

[Whereupon, at 3:56 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. BILL NELSON TO DR. MICHAEL D. GRIFFIN

Question 1. In your opinion what would it take to get the Alpha Magnetic Spectrometer (AMS) up to the International Space Station (ISS)?

Answer. Consistent with the report NASA submitted to the Subcommittee on February 22, 2008, regarding Alpha Magnetic Spectrometer (AMS), a Space Shuttle flight is not a viable approach to launching AMS to the International Space Station (ISS). The Space Shuttle manifest is fully subscribed with hardware and logistics intended to safely maintain the ISS in the post-Shuttle era. Manifesting AMS on one of the few remaining scheduled Space Shuttle flights would mean bumping a large quantity of higher priority ISS hardware and spares intended to maintain the ISS after September 2010. As a result, no Space Shuttle payload opportunities for AMS are available, even if the program is able to fly the two contingency flights that could be added to the manifest if they can safely be flown before program retirement in September 2010. NASA will continue to evaluate the hardware performance on ISS. If the observed performance of ISS systems proves to be better than predicted and the Shuttle continues to fly on schedule, NASA may reevaluate the option of replacing spares with AMS before a final decision is necessary in February 2009.

Adding an additional Space Shuttle flight to the manifest before September 2010, assuming contracts could be reworked, sufficient parts could be built and the schedule would allow such a change, would cost approximately $300–$400M and would mean accepting additional schedule and programmatic risk in the Shuttle program. Adding an additional Space Shuttle flight to the manifest after September 2010 and maintaining the infrastructure needed to safely fly the Space Shuttle into FY 2011 would cost approximately $3–$4B, and have both a significant negative impact on NASA's Exploration program and the potential of adding additional safety risks to the Space Shuttle program.

Modifying the AMS hardware to fly on an Expendable Launch Vehicle (ELV) would delay the launch until 2013 or 2014 and add an additional $570M to $1.0B to the cost of the project. Moreover, a 2013 or later ELV launch implies that the baseline AMS three-year science mission on ISS may not be completed by FY 2016.

Question 2. Can you comment on the current state of U.S. wind tunnel capabilities?

Answer. Over the last decade, in response to changes in the Aerospace arena (primarily economic), many U.S. wind tunnels have been closed to reduce excess capacity and eliminate redundant capabilities. While there may be some further reductions, primarily due to redundancy, the remaining facilities will represent a basic capability to meet current and perceived future demands.

Question 2a. Do you see our wind tunnel facilities as a national capability that should be maintained?

Answer. Yes. The majority of the remaining U.S. facilities are unique and are a critical capability required to support the U.S. aerospace industry.

Question 3. Would you support commissioning a study to examine this issue and produce recommendations on retaining this capability?

Answer. Currently there are a series of studies addressing this issue, and several others have been completed over the last few years. The results of these studies should be digested before a new study is considered. The current studies addressing the U.S. wind tunnel situation are as follows:

- National Partnership for Aeronautic Testing (NPAT)—NPAT is addressing the potential combined needs of both NASA and DOD, specifically looking at rightsizing the portfolio and establishing reliance across the agencies with the potential of a corporate management structure.
- National Plan for Aeronautics Research and Development and Related Infrastructure—This effort being conducted under the auspices of the National Aero-

nautics R&D Policy is addressing the future wind tunnel needs required for the Nation.

- U.S. Industry Working Group—This group under the auspices of the American Institute of Aeronautics and Astronautics (AIAA) is compiling the wind tunnel requirements for the U.S. aerospace industry and mapping these requirements against the current inventory of U.S. wind tunnels.
- Transonic Study, Supersonic Study, Subsonic Study & Hypersonic Study—These four studies that are currently being conducted jointly between NASA and DOD are cataloging the capabilities and health of NASA and DOD wind tunnels.
- Over the last 2 years RAND and the Institute for Defense Analysis (IDA) have conducted studies pertaining to the status of the U.S. Government wind tunnels.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TED STEVENS TO DR. MICHAEL D. GRIFFIN

Question 1. In order to avoid being wholly dependent on Russian launch vehicles for human access during the gap, does it make sense—and isn't it the responsible thing to do—to develop a back-up plan to extend the life of the Shuttle for some period of time beyond 2010 so that we at least maintain the option to insure U.S. human access to space? Obviously, such a plan would have considerable cost associated with it, but how are we in the Congress to judge whether or not it should be funded if we aren't able to see it?

Answer. NASA does not believe extending the Space Shuttle program beyond 2010 is a viable option to address the challenges we face. NASA cannot continue flying the Space Shuttle while simultaneously and aggressively developing the next-generation exploration systems under the Constellation program. There are several reasons for this.

First, maintaining even a minimal capability to launch two Shuttle flights per year after FY 2010 would require nearly the same infrastructure and vendor capabilities we have today, at a cost of approximately $2.7–$4.0B per year. These funds would have to come at the expense of Constellation development. Second, the Constellation architecture is designed to take advantage of Space Shuttle infrastructure, production capabilities, and workforce once they are no longer needed for flying the Shuttle. If the Shuttle were kept flying past 2010, these capabilities could not be released for Constellation's modification and use.

In addition to these two main reasons, it will also be extremely difficult to keep the Shuttle workforce engaged if Shuttle retirement is extended. A very dedicated workforce is needed to safely operate this complex machine. By ending on a planned date, known well in advance, is much preferred for the workforce than a floating end date. Finally, the Shuttle is an extremely complicated vehicle to operate, and it should only be flown as long as its capabilities are required to assemble the Space Station. The Orion Crew Exploration Vehicle is a safer vehicle for crew transport, and unlike the Shuttle, will be able to transport crew to the Moon.

As a result, keeping Shuttle flying past 2010 would only compound the problem of getting Constellation into service.

Question 2. Under your current plans, for what period of time will the U.S. be completely reliant on foreign launch vehicles for human access to space, if U.S. commercial providers do not deliver any such capability? Please provide what alternative foreign launch vehicles you anticipate using, over what period of time, and at what cost.

Answer. NASA plans to retire the Space Shuttle at the end of FY 2010. The next new U.S. crewed space vehicle will be the Orion Crew Exploration Vehicle, which is expected to have its first crewed flight to the International Space Station (ISS) in March of 2015. This would mean that the U.S. would not have a domestic crew launch capability for about 4.5 years, assuming no change in the current development program of Orion. While one of NASA's funded Commercial Orbital Transportation Services (COTS) agreements includes provisions for the development of a "Capability D," which would demonstrate commercial crew transportation services to the ISS, this capability has no Federal funding at this time. In addition, it is NASA's plan to first have a COTS provider successfully demonstrate and then establish routine cargo services to the ISS prior to initiating the competition for the development and demonstration of a commercial crew service.

At this time, the only spacecraft that could provide the required crew services and rescue capability is the Russian Federal Space Agency's Soyuz crew transport.

Therefore, use of Russian systems for ISS crew transportation and rescue would still be essential. NASA is currently constrained from purchasing Soyuz services after December 31, 2011, by the Iran, North Korea and Syria Nonproliferation Act (INKSNA, 50 U.S.C. 1701 note). On April 11, 2008, NASA submitted to the Congress a proposed amendment to extend the exception for payments to Russia for Soyuz crew transportation and rescue services until the Orion Crew Exploration Vehicle reaches Full Operational Capability. NASA looks forward to working with the Congress on enactment of this legislation. It is important to note that this long-standing partnership is interdependent. While NASA is relying on Russia for crew transportation services, Russia depends on the United States to meet operational, engineering, and safety requirements on the ISS.

Currently, NASA purchases comprehensive Soyuz support, including all necessary training and preparation for launch, crew rescue and landing for an entire long-duration mission. NASA does not purchase Soyuz launches, but rather a round trip "seat" or crew rotation. Soyuz can accommodate up to three seats per launch. At this time, it is premature to speculate on the cost of any future contract with Russia to provide crew transport and rescue services. To meet our U.S. obligations for U.S., Canadian, European and Japanese crew, we would require six seats per year. The total would depend on when a U.S. capability is operational.

Question 3. What is NASA doing to make sure the country gets the best return on its very large investment in building the International Space Station? What are your plans to ensure that U.S. scientists—not just NASA researchers—have access to this unique National Laboratory?

Answer. NASA has a research program that utilizes the International Space Station (ISS) with the support of NASA and non-NASA scientists. This research portfolio includes experiments in the fields of Human Research and Countermeasure Development for Exploration, Fundamental Physical and Biological Sciences, and Technology Development for long-duration space missions. A major portion of research is solicited through NASA Research Announcements that are open to scientists from all U.S. institutions. In most cases NASA's role is to facilitate the execution of this research on the ISS.

In addition, as reported to the Congress in April 2007, NASA has three tactical initiatives underway to identify expanded uses of the ISS beyond NASA and enter into agreements with non-NASA entities for use of the ISS in the post-assembly time-frame.

Education Initiative

NASA, in conjunction with the National Institutes of Health, the National Science Foundation, the Department of Energy, and the Department of Defense, has identified potential specific educational projects that could use or center on the International Space Station. The Department of Education has participated in the development of this report and is preparing an accompanying statement that warrants the validity of these educational projects for advancing progress in Science, Technology, Engineering, and Mathematics education in accordance with national policy.

Basic Research Initiative

NASA continues to meet with, and cooperatively provide information to, other government agencies (OGAs) interested in utilization of the ISS. It is anticipated that OGA discussions may lead to Memoranda of Understanding (MOUs) for use of the ISS that are similar in scope to the MOU signed by the National Institutes of Health (NIH) and NASA in September 2007. With respect to this existing MOU, NIH Institute Directors discussed use of the ISS National Laboratory at an NIH leadership meeting on February 28, 2008. As a result, the plan for a 2008 NIH research announcement specific to ISS opportunities is now under development.

Applied Research Initiative

In August 2007, NASA issued an announcement of opportunities for use of the ISS by domestic non-government entities for research and development (R&D) purposes. The proposals received were evaluated during the Fall of 2007, and NASA decided to pursue development of three Space Act Agreements (SAAs) as a result. The potential agreements, which involve the exchange of proprietary information that cannot be discussed at this time, are with two private firms and one university. We anticipate concluding these agreements in the Spring of 2008, and are in the process of establishing a pilot program to test the experiment hypotheses and business models as proposed. In addition, NASA is continuing to cooperatively exchange information on ISS R&D opportunities with private firms and nonprofit institutions that have displayed an interest in ISS utilization. It is expected that these discussions may lead to private initiatives to form institutes or consortia for ISS utiliza-

tion. Along these lines, the U.S. Chambers of Commerce, Space Enterprise Council, plans to host a May 2008 meeting at its headquarters in Washington D.C. specifically for the purpose of discussing ISS National Lab opportunities. The top 100 corporate R&D investors will be invited to attend.

The education, basic, and applied research initiatives are all progressing well and non-NASA interest in utilization of the ISS continues to grow, as predicted, with the completion of each new assembly flight and the resultant reduction in perceived risk.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK PRYOR TO DR. MICHAEL D. GRIFFIN

Question 1. NASA's Education program is an important element of the Nation's commitment to excellence in science, technology, engineering and mathematics (STEM). The NASA Experimental Program to Stimulate Competitive Research (EPSCoR) provides 26 jurisdictions or states that traditionally do not receive significant NASA research funding with an opportunity to participate with NASA on science and technology projects. The NASA Space Grant program is a national network of colleges and universities that provide important fellowships and scholarships for students at a time when NASA is trying to recruit its next generation of scientists and engineers. In FY 2008, Congress appropriated $12.8M for EPSCoR and $35.7M for Space Grant. The Fiscal Year 2009 budget proposal for both programs is significantly below their historical funding. Please explain what steps NASA's Office of Education is taking to expand these programs, support STEM education initiatives, and train NASA's future workforce?

Answer. Education is and will continue to be a fundamental element of NASA's activities reflecting a diverse portfolio of higher, elementary/secondary, and informal education programs. The FY 2009 budget request in no way reflects a de-emphasis in education programs.

In order to maintain an ideal portfolio identified by the Education Coordinating Committee, the Office of Education balanced the Congressional priorities—EPSCoR, Space Grant, and Motivating Undergraduates in Science and Technology Project (MUST)—with the recommendations from the National Research Council of the National Academies of Sciences and NASA's three education outcomes.

The FY 2009 President's request includes $28.7M for Space Grant and $8.3M for EPSCoR. The requested funding allows NASA to maintain research infrastructure development in all states and provide six new research awards. Funds will be apportioned to the Space Grant consortia in a *pro rata* manner consistent with 35 Designated consortia and 17 Program Grant/Capability Enhancement consortia.

Additionally, through the annual Progress Report and Proposal/Budget submission, the 52 consortia would determine which of their consortium projects would be reduced or terminated based on available funding while remaining in alignment with the NASA Education Strategic Framework, outcomes, objectives, and measures.

Question 2. In the early 1990s NASA decided in favor of Principal Investigator (PI) led missions for the *Discovery,* Scout, and New Frontiers programs. The philosophy behind PI-led missions is that space missions should be science driven, and new PIs and new kinds of science are to be encouraged. In order to implement the mission, a science PI partners with a NASA Center, which manages the project and an industrial spacecraft provider. Without community or National Academies' input, it appears that the Science Mission Directorate has changed the ground rules and now requires that the PI must have significant prior experience in leading space missions. Please explain how this new requirement will result in better science and management of NASA space missions?

Answer. Though NASA is no longer requiring specific PI experience, a PI-led mission is more likely to be successful if the PI-led management team has demonstrated relevant scientific, leadership, and managerial skills through appropriate prior experiences. Having a PI who has played a relevant and significant role in a spaceflight mission or space instrument project can help reduce the inherent risk in PI-led missions. When the PI does not have specific experience, this can be mitigated by assembling a strong mission management team that includes not only the PI, but also the project manager, the projects scientist, and the mission systems engineer.

NASA has programmatic reasons to reduce the probability that its missions are not achieved within the planned cost and schedule commitments. Overruns and delays adversely affect the frequency of future missions that NASA can mount and additionally can jeopardize the viability of the PI-led mission model. Therefore, PI-

led mission teams must demonstrate appropriate experience and expertise in order to significantly mitigate these risks to the benefit of NASA and the science community.

In response to community input and the experienced gain through the 2007 Small Explorer solicitation for small PI-led mission proposals, NASA is modifying its policies and requirements in this area. The experience and expertise of the proposed mission management team will be a required evaluation factor in all future science Announcements of Opportunity.

Question 3. After the retirement of the Space Shuttle, NASA will have to rely upon Russia for crew transport to and from the International Space Station (ISS). NASA's waiver from the Iran, North Korea, Syria Nonproliferation Act (INKSNA) expires January 1, 2012. The COTS Space Act Agreements include an unfunded option to demonstrate Capability D, the transport of crew to and from the ISS. Would it be prudent for NASA to provide some funding for Capability D as an "insurance policy" against the expiration of the INKSNA waiver?

Answer. As part of COTS, NASA intentionally limited its investment in privately developed spacecraft by first requiring the successful demonstration of an orbital cargo mission before considering additional investment in the more difficult crew transportation capability. Some of the top risks associated with approaching and berthing with the ISS are common to both cargo and crew missions and waiting for successful cargo mission demonstrations will close these risks before placing additional crew in the mix. In essence, NASA believes it is important to first demonstrate cargo services before even considering a demonstration of the transportation of our most valuable commodity—American astronauts.

Capability D is currently unfunded. Given that technological advancements in the commercial space sector will likely occur between now and 2010, if sufficient funding were available for a Capability D demonstration, NASA would hold a full and open competition to find the best partner to demonstrate crew transportation services. Doing so would ensure that NASA has the best proposals to choose from at the best value for the American taxpayers.

NASA prefers to purchase U.S. commercial crew transportation and rescue services once they have been demonstrated rather than purchase Russian Soyuz services. However, even if Capability D becomes operationally available during this time-frame, NASA will still need to purchase Russian Soyuz crew transportation services to fill the gap between Shuttle retirement and Capability D availability.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DAVID VITTER TO DR. MICHAEL D. GRIFFIN

Question 1. Can you explain the thinking behind a course of action that would have the U.S. finally complete a space station—at a cost of $50 billion to $100 billion, depending on whether you include launch costs—and then immediately and voluntarily suspend our ability to put U.S. astronauts and researchers aboard that station?

Answer. Through a mixed-fleet strategy, NASA plans to ensure that capability to operate, maintain, and productively utilize the ISS continues to be available after the Space Shuttle is retired at the end of FY 2010.

Following the *Columbia* accident, NASA took to heart the commentary of the *Columbia* Accident Investigation Board concerning the direction of the Nation's space activities and established a new U.S. Space Exploration Policy, endorsed by the Congress in the NASA Authorization Act of 2005 (P.L. 109–155), which calls for completion of the International Space Station (ISS), retirement of the Space Shuttle and development of new transportation systems, including the Orion Crew Exploration Vehicle (CEV) and the Ares family of launch vehicles.

In order to ensure the steady development of the Nation's exploration capabilities NASA must retire the Space Shuttle, and focus human, infrastructure, and monetary resources toward development of the new systems. We cannot simultaneously continue to operate the Shuttle fleet and develop Orion, so we must phase out the former as we ramp up the latter, if we are to continue to move forward to achieve our Exploration goals.

NASA recognizes the importance of America's investment in the ISS and the formidable—and increasing—research capabilities of this National Laboratory. Consequently, NASA is supporting the development of commercial services to sustain the ISS. As a backup, NASA is also ensuring that its new exploration vehicles are capable of supporting the ISS, and is maintaining the option of purchasing Russian crew transfer capabilities.

NASA is making an investment of $500M to spur the development of Commercial Orbital Transportation Systems (COTS) through funded Space Act Agreements with U.S. commercial space industry partners. The companies pay for the development of these COTS vehicles by means of private sector investment, leveraged with NASA's investment, with the anticipation of selling COTS services to support the ISS to NASA.

We have known we would require use of Russian crew transportation and rescue services following retirement of the Shuttle, and for that reason, we sought an amendment in 2005 to what was then the Iran Nonproliferation Act (INA). In 2000, Congress passed the INA, which was subsequently amended to become the Iran, North Korea and Syria Nonproliferation Act (INKSNA). Among other things, INKSNA prohibits the U.S. (NASA) from making barters and purchases from the Russian Government and proscribed Russian entities in connection with the International Space Station due to concerns with Russian proliferation. In 2005 Congress passed a legislative exception to the prohibition allowing NASA to make such barters and purchases until December 31, 2011. In April 2008, NASA submitted to Congress a proposed amendment to INKSNA that would permit NASA to continue to procure Russian support for the ISS until suitable U.S. capabilities are in place.

Question 2. I understand the budgetary planning horizon for the Space Station is 2015 or 2016. Is that correct?

Answer. The budget horizon associated with the President's FY 2009 budget request runs through FY 2013. The notional planning horizon for ISS operations runs through 2015 because U.S. Station components are certified for 15 years on-orbit, and the U.S. Laboratory was launched in February 2001. While NASA has not assumed any budget for ISS operations and research beyond this planning horizon the Agency has not taken any actions to preclude continuation of Station operations and research beyond that year. It will be up to future Administrations and Congresses to make the decision regarding the Station's orbital lifetime. NASA is currently preserving options to continue operations beyond this point.

Question 2a. And yet the current plan indicates we won't have a Shuttle replacement ready until 2015—and likely 2016. How do you propose we can expect to actually use our newly-finished Space Station between 2010 and 2016?

Answer. Both crew and cargo transportation capability will be necessary to operate, maintain, and use the ISS productively, during the period 2011–2016.

The United States will rely on the Russian Soyuz for crew transport/rescue capabilities until the Orion Crew Exploration Vehicle comes on line, or a U.S. commercial COTS vehicle for crew transport/rescue is successfully demonstrated. NASA currently has a contract with Russia for crew transportation and rescue through 2011. And, in April 2008, NASA submitted to Congress a proposed amendment to the Iran, North Korea, and Syria Nonproliferation Act (INKSNA, 50 U.S.C. 1701 note) that would permit NASA to continue to procure Russian support for the ISS until U.S. capabilities are in place.

With respect to cargo transportation capability, COTS agreements with both the Space Exploration Technology Corporation (SpaceX) and Orbital Sciences Corporation (OSC) include milestones for cargo capability demonstrations in the 2010 timeframe. NASA released the Request for Proposals (RFP) for Commercial Re-supply Services (CRS) on April 14, 2008, which will allow contract mechanisms to be in place for services in the 2011–2015. NASA plans to award contracts by the end of calendar year 2008. In the event that domestic, commercial cargo transportation capability is delayed, NASA will rely on the existing and planned services of the ISS partnership until such time as U.S. services become available. The ISS partners have existing capabilities through the Russian Progress vehicle, and planned capabilities through the European Automated Transfer Vehicle (ATV), which was successfully launched on March 8, 2008, and subsequently docked on April 3, 2008, with the International Space Station, and the Japanese HII Transfer Vehicle (HTV), which is scheduled for its maiden launch in September 2009. The planned ATV and HTV flights are part of the negotiated offsets to NASA for launching their respective modules to space.

Through this mixed-fleet strategy, NASA plans to manage risk in such a way as to ensure that capability to both operate and maintain, and productively utilize the ISS continues to be available after the Space Shuttle is retired at the end of FY 2010.

Question 2b. What steps would be required to make a determination as to the maintenance and use of the ISS after 2016? When would you project that such steps would be implemented?

Answer. Continued operation and use of the ISS after 2015 will depend on an assessment of the benefits and costs by future Administrations and Congresses. Key

factors are likely to include: (a) cost of cargo and crew transportation; (b) cost of operation and research; (c) perceived benefits of operations and research; (d) national and international policy objectives in the future; (e) the technical feasibility of continued safe operations; and (f) interest in the National Laboratory from other government agencies and the commercial sector. During the period from 2011 to 2015, the productivity potential of the ISS should become more clear and by FY 2014, NASA will have the information needed for the Administration and Congress to make an informed decision in cooperation with the ISS international partners. NASA is currently taking no steps that would preclude continued operation and utilization of the ISS beyond FY 2015. NASA is technically prepared to extend the life of ISS and has begun collecting technical data to allow for life extension.

Question 3. You have indicated you plan to fill the "cargo gap" for station resupply using the COTS (Commercial Orbital Transportation System) program. You have budgeted $500 million total over a period of 5 years, and divided that amount between two separate development efforts. Do you believe this funding level is adequate?

Answer. Yes, the funding level is adequate. The existing funding—$500M over 5 years—has enabled NASA to enter into funded Space Act Agreements with two partners. It is our judgment that this is a sufficient number of funded partners to provide a reasonable chance of at least one company being able to offer NASA cargo transportation services after the retirement of the Space Shuttle in 2010.

Question 4. If, for whatever reason, we are unable to get U.S. crew members to the space station, what is the impact of that on your cargo and resupply requirements?

Answer. The most critical issue would be the ability to safely operate and maintain the ISS with a reduced complement of only three crewmembers—none of whom would be American. Currently, operations and maintenance of the U.S. operating segment (USOS) of the ISS is estimated to require 65 crew hours per week. This work requires extensive knowledge in U.S. systems operations, and cannot be effectively done by a non-U.S. crew member. NASA would need to spend a large amount of time training others to operate the U.S. systems and it is not practical to provide this level of training to our partners. The U.S. systems also provide key services for the partners' power, communication, data, thermal control, etc. Without U.S. crew on the ISS, the critical ISS systems will fail. In this scenario, it would make little sense for the U.S. to continue to provide logistics for a Station that we could not use or maintain. The need for cargo goes to zero in this scenario. In addition, under the ISS international agreements, the U.S. is responsible for crew transportation, crew rescue, and some cargo upmass and downmass for Canada, Europe, and Japan. For these reasons, NASA intends to sustain U.S. astronauts aboard ISS to minimize risks to the continued operation of the spacecraft.

Question 4a. What would be the impact of a reduction in cargo requirements on the business case for your COTS contractors?

Answer. NASA has not specifically analyzed the impact of a reduction in cargo requirements on the business cases of future Commercial Re-supply Service (CRS) contractors (which are proprietary).

Question 5. Your intention to transport U.S. crew members to the ISS after 2010 is to send them on Russian Soyuz vehicles, which you have contracted to pay Russia for, at a cost of over $700 million, through 2011. What is the cost per launch for that service?

Answer. NASA purchases comprehensive Soyuz support, including all necessary training and preparation for launch, crew rescue and landing for an entire long-duration mission. These services amount to an average of $26M for each crew rotation purchased. NASA does not purchase Soyuz launches, but rather a round trip "seat" or crew rotation. Soyuz can accommodate up to three seats per launch. The $700M contract includes items other than crew transportation, such as training, habitation, and rescue. It includes cargo transport as well as other items needed for ISS. The current contract only purchased the minimum cargo capability to keep ISS functional while the U.S. commercial market develops.

Question 6. Under current law, you cannot even buy those launch services from Russia after 2011. How do you propose to get U.S. crew members to the station after 2011?

Answer. NASA can't get U.S. crew members to the ISS after 2011 until a new U.S. capability comes on line, unless Congress amends the Iran, North Korea, and Syria Nonproliferation Act (INKSNA) to enable the Agency to purchase Russian services beyond 2011.

Question 6a. If an extension were granted by the Congress, allowing purchase of those launch services, what would you expect the total cost to be for using those capabilities, through 2016?

Answer. At this time, it is premature to speculate on the cost of any future contract with Russia to provide crew transport and rescue services. In order to meet our U.S. obligations for U.S., Canadian, European and Japanese crew, NASA would require six seats per year. The total cost would depend on when a U.S. capability is operational.

Question 7. In preparing to negotiate an expanded contract for Russian launch services, assuming an exemption is granted which allows you to proceed with that negotiation, how do you believe the U.S. negotiating position could be improved by specific actions that might be taken or initiated to either accelerate the development of the Ares/Orion projects or to actively pursue alternative U.S. commercial alternatives for human access to ISS? In particular, address the cost-benefit analysis of undertaking those acceleration or development activities versus making the anticipated expenditures for Russian-provided services.

Answer. It is important that NASA receive relief from the provisions of the Iran, North Korea and Syria Nonproliferation Act (INKSNA) as soon as possible so that the Agency can begin negotiations with Russia for Soyuz crew transport and rescue services; the earlier the Agency is able to begin these discussions, the more effective its negotiating position will be. If the legislative authority NASA requested last April is not enacted this fall, we face the very real prospect of a gap in U.S. crew presence onboard the ISS beginning in late 2011, jeopardizing its safety and viability. U.S. crew is required onboard to operate the Space Station. Without concluding contractual arrangements in 2008 for crew rotation and rescue services after 2011, the production of future Soyuz vehicles to meet U.S. obligations will be at risk. Negotiations for the procurement of Soyuz must begin approximately 36 months prior to launch in order to support Russia's well established timeline for the production of the Soyuz vehicles. The timing of enactment of Congressional authority is important. Delays will reduce the time allowed for contract negotiations, which in turn would likely lead to higher prices for these services. It is important that NASA be in a position to sign a contract by October 2008 with the Russian Space Agency, or the continued operation of the ISS after 2011 could be in jeopardy.

Accelerating the development of the Orion Crew Exploration Vehicle (CEV) would reduce the amount of time NASA would be reliant on Soyuz crew transportation and rescue services, though it would not obviate the need for such services, and the cost of acceleration would almost certainly be greater than any savings accrued by avoiding purchase of additional Soyuz vehicles. Orion is scheduled to achieve full operational capability—including crew rescue—in 2016; if Orion's development were accelerated it would not be able to provide crew transport to the ISS until several years after retirement of the Space Shuttle at the end of FY 2010, though the amount of Soyuz services NASA would have to purchase would likely be reduced.

The estimated development and qualification time for a Capability D spacecraft is three to 6 years; thus, even if the effort were currently funded, NASA would still need to purchase Russian Soyuz crew transportation services to fill the period between Shuttle retirement and the Capability D availability. It is NASA's opinion that it is unrealistic to expect that the price per seat for Capability D will be significantly less than the cost of Soyuz services, and initially, it is likely to be higher as the cost will need to reflect at least a portion of the development cost outlays.

Question 8. What is the earliest time you could initiate efforts to achieve Capability D, for human transport capability, under the COTS program, and when could it be reasonably expected that such a capability would be available to support U.S. human access to low-Earth orbit, and specifically to the International Space Station? What additional funds would be required, and over what period of time, to implement Capability D? What sort of new competition, if any, would you anticipate, to obtain additional offers to provide Capability D services?

Answer. NASA estimates that industry would require a development period of between 3–6 years until a fully operational Capability D for crew transportation and rescue services would be available. Credible industry proposals for Capability D would need to take into consideration an extended development period, major financial investments, and high infrastructure costs. In order for NASA to initiate the first phase of a Capability D option, funding on the order of several hundred million dollars per partner would have to be made available through the development period. NASA estimates that an industry partner would have to spend well over $1.0B in the development of Capability D, either from company reserves or from outside investments in addition to the NASA funding. NASA believes that a co-investment approach would appropriately balance the government's contribution with the desire

to stimulate the market and ensure commitment from industry for a follow on procurement of demonstrated crew transportation services. This approach would be consistent with the current funded Space Act Agreements with SpaceX and Orbital Sciences Corporation for development and demonstration of cargo delivery.

Capability D is currently unfunded. NASA does not support funding Capability D at the expense of NASA programs as proposed in the President's FY 2009 budget request. Should NASA be required to initiate Capability D within requested funds, the funds needed for this commercial demonstration would have to come from higher priority activities. The effect may be to delay the planned March 2015 operational readiness of the next-generation human spaceflight vehicles, or eroding funds available to deliver cargo to the International Space Station.

Given that technological advancements in the commercial space sector will likely occur between now and 2010, if additional funding were made available for a Capability D demonstration, NASA would hold a full and open competition resulting in funded Space Act Agreements to find the best partners to demonstrate crew transportation services. Doing so would ensure that NASA has the best proposals to choose from at the best value for the American taxpayers.

Even if Capability D becomes operationally available during this time-frame, NASA will still need to purchase Russian Soyuz crew transportation and rescue services to fill any gap between Shuttle retirement and the projected Capability D operationally available date.

Question 9. Can you provide for the record a detailed listing of all major modifications or terminations—either of contacts or of orders from vendors—you have made to date and the schedule for those you plan to make as you start shutting down the Space Shuttle program?

Answer. NASA has not terminated any prime contracts for the Space Shuttle program to date, and will not do so until after the last Space Shuttle mission in 2010. The Space Shuttle prime contractors determine how long to maintain their subcontractor, vendor, and supplier relationships based on the needs of that specific prime contractor to continue to support the fly-out of the Space Shuttle manifest. Starting in 2005, as production parts and spares were delivered in sufficient quantity to complete the remaining Space Shuttle mission manifest, prime contractors began to complete planned supplier contracts and discontinued placing orders with vendors.

The table below details the capabilities discontinued within the projects of the Space Shuttle Program (SSP), including the Reusable Solid Rocket Motor (RSRM), Orbiter, Launch and Landing, and Space Shuttle Main Engine (SSME) projects. Acronyms and abbreviations are defined below the table.

Table.—Discontinued Shuttle Program Capabilities

Project	Capability title	Decision summary	Release date	Contractor name
RSRM	Fabricate steel forgings	Vendor not needed to produce case hardware due to sufficient inventory.	10/31/05	Ladish Company
RSRM	Heat treat large metal components	Vendor has shut down at their own request.	2/1/06	Bodycote
Orbiter	Production/Repair/FATT&E of Fuel Cells	Turn off production, but maintain capability to repair, and perform Failure Analyses and Test, Tear-Down and Evaluation of Fuel Cells at Original Equipment Manufacturer—UTC Fuel Cells.	5/24/06	UTC Fuel Cells.
Orbiter	Production of TPS FRSI and Thermal Materials	Last planned purchase for SSP completed in 2006.	9/30/06	Albany International

Table.—Discontinued Shuttle Program Capabilities—Continued

Project	Capability title	Decision summary	Release date	Contractor name
Orbiter	Production of D&C Switches and Vertical Scale Meters	The Orbiter Project Office and the Space Shuttle Program are planning on not placing any production orders or skills retention contracts with ARC—Applied Resources Corp. because delivery of the VSM hardware will provide the Program with sufficient spares to support through 2010. The contract will close as part of normal business practices and will result in no cost to the Orbiter Project Office or Space Shuttle Program.	9/30/06	Applied Resources Corp.
Orbiter	Production/Repair/FATT&E of GN&C Star Trackers	Turn off Production, but maintain capability to repair and perform Failure Analyses and Test, Tear-Down and Evaluation of Star Trackers at Ball Aerospace, the original equipment manufacturer.	9/30/06	Ball Aerospace
Orbiter	Repair/FATT&E of C&T S-Band Preamplifier	Orbiter Phase-out Panel—February 5, 2006. The NASA Shuttle Logistics Depot will take over from EDO Corporation to perform Failure Analyses and Test, Tear-Down and Evaluation of the Space Shuttle Communication & Tracking S-Band communication system. There are no anticipated workforce, environmental, or historic preservation impacts associated with the closeout of this work at EDO. Once EDO decommissions the area dedicated to SSP, they will utilize it for other business.	9/30/06	EDO Corp (AIL).
Orbiter	Repair/FATT&E ELCSS Components	Discontinue capability to manufacture new portable life support capabilities for current generation EVA suits while maintaining capability to repair and perform Failure Analyses and Test, Tear-Down and Evaluation of Environment Control & Life Support Components at Hamilton Sundstrand, the original equipment manufacturer.	9/30/06	Hamilton Sundstrand
Orbiter	Production of Display & Control Flood Lights	Discontinue contract with Vendor.	9/30/06	Perkin Elmer Optoelectronics
Orbiter	Repair/FATT&E of MADS Recorder	Closeout of Sypris scheduled for March 31, 2007. There are no potential impacts associated with the closeout of the capability at Sypris.	9/30/06	Sypris Data Systems, Inc.
Orbiter	Production/Repair/FATT&E of Auxiliary Power Unit Gas Generators	Production of Auxiliary Power Unit (APU) Gas Generators by Hamilton Sundstrand supplier Aerojet is phased out. The capability to repair and perform Failure Analyses and Test, Tear-Down and Evaluation of, those units at Aerojet or Hamilton Sundstrand is maintained.	10/1/06	Hamilton Sundstrand Corp.

Table.—Discontinued Shuttle Program Capabilities—Continued

Project	Capability title	Decision summary	Release date	Contractor name
Launch & Landing	Launch Control Center Firing Room 1	Transfer Firing Room 1 following successful Shuttle launch from Firing Room 4. Firing Room 1 is no longer usable by Shuttle, and Shuttle equipment to be removed for spares and excess. Firing Room 1 then turned over to Constellation for facility demolition and modification.	1/2/07	NASA Kennedy Space Center (U.S. Govt.)
SSME	Stennis Space Center Assembly & Delivery A–1 Test Support	SSME ended testing on A–1 test stand in October 2006. Test stand operations transitioned to Constellation Program on Nov 9, 2006. • Excess assets have been identified for SSME. • SSME testing on A–2 will continue until the end of the Space Shuttle Program.	2/28/07	NASA Stennis Space Center (U.S. Govt.)
Orbiter	Repair/FATT&E of Data Processing System Data Bus Isolation Amplifier and Multiplexer Interface Adapter	BAE made a decision to stop supporting the SSP. They have requested disposition of the Bond Room (*i.e.,* flight hardware and associated piece-parts) and Special Test Equipment (STE) located at their facility. There are no other known users of this hardware.	8/14/07	BAE Systems Aerospace, Inc.

Acronyms and Abbreviations:

APU	Auxillary Power Unit
C&T	Communication and Tracking
D&C	Display and Control
DPS	Data Processing System
ECLSS	Environmental Control and Life Support System
EDO	[Not an acronym; Name of Corporation]
FATT&E	Failure Analysis, Test, Tear-Down and Evaluation
FRSI	Felt Reusable Surface Insulation
GN&C	Guidance, Navigation, and Control
MADS	Modular Auxiliary Data System
NSLD	NASA Shuttle Logistics Depot
OEM	Original Equipment Manufacturer
TPS	Thermal Protection System
VSM	Vertical Scale Meters

From prime-contractor-supplied data, NASA estimates that the number of active Space Shuttle flight hardware suppliers was reduced by prime contractors from approximately 1,500 at the end of FY 2004 to approximately 1,200 in FY 2007. Space Shuttle prime contractors base subcontractor, supplier, and vendor release dates on analysis of requirements to support Space Shuttle production, sustaining engineering, readiness for failure analysis, ground and mission operations skill requirements, and services. NASA tracks the phase-out of suppliers and vendors by the prime contractors as part of the Space Shuttle Transition and Retirement Strategic Capabilities Assessment and the Space Shuttle Critical and Single Source Supplier Logistics Assessment.

Question 10. Please provide for the record details regarding your plans—and anticipated costs—for implementing disposition of Shuttle-related hardware, facilities, tooling, etc., as you terminate the Space Shuttle Program.

Answer. NASA's Human Space Flight Transition Plan (November 2006) and the Space Shuttle Program Transition Management Plan (March 2007) outline plans for the disposition of Shuttle related hardware, facilities and tooling. These plans are consistent with Space Shuttle project plans for the retirement of each major element's equipment and facilities. NASA established a Space Shuttle Transition and Retirement Strategic Capabilities Assessment (SCA), which schedules the retirement or transfer of each Space Shuttle technical capability. Each capability is a

bounded function performed for the Space Shuttle Program in order to accomplish its mission execution requirements. A functional capability is comprised of government and contractor workforce, facilities/equipment, suppliers, and contracts that together perform a high-level function (*e.g.,* Orbiter processing). Management key decision dates, Space Shuttle Program "last need" dates, and Space Shuttle Program release dates have been established for each capability. As each capability reaches the Management Key Decision Date milestone, a detailed plan, including disposition of Shuttle-related equipment, facilities and tooling, is confirmed.

Space Shuttle Transition and Retirement costs for activities which need to be conducted prior to the end of FY 2010 are included within the Space Shuttle Program budget. NASA has not yet budgeted for Shuttle retirement costs beyond FY 2010, since trade studies are still being conducted to choose the most efficient and cost effective methods to disposition the large quantity of equipment and facilities—either by transfer to Constellation or through disposal. In generating cost estimates for Shuttle retirement, NASA found that the total cost is very sensitive to the assumed final destination and user of the equipment (*e.g.,* Constellation Program, General Services Administration sale, museum display, scrap) and what needs to be done to prepare the equipment (*e.g.,* nothing, decontamination, bulk storage, destruction). NASA facilities usage costs are driven both by the timing of Constellation needs and by the time required to prepare and excess Shuttle equipment for final disposition. In studying the cost of Shuttle retirement since FY 2004, NASA has found that as the Agency acquires more detailed information and conducts more detailed trade studies on disposition plans, the projected cost for disposition action required in FY 2011 and beyond continues to decrease. For example, as more detailed data on equipment condition and characteristics are researched, the quantity of equipment requiring expensive decontamination or demilitarization has been reduced. NASA anticipates that the costs to finish Space Shuttle retirement will be proposed as part of the FY 2010 President's budget request.

Question 11. As you know from our previous discussions, I am concerned about the impact of the Shuttle termination on our current Shuttle work-force. You have generated plans for carrying out that transition and doing what you can to mitigate that impact. Is there anything this subcommittee or the Congress can do to make that task easier?

Answer. Congress and the Subcommittee can help make the transition successful by continuing to support the U.S. Space Exploration policy as stated in the NASA Authorization Act of 2005 (P.L. 109–155), and providing full funding of the annual NASA budget requests (which enable Constellation development to proceed on schedule). It is important to maintain support for the Lunar Capability elements of Constellation, such as the Ares V Cargo Launch Vehicle, as these elements will utilize many of the personnel, facilities, and infrastructure made available immediately after the last Shuttle mission in 2010. In the future, NASA may identify specific authorities which could reduce costs to dispose of Shuttle equipment and facilities no longer needed after 2010 and not required for Constellation. Minimizing those costs will help the Agency avoid diverting funds from Constellation development and help minimize the gap between the last Shuttle mission and the Initial Operational Capability of the Orion Crew Exploration Vehicle.

Question 11a. Do you need any new authority for workforce-related actions?

Answer. In 2007, NASA identified potentially beneficial workforce authorities related to the civil service employees, including conversion incentives to go from permanent to temporary employment, and extended time health benefits coverage after leaving employment.

Question 11b. How confident are you that the plans in place will make the best possible use of our skilled and talented workforce?

Answer. NASA has high confidence that current plans will make best use of the skilled workforce, but it is important to note that any reduction to requested annual appropriations constrains Constellation's development, stretching out schedules and increasing the gap between Shuttle and Orion. The longer the gap, the more difficult it becomes to retain our needed workforce, as skilled and dedicated workers may leave for near-term work in other fields. NASA buys products and services from industry, and does not determine contractor workforce levels, and it is industry's responsibility to train, retain, and motivate workforce within the constraints of funding to deliver the agreed to products and services.

Question 11c. What analysis has NASA done to understand the cost of the spaceflight gap, in terms of loss of workforce and skills, and how those operational kinds of skills are re-gained once development activity is completed on the new launch systems and activity returns to a focus on operations? Is the potential cost of that workforce evolution built into the current budget request, or are there plans

to do so in future requests, especially in terms of the training and the skills development that will be needed?

Answer. NASA is conducting a Shuttle Workforce Mapping Study to understand how skilled workforce will move or change as the Shuttle Program ends and Constellation Program progresses through development and on into operations. In November 2007, NASA completed the first phase of the study, which focused on the detailed skills and staffing plans for the Agency's civil service workforce. NASA is continuing the second phase of the study, which examines the top-level skills of the human spaceflight industrial supply base, including ground processing and mission operations. This second phase will be completed during the summer of 2008, and will inform future contract acquisition plans. NASA has made a substantial investment in training an industrial human spaceflight workforce with unique skills, and the Agency believes that this highly skilled, experienced, and dedicated human spaceflight workforce will be employed by successful bidders for future Constellation development work. The specific geographic distribution and quantity of each type of work continues to be determined as NASA competes and selects contractors to design and develop Constellation. As Constellation contractors further define their vehicles through successful design reviews, suppliers and vendors will be selected.

By providing current Shuttle contractors assignments related to Constellation, NASA is already providing the tools, training, and opportunities for workers to gain experience and skills on new processes that will be implemented for Orion/Ares. Some of these new processes are being utilized in Shuttle processing to provide experience that the workforce will need for Constellation. This hands-on experience will qualify employees for future work. Examples of cross-training opportunities include:

- The United Space Alliance Shuttle Program Operations Contract workforce is being used by Constellation to process the Ares I–X vehicle for its first test flight in April 2009. The first flight of Ares will be conducted by the Space Shuttle workforce.
- On STS–118, a single Solid Rocket Booster was stacked 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, *Endeavor* was powered up in the KSC Operations and Checkout building using a new "paperless" process as a test of future procedures for the Orion spacecraft. The Shuttle workers gained a new tool for the remaining Space Shuttle missions, and were able to preview and critique a new procedure planned for Constellation.

NASA has not specifically built funding for the potential costs of workforce retraining into Constellation budgets, because Constellation projects negotiate the value of work with successful prime contractors based on a company's specific proposal. By conducting Constellation contract competitions according to the NASA Human Space Flight Integrated Acquisition Roadmap schedule, NASA is identifying which companies will perform Constellation development work even as the Agency continues to fly the remaining Space Shuttle missions. This allows proposing companies to recruit from the existing human spaceflight workforce, and it enables workers to see—prior to the last Shuttle mission—which companies will conduct which work, so they can plan their careers accordingly. Constellation will hold budget reserves which will be allocated to address technical problems during development; reserves may also be used to address extraordinary issues related to retraining, but that application is not anticipated.

Question 12. We hear complaints that NASA's programs and budget have become unbalanced in recent years, with inadequate attention and resources placed on areas such as Space Science, Earth Science, Aeronautics Research, Life and Microgravity Science, and so on. I noted in your statement you used the term "balanced" four different times in the first three paragraphs. You are obviously wanting to make a point. Can you give us a quick thumbnail view of how to respond to claims of imbalance in NASA's overall programs?

Answer. The NASA budget request reflects the priorities and goals contained in the President's civil space exploration and aeronautics research policies, and it is also consistent with NASA Authorization Act of 2005 that put those goals into public law. The NASA budget request is 'balanced' with respect to Agency's direction and guidance from the White House and Congress. Additionally, when compared to historical data, the percentage of NASA funds for human spaceflight is the same (~62 percent) as it was during the years of Apollo. Therefore, the NASA FY 2009 budget request is also "balanced" with respect to historical NASA budgets.

Question 13. The NASA Authorization Act of 2005 underscored the importance of developing a National Aeronautics Research Policy to help guide decisions about the proper content of government-funded aeronautics research activities and the level of resources to be provided to them. Can you provide, for the record, a trace between the budget request for aeronautics research and the specific elements of the National Research Policy and the National Aeronautics Research Plan, both of which have been issued since the passage of the 2005 Act?

Answer.

The Alignment of the NASA Budget Request for Aeronautics Research with the National Research and Development (R&D) Policy

NASA's current budget request for aeronautics research implements NASA's overall aeronautics program under the Aeronautics Research Mission Directorate (ARMD) which NASA restructured in FY 2006 to focus on long-term, cutting-edge research in traditional aeronautics disciplines as well as in emerging fields with direct applications to aeronautics. Under the restructuring, ARMD established four programs: the Fundamental Aeronautics Program, the Aviation Safety Program, the Airspace Systems Program, and the Aeronautics Test Program. Although the restructuring was conducted before the completion of the National Aeronautics R&D Policy, NASA's aeronautics programs are strongly aligned with the principles of the policy because both took into consideration many of the same reports and studies that have been conducted over the past several years on the Nation's aeronautics enterprise. The primary examples are:

- The Fundamental Aeronautics Program directly addresses the first Policy's principle of "mobility through the air" by conducting research that can enable the development of advanced aircraft systems that fly with higher performance, lower fuel consumption, and minimum environmental impact (noise and emissions) at a range of speeds and from a wide variety of airports. The Airspace Systems Program directly addresses this principle by conducting air traffic management research that will develop concepts, capabilities, and technologies required to meet the Nation's anticipated growth in airspace operations, both in the air and on the ground.
- Both the Fundamental Aeronautics Program and the Aviation Safety Program addresses the Policy's second principle of "national security and homeland defense" by conducting "dual-use" research in a number of areas including advanced aircraft design, integrated propulsion concepts, multi-functional materials development, and advanced aviation safety technologies.
- The core mission of the Aviation Safety Program directly addresses the Policy's third principle that states that aviation safety is paramount.
- All of ARMD's programs directly address the Policy's fifth principle of developing a "world-class aeronautics workforce" by focusing on cutting-edge research, and by fostering intellectual partnerships with industry and academia by means of cooperative Space Act Agreements and fully and openly competed research awards that emphasize true collaborations among partners. In addition, ARMD currently funds graduate student scholarships and intends to expand its scholarship efforts to include scholarships for undergraduates. Both the undergraduate and graduate scholarships will include summer internship opportunities at NASA research centers.
- The Fundamental Aeronautics Program simultaneously addresses the Policy's sixth principle of "assuring energy availability and efficiency" and seventh principle of "protecting the environment" by conducting research to improve aircraft performance, increase fuel efficiency, lower emissions (including particulate matter) and reduce noise. In addition, the Airspace Systems Program also addresses these two principles by conducting research to improve efficiency and reduce environmental impact through better utilization of the airspace.

The Alignment of the NASA Budget Request for Aeronautics Research with the National Plan for Aeronautics Research and Development and Related Infrastructure

Airspace Systems Program

Research activities conducted in the Airspace Systems Program focus on mobility which is defined in the National Aeronautics R&D Plan, Chapter 2: "Mobility through the air is vital to economic stability, growth and security as a Nation."

From its inception, the Airspace Systems Program and its two projects (NextGen-Airspace and NextGen-Airportal) were planned using guidance from the Joint Planning and Development Office (JPDO) on the research and development that is re-

quired to achieve the Next Generation Air Transportation System (NextGen) vision. In 2007, NASA and the JPDO reviewed and agreed on the alignment of the NextGen-Airspace Project and NextGen-Airportal Project research with the JPDO R&D Plan and Integrated Work Plan. Both of these key JPDO documents were used in defining the roadmap for research for the National Aeronautics R&D Plan.

Chapter 2, focusing on mobility, identify five specific goals:

1. Develop reduced aircraft separation in trajectory- and performance-based operations.

2. Develop increased NAS capacity by managing NAS resources and air traffic flow contingencies.

3. Reduce the adverse impacts of weather on air traffic management decisions.

4. Maximize arrivals and departures at airports and in metroplex areas.

5. Develop expanded aircraft capabilities to take advantage of increased air transportation system performance.

The Program leads research activities for Goals 1, 2, and 4 with the collective research output of its two projects contributing to these goals. The NextGenAirspace Project explores and develops concepts, and integrated solutions providing research data to define and assess allocation of ground and air automation concepts and technologies necessary for the NextGen. Its fundamental research purpose is to address the demand/capacity imbalance problem in the NAS in the most safe, equitable, and efficient manner. The NextGen-Airportal Project investigates innovative new technologies, approaches, and procedures with the goal of enabling enhancements within the airport and terminal domains to meet NextGen capacity and efficiency goals.

The Program has a supporting role for Goal 3, and participates in the development of requirements for the integration of weather information into the ATM decision-making process. The Program also has a supporting role for Goal 5, and participates in the development of trade space metrics to understand realizable trades within noise, emissions and performance parameters for advanced aircraft that will operate in NextGen. One hundred percent of the Program and Project budgets are focused on these five goals.

Aviation Safety Program

Research activities conducted in the Aviation Safety Program focus on safety which is defined in the National Aeronautics R&D Plan, Chapter 4: "Aviation Safety is Paramount"

The Aviation Safety Program was originally formulated in 1998 to develop technologies in support of a National Goal to reduce the U.S. aviation fatal accident rate by 80 percent by 2007. Building on that benchmark, the current Program, in collaboration with the JPDO is now focused on developing technologies in support of NextGen safety needs. In 2007, NASA and the JPDO reviewed and agreed on the alignment of the Aviation Safety Program research with the JPDO R&D Plan and Integrated Work Plan. Both of these key JPDO documents were used in defining the roadmap for the research for the National Aeronautics R&D Plan.

Chapter 4, focusing on safety, identify three specific goals:

1. Develop technologies to reduce accidents and incidents through enhanced vehicle design, structure, and subsystems.

2. Develop technologies to reduce accidents and incidents through enhanced aerospace vehicle operations on the ground and in the air.

3. Demonstrate enhanced passenger and crew survivability in the event of an accident.

The Program leads research activities for Goals #1 and #2. In particular, three of the four Projects within the Program contribute to Goal #1: the Integrated Vehicle Health Management (IVHM) Project, the Aircraft Aging and Durability (AAD) Project, and the Integrated Resilient Aircraft Control (IRAC) Project. The IVHM project conducts research to advance the state of highly integrated and complex flight-critical health management technologies and systems. The AAD project develops advanced diagnostic and prognostic capabilities for detection and mitigation of aging-related hazards. The IRAC project conducts research to advance the state of aircraft flight control automation and autonomy in order to prevent loss of-control in flight. The fourth Project, the Integrated Intelligent Flight Deck (IIFD) Project, contributes to Goal #2. The IIFD project pursues flight deck related technologies that will ensure crew workload and situation awareness are both safely optimized and adapted to the future operational environment as envisioned by NextGen. A component of the IVHM Project which focuses on research for new data-mining tools and methods also contributes to Goal #2. Additionally, research within the AAD

Project relative to aging hazards for materials and structures can be applied to Goal #3. 100 percent of the Program and Project budgets are focused on these goals.

Fundamental Aeronautics Program

Research activities conducted in the Fundamental Aeronautics Program contribute to three of the principles outlined in the National Aeronautics R&D Policy:

1. Mobility through the air is vital to economic stability, growth, and security as a nation.
2. Aviation is vital to national security and homeland defense.
3. Assuring energy availability and efficiency is central to the growth of the aeronautics enterprise, and the environment must be protected while sustaining growth in air transportation.

The Fundamental Aeronautics Program is dedicated to the mastery and intellectual stewardship of the core competencies of aeronautics for the Nation across *all* flight regimes. The work in the Program directly benefits the public through the development of techniques and concepts for both subsonic (including rotorcraft) and supersonic vehicles that are cleaner, quieter, and more energy efficient. Research in revolutionary configurations, lighter and stiffer materials, improved propulsion systems, and advanced concepts for high lift and drag reduction all target the efficiency and environmental compatibility of future air vehicles. In addition, the Program conducts research in the hypersonic regime that, in addition to providing technologies for revolutionary, low-cost access to and from space, can be employed in systems used for national security and homeland defense.

More specifically, the National Plan for Aeronautics R&D and Related Infrastructure outlines in Chapter 2, focusing on mobility, five separate goals. The 5th goal—Develop expanded aircraft capabilities to take advantage of increased air transportation system performance—is directly addressed by the Fundamental Aeronautics Program in collaboration with the Airspace Systems Program. A variety of different air vehicles will be enabled by the research in the FA program within the Subsonic Fixed Wing (SFW), Subsonic Rotary Wing (SRW), and Supersonic (Sup) projects. More details can be found in the actual document.

Chapter 3 of the Plan focuses on national security and homeland defense. Of the 5 goals outlined in that Chapter, the Fundamental Aeronautics Program contributes concepts and technologies for four of them: Goal 1 (improved airframe aerodynamic efficiency) is mainly addressed by work in the SFW project; Goal 2 (improved rotorcraft) is directly addressed by the SRW project; Goal 3 (improved gas turbine engines) is addressed by a combination of SFW, SRW, and Sup, and Goal 5 (hypersonic flight) is the subject of the research conducted in the Hypersonics (Hyp) project.

Finally, Chapter 5 of the Plan focuses on energy availability and efficiency, and protecting the environment. While the SRW and Sup projects contain major elements in support of this goal, it is the SFW project that has the largest contribution to this goal. SFW is working on technologies to enable aggressive goals for performance improvements of future generations of fixed-wing vehicles starting with N+1 (the generation after the current one, represented by the Boeing 787), all the way to N+3 (two generations beyond that; expected to enter into service in the 2030–2035 period). The SFW project contributes to Goal 1 (new aviation fuels) and Goal 3 (advanced technologies for reduced environmental impact). In fact, the entire SFW project is organized around a balanced approach to achieving performance, noise, and emissions targets that will result in the possibility of growing the NextGen without increasing the resulting environmental impact.

Aeronautics Test Program

The Aeronautic Test Program (ATP) focuses on ensuring that NASA and the Nation have the right set of wind tunnel and flight test facilities in place and that these facilities are healthy and represent the capabilities that NASA and the Nation need to support the Nation's AeroSpace plans.

The ATP activities are in alignment with the goals of Chapter 6 of the National Plan for Aeronautics Research and Related Infrastructure, specifically Goal #1—"Determine the national RDT&E infrastructure that satisfies national aeronautics R&D goals and objectives" and Goal #2—"Establish a coordinated management approach for Federal RDT&E infrastructure that is based upon a national perspective and interagency cooperation."

ATP plans and activities are done in coordination with DOD through the National Partnership for Aeronautical Testing (NPAT) Council and with industry through the U.S. Industry Test Facilities Working Group. This close coordination ensures a national perspective is inherent in the definition and implementation of ATP plans.

Question 13a. Please provide a summary of the aeronautics research activities that have been reduced or eliminated from NASA's aeronautics research program in response to the National Research Policy and the National Aeronautics Research plan, the budget amounts associated with those activities.

Answer. At this time, no NASA Aeronautics research programs have been reduced or eliminated in response to last year's National Aeronautics R&D Policy or the recent National Aeronautics R&D Plan. The Policy does not contain the detailed information needed to make these types of decisions. The National Science and Technology Council's Aeronautics Science & Technology Subcommittee is currently writing an Appendix to the Plan which will include a preliminary assessment of current relevant Federal aeronautics R&D activities to identify areas of opportunity for potential increased emphasis, as well as potential areas of unnecessary redundancy. When completed, this Appendix can be used by NASA to assess its aeronautics research portfolio. The Appendix is scheduled to be completed by the end of December 2008.

Exploration

Question 14. Your statement suggests that "dithering and debating" over NASA's goals and methods are counterproductive, and I can understand that sentiment. However, projects supported by public funds—especially those that take years to implement—have to be continuously justified and rejustified in the context of changing national priorities. How do you strike the balance between remaining on course with a chosen strategy and ensuring that new information and even new alternatives to that strategy are fairly and fully considered—if for no other reason than to validate the strategy you have selected?

Answer. NASA's goals have been defined by Presidential policy and endorsed by Congress, and our strategy for achieving them has been crafted after careful consideration and thorough analysis. We are always open to new information, whether from within NASA or some independent external source; but it must indeed be new information. At the level of our architecture—our plan to use both the Ares I and Ares V—no new information has come to light that would suggest a change in our architecture is required.

A level below the architecture is the design level—decisions about what kinds of engines to use, or what kind of materials to use, or what specific outer shape should be used for the Orion. We have already had one major design change which led to great life cycle cost savings—our decision to use a five-segment booster and J–2X engine for both the Ares I and Ares V. As we progress through each design review and each milestone we are continually conducting design trades in an effort to learn as much as we can about the implications of our choices. If we learn something in the course of those trades that suggests making a change to improve performance or reduce costs, then we will look very carefully at that and perhaps make a change.

Question 15. The changes made in the planned configuration of the Ares launch system, namely the decision not to use the SSME and the movement to a five-segment 1st stage, appear to have moved that development away from the goal of maximizing use of current capabilities that was established in the 2005 NASA Authorization Act. Please provide for the record a summary of those and other changes made as the design concept has matured, and the degree to which those changes result in a lesser utilization of existing capabilities, as defined by the Act.

Answer. The ESAS recommended Crew Launch Vehicle (CLV) architecture, was derived from elements of the existing Space Shuttle system. It was a two-stage, series-burn configuration with the CEV positioned on the nose of the vehicle. Stage 1 was derived from the Reusable Solid Rocket Motor (RSRM) and was composed of four field-assembled segments. Stage 2 utilized LOX and Liquid Hydrogen (LH_2) using a single Space Shuttle Main Engine (SSME) derived engine modified for altitude start and expendability.

The Ares I architecture has changed from the original ESAS architecture to employ a 5-segment RSRM (a motor still of Shuttle heritage that will be supported with Shuttle infrastructure) and a lower cost J–2X upper stage engine instead of the SSME. There are not real impacts to utilization of existing capabilities in that ATK, the provider of Shuttle SRBs is the prime contractor for the Ares I first stage development. Additionally, Pratt & Whitney Rocketdyne, manufacturer of the SSME, was selected as the J–2X engine prime contractor.

Question 16. NASA has considered—and rejected—alternative approaches to Space Shuttle replacement vehicles which would have made more use of existing Space Shuttle infrastructure, workforce, etc., please provide a description of those alternative approaches and the basis for their dismissal as viable alternatives.

Answer. NASA evaluated many launch vehicle options that could be utilized for human space exploration missions. The principal factors considered were the desired

lift capacity, the comparative reliability, and the development and life-cycle costs of different approaches. Among these approaches, NASA considered existing vehicles, such as the EELV fleet, to meet crew and cargo transportation needs. The information below outlines why NASA decided to move forward with the Ares launch vehicles after careful consideration and study of other launch alternatives.

Developing NASA's Exploration Architecture

NASA is developing the Exploration architecture to safely and affordably transport humans and cargo beyond low-Earth orbit (LEO). This multi-purpose architecture is not simply a "ferry to the International Space Station (ISS)," or a "Shuttle replacement." Instead, by utilizing tested human space elements, it includes the Heavy Lift Launch Vehicle (HLLV) to deliver up to 70–75 metric ton (mT) of cargo to Trans Lunar Injection (compared to the Apollo/Saturn capability of approximately 47 mT).

NASA studied hundreds of commercial, government and concept launch vehicle and architecture systems prior to 2005, culminating in the release of the Exploration Systems Architecture Study (ESAS). NASA studied Space Shuttle-derived, EELVderived as well as "clean sheet" launch vehicle architectures in cooperation with the U.S. launch industry, and concluded that the Ares I and V system architecture provided the optimal solution for both LEO and beyond LEO applications. Figures of Merit (FOMs) used during the studies—cost, reliability, human safety, programmatic risk, mission performance and schedule—were applied to drive out the best alternative in the analysis. Additional considerations included legal requirements from the NASA Authorization Act of 2005 (P.L. 109–155), workforce skills and industrial capabilities. After a thorough analysis of the entire Exploration architecture requirements, EELV solutions were ultimately determined to be less safe, less reliable, and more costly than the Shuttle-derived solutions in development.

The ESAS concluded that NASA should adopt and pursue a Shuttle-derived architecture as the next-generation launch system for exploration missions due to their significant advantages, particularly with respect to safety, reliability, and cost. The extensive flight and test databases of currently flying hardware/software give a very strong technical and safety foundation with clearly defined and understood elements to anchor next-generation vehicles and minimize development costs and risks to flight crew. In addition, NASA's approach allows the Nation to leverage significant existing ground infrastructure investments (Kennedy Space Center (KSC); Michoud Assembly Facility (MAF), etc.) and personnel with significant human spaceflight experience. Overall, NASA's Shuttle-derived approach was found to be the most affordable, safe, and reliable approach, both by leveraging proven human rated vehicle and infrastructure elements and by using common elements across the architecture. While NASA continues to conduct trade studies aimed at refining the Ares V architecture for minimum development risks and operational costs, the Agency is committed to the fundamental Ares I–V approach established over 2 years ago.

The Ares *versus* the EELV

Vehicle Performance: The EELV crew transport options examined were those of the Delta IV and Atlas V families. The study focused on the heavy lift versions of both Delta (currently flying) and Atlas families (drawings only), and confirmed that none of the medium versions of either vehicle had the capability to accommodate the Orion Crew Exploration Vehicle lift requirements. The Medium class EELVs, with no additional solid boosters, significantly under performed by approximately 40–60 percent. The option of using small, strap-on solid boosters was eliminated for safety reasons in the Orbital Spaceplane Safety Study conducted in 2004. Both EELV-heavy vehicles were assessed to require significant modification for human rating, particularly in the areas of avionics, telemetry, structures, and engine selection. Additionally, both the Atlas and Delta Heavy classes required development of new upper stages to achieve the lift performance required to launch Orion. Ares I is designed to launch the 23.3 mT Orion vehicle, which consists of the crew and service modules, into LEO. The Ares can also launch a 20.3 mT Orion to the inclination of the ISS.

The ESAS assessment showed that lunar missions requiring more than three launches dramatically reduced the probability of mission success. Therefore, NASA issued an architecture goal to minimize complex on-orbit assembly, and also placed a limit to no more than three launches for a mission. For lunar missions, this equates to a launch vehicle design with a lift capability near 100 mT or greater to LEO. Early in the trade study process, NASA identified the current EELV fleet, if used for lunar cargo missions, would require more than seven launches per lunar mission. This very high number of flights per mission is unacceptable from a mis-

sion success probability standpoint and did not meet the NASA goal of three launches maximum.

While elements of current EELVs can be utilized to develop a 100 mT LEO equivalent launch vehicle (boosters, engines, etc.), the lack of acceptable EELV boost stage performance (compared to Shuttle-derived hardware) drives the need for an additional Liquid Oxygen (LOX)/Liquid Hydrogen (LH2) stage to reach orbit. The EELV-derived solutions required two upper stages as well as additional strap on core boosters to provide the necessary lift capability to minimize launches for on-orbit assembly. These characteristics were deemed to decrease mission safety and reliability while increasing costs to unacceptable levels based on NASA requirements. NASA did not pursue "clean sheet of paper" designs because it was deemed too risky and expensive.

Crew Safety/Reliability: The current EELVs were designed to carry unmanned payloads. Modifying the EELV design to meet the Human Rating Requirements would require changes in areas such as flight termination system changes to add a time delay for an abort scenario and inflight crew control/abort capabilities. The use of EELVs for crew transportation would also require NASA to invest significant funds into pad modifications required for crew access/emergency egress that currently does not exist at the EELV launch site. Based on ESAS assessments, the Shuttle-derived launch vehicle was highest-rated in terms of crew safety by about a factor of two over other options (Loss of Crew approximately $\frac{1}{2000}$). This confidence for crew safety is driven by the extensive history of the Shuttle system, which far surpasses the experience base for any other existing system. To add to the reliability of the system, the Ares I hardware is recovered and inspected for any system anomalies. In addition, Shuttle propulsion systems are already "human-rated" which mitigates one of the highest programmatic risks for a launch vehicle. Leveraging systems that are already human rated reduces the uncertainties and risks associated with human rating the new CLV. In addition, the current EELVs have a booster structural Factor of Safety (SF) of $\leq$1.25, where NASA requires that all structures have a 1.4 Factor of Safety (NASA Standard NASA–STD–5001). If the Agency were to accept the reduced SF of the EELVs, a large engineering and development effort would be required to validate structural integrity relative to NASA Standard and would likely eventually lead to some structural redesign of select systems. In addition, main propulsion systems would require modification, for example, the RL–10 upper stage engine would also require human rating in areas such as: redundancy upgrades; increased subsystem robustness; fault detection; isolation and recovery; engine redlines; safe in-flight shutdown mode; and, any design changes from structural assessments. For Atlas V, RD–180 American co-production and human rating would be required adding greater challenges. From a human rating perspective, the RD–180 will require additional redundancy and increased robustness in select systems. Finally, for Delta IV, several modifications would be required to human rate the RS–68 including extensive health monitoring, increased robustness of subsystems, and elimination of the fuel-rich environment at liftoff which would pose a crew hazard.

Life Cycle Costs: The Ares I and Ares V combination for lunar missions provides significantly lower non-recurring cost than that of the current EELV launch vehicle families. The Shuttle derived launch vehicle combination allows for a "1.5 launch" solution whereas the EELV architectures required two HLLV launches with more expensive hardware costs. It was determined that the total EELV-derived CLV plus EELV-derived Cargo Launch Vehicle (CaLV) Design, Development, Test, and Evaluation (DDTE) costs are approximately 25 percent higher for EELV-derived *versus* selected Shuttle-derived architecture.

The launch cost for human rated, EELV-derived systems is significantly higher than the current cost of a medium-class EELV. This launch cost also does not include the non-recurring development investment required to meet the Orion's lift requirements and human rate these systems, which has been estimated to cost in the several billions of dollars. In order for the unmanned payload customers to not incur the unnecessary additional costs for human-rated systems on the EELV, the EELV providers would likely need a unique human-rated variant which would increase the costs.

NASA continued to refine its launch recommendations post-ESAS. In early 2006, NASA modified the architecture from a four-segment Reusable SRB (RSRB)/single Space Shuttle Main Engine (SSME) upper stage CLV, and a five-segment RSRB/Expendable SSME Core/J–2X Earth Departure System (EDS) CaLV to a five-segment RSRB/single J–2X upper stage CLV, and five-segment RSRB/RS–68 Core/J–2X EDS. After careful analysis, NASA elected to forgo the modification of the SSME for altitude-start and proceed directly to development of a common J–2X engine for both the Ares I upper stage and the Ares V Earth departure stage, which sends the

Orion crew capsule/lunar lander combination to the Moon. This new approach eliminates a top ESAS-identified risk—SSME altitude start—and addresses another risk—J–2X development—sooner thereby lowering overall Exploration risks and costs. In addition, the inordinate expense of using five SSMEs with each cargo launch made the selection relatively simple (and much less costly), utilizing the expendable RS–68 engine with the added advantage of using a common engine to meet both Department of Defense and NASA needs. With this approach, engine development for the Ares I provides a significant and direct "down payment" on the Ares V test and development plan. Selecting common hardware not only maximizes nonrecurring investments and reduces overall lifecycle cost; it also gets NASA closer to enabling a lunar transportation system. Concentrating efforts on two major propulsion developments rather than on five, as was originally proposed, will reduce development costs by hundreds of millions of dollars and save billions in operations costs. These combined changes represented a projected savings of over $5 billion in life cycle costs over the initial ESAS recommendations.

Infrastructure and Capability Retention: While NASA will continue to use existing U.S. expendable launch vehicles for the robotic exploration missions (five to eight launches per year), the Ares V system leverages heritage human-rated systems such as the Shuttle Solid Rocket Motor; the Solid Rocket Booster, as well as heritage infrastructure, including the MAF in Louisiana; and the Vertical Assembly Building and crawler and launch complex 39 at KSC in Florida. To sustain the manufacturing infrastructure capability required for the Ares V between Shuttle retirement and the first human lunar launch, NASA's Exploration architecture (Shuttle derived Ares I) ensured America's industrial base for production of large solid rocket systems, high-performance liquid engine systems, large lightweight stages, large-scale launch processing infrastructure, and the current production level of solid propellant fuels is available to support the Ares V. If NASA selected the EELV-based CLV options, this would have required a significant amount of "keep alive" costs to maintain the industry and Center infrastructure and skills assets for eventual use on Ares V development.

External Reviews: Several external reviews have been conducted with regard to NASA's launch vehicle selection. NASA's conclusions regarding the Space Shuttle-derived Ares I and V vehicles have received agreement by the Department of Defense (DOD) and elements of NASA's plan were validated by Congressional Budget Office (CBO) and Government Accountability Office (GAO) reports. In 2005, the DoD reviewed NASA's analysis and concurred with NASA's approach. A joint recommendation was formally submitted in a memorandum to the Director of the Office of Science and Technology Policy, Dr. John Marburger III, in August 2005.

In October 2006, CBO concluded a study on the NASA's selection of the Ares I and Ares V launch vehicles ("Alternatives for Future U.S. Space Launch Capabilities Report"). The CBO report contrasted CBO's analysis with the recent NASA ESAS report and resulting implementation approach and identified a number of observations, highlighting four main points:

1. fewer launches per exploration mission increases overall mission reliability;
2. NASA's Shuttle-derived launch vehicle approach is the most economical option when minimizing the number of launches;
3. since CBO cost results are consistent with NASA's ESAS conclusions, and since NASA also based its launch decisions on safety and reliability (not assessed by CBO), NASA's selection of a Shuttle-derived launch vehicle is further validated by the CBO study; and,
4. the CBO estimates for the NASA-selected launch vehicles are within NASA budget projections.

And the most recent report from the GAO in November 2007 ("Agency Has Taken Steps toward Making Sound Investment Decisions for Ares I but Still Faces Challenging Knowledge Gaps Report") noted that "NASA has taken steps toward making sound investment decisions for Ares I." The GAO report also noted that:

> "Furthermore, NASA's decision to include the J–2X engine and five-segment booster in the Ares I design in order to reduce long-term operations and support cost is in line with the practices of leading commercial developers that give long-term savings priority over short-term gains. The Ares I project was also proactive in ensuring that the ongoing project was in compliance with NASA's new directives, which include elements of a knowledge-based approach. NASA's new acquisition directives require a series of key reviews and decision points between each life cycle phase of the Ares I project that serve as gates through which the project must pass before moving forward . . . We found that the Ares I project had implemented the use of key decision points and adopted the rec-

ommended entrance and exit criteria for the December 2006 Systems Requirements Review and the upcoming October 2007 Systems Definition Review."

Summary: NASA is designing transportation architecture, not just a point solution for access to LEO. In deciding on this architecture, NASA considered principal factors such as performance, reliability and development and life cycle costs when comparing alternatives. NASA also took into consideration the growth path to heavy lift capability which results from the choice of a particular launch vehicle family. To grow significantly beyond today's EELV family for lunar missions requires essentially a "clean sheet of paper" design, whereas the Ares V design makes extensive use of existing elements, or straightforward modifications of existing elements, which are also common to Ares I. The Shuttle-derived launch vehicle architecture selected by NASA meets all of the goals and objectives to achieve the exploration mission, while also:

- providing the best possibility of meeting stakeholder and customer requirements, including legal mandates, within the funding available and time-frame desired;
- providing the safest, most reliable and cost effective launch vehicle for NASA missions;
- maximizing leverage of existing, human rated systems and infrastructure;
- leveraging collaboration between the retiring Shuttle Program and emerging Constellation projects by sharing lessons learned and transitioning valuable resources, ranging from a specialized workforce to a unique launch infrastructure;
- creating the most straightforward growth path to later Exploration launch needs; and,
- ensuring the industrial base for production of large solid rocket systems, high performance liquid engine systems, large lightweight stages and critical, large scale launch processing infrastructure.

Question 17. Last year, the Congress enacted the America COMPETES Act, which included language directing that NASA shall be a full participant in interagency activities directed at improving our Nation's technological capabilities and competitiveness, and supporting efforts to improve Science, Technology, Engineering and Mathematics (STEM) disciplines in education. Can you discuss what you believe to be NASA's role in implementing this direction from the Congress?

Answer. The America COMPETES Act (P.L. 110–69) establishes NASA as a full participant in all interagency activities to promote competitiveness and innovation and to enhance science, technology, engineering and mathematics education. In addition to its importance to our Nation's economic and technological status, a highly educated and well-prepared workforce has been and continues to be particularly critical to the success of NASA's mission.

NASA's Education projects are inherently unique, and the Agency will continue to use its ability to inspire, engage, and educate students in new ways in support of the Act, which aims to keep America the most innovative nation in the world by strengthening our scientific education and research, improving our technological enterprise, attracting the world's best and brightest workers, and providing 21st century job training. As the education goals of America COMPETES so closely model that of NASA, the Agency's role is to continue to be a model of excellence in managing a portfolio of unique STEM engagement and education projects (including USRP) based on NASA content, while collaborating with other agencies, acting as lead Agency for the ISS National Laboratory, and reporting specific findings as directed.

NASA's Education Goals, upon which its portfolio is based, are the following:

- Strengthening NASA and the Nation's future workforce—NASA will identify and develop the critical skills and capabilities needed to ensure achievement of NASA's exploration mission. To help meet this demand, NASA will continue contributing to the development of the Nation's science, technology, engineering, and mathematics workforce of the future through a diverse portfolio of education initiatives that target America's students at all levels, especially those in traditionally under-served and underrepresented communities.
- Attracting and retaining students in STEM disciplines—To compete effectively for the minds, imaginations, and career ambitions of America's young people, NASA will focus on engaging and retaining students in STEM education programs to encourage their pursuit of educational disciplines critical to NASA's future engineering, scientific, and technical missions.

- Engaging Americans in NASA's mission—NASA will build strategic partnerships and linkages between STEM formal and informal education providers. Through hands-on interactive educational activities, NASA will engage students, educators, families, the general public, and all Agency stakeholders to increase Americans' science and technology literacy. These three goals complement one another. By engaging Americans in NASA's unique mission, the Agency can better attract and retain students in STEM disciplines, thereby strengthening NASA and the Nation's future workforce.

In cooperation with other Federal agencies, NASA will continue to coordinate education programs, sharing resources, and eliminating wasteful duplication of effort. NASA coordinates its Education Program through the Academic Competitiveness Council (ACC) and the National Science and Technology Committee's Education Subcommittee. NASA uses these forums to collaborate with other scientific and education agencies (*e.g.,* Department of Education, Department of Energy, and National Science Foundation), seeking ways to minimize redundancies and replicate effective practices and maximize collaboration in efforts to improve STEM education.

Additional Background

NASA's founding legislation, the Space Act of 1958, directs the Agency to expand human knowledge of Earth and space phenomena and to preserve the role of the United States as a leader in aeronautics, space science, and technology. High achievement in STEM education is essential to the accomplishment of NASA's mission. The Strategic Management of Human Capital initiative, under the President's Management Agenda, requires agencies to "build, sustain, and effectively deploy the skilled, knowledgeable, diverse, and high-performing workforce needed" to meet Agency core competencies. Our education investments will contribute to the Agency's human capital needs.

All of NASA's education efforts are part of an integrated Agency-wide approach to human capital management. Within the NASA Strategic Plan, education is identified as a cross-cutting function that supports all of the Agency's strategic goals and objectives. The NASA Strategic Management and Governance Handbook requires the Office of Education to submit a plan for Agency education implementation that provides guidance for the execution of programs and projects supporting those strategic goals and objectives. The input is submitted annually as part of the single Institutional Implementation Plan for the Agency.

Question 17a. Please provide for the record an accounting of NASA activities and projects which you believe address the objectives of the America COMPETES Act.

Answer. NASA is collecting data to be used in a comprehensive annual report containing education activities conducted; goals; and objective metrics for funding decisions including program/project description, amount spent on each program/project, and number of students or teachers served by each program/project that will be submitted January 2009 pursuant to section 2001(e) of the America COMPETES Act. The Office of Education is also making related preparations regarding the Assessment Plan which is due August 2008 pursuant to section 2001(f).

The information will be collected via many internal activities. NASA's Office of Education has established a comprehensive portfolio management process that ties all NASA Education projects to long-term and annual goals and has resulted in significant restructuring of the education portfolio. All budget requests are tied to annual and long-term goals. The NASA Education Coordinating Committee, composed of individuals representing all Agency organizations with a role in education, oversees the entire strategic planning process for the NASA Education, ensuring that NASA maintains a balanced and effective portfolio of education projects aligned with the official outcomes and objectives. In December 2007, NASA Education finalized baselines for its performance measures, and is currently establishing a single database and reporting system for all of its projects. The Office of Education continues to perform summative and formative evaluations of projects, and it is using the results of independent evaluations to restructure and improve individual projects.

- NASA is utilizing the existing Undergraduate Student Research Program (USRP) to support basic research projects on STEM subjects. The USRP is one of NASA's workforce development projects for undergraduate students. It will incorporate science, technology, engineering, and mathematics (STEM) activities of each of NASA's field centers and the Jet Propulsion Laboratory (JPL). Undergraduate students selected for this program will undertake research internships at NASA field centers under the tutelage of NASA scientists and engineers.
- NASA's document, "An Opportunity to Educate: ISS National Laboratory," presents a plan to validate the National Laboratory Education Concept Develop-

ment Task Force's strategy for using ISS resources and accommodations as a venue to engage, inspire, and educate students, teachers, and faculty in the areas of science, technology, engineering, and mathematics. On June 20, 2008, the plan for the National Laboratory was transmitted to Congress. Through the implementation of selected demonstration projects, NASA and the participating external organizations will learn lessons that will allow the ISS National Laboratory to be optimized for the full operation phase of the ISS.

- While not referred to specifically in the Act, NASA's Higher Education Program is a portfolio of activities and projects that invest in innovation through research and development to directly improve the competitiveness of the United States. The Program focuses on supporting institutions of higher education in strengthening their research capabilities and providing opportunities that attract and prepare increasing numbers of students for NASA-related STEM careers. The research conducted by the institutions will contribute to the research needs of NASA's Mission Directorates. The student projects, including USRP, serve as a major link in the student pipeline for addressing NASA's Human Capital Strategies and the President's Management Agenda. More information can be found at *http://www.nasa.gov/education.*
- The program/projects within the Higher Education Program that support NASA's Higher Education Outcomes and Objectives are: National Space Grant College and Fellowship Program (Space Grant); The Experimental Program To Stimulate Competitive Research (EPSCoR); USRP, Graduate Student Researchers Project (GSRP), and the Minority University Research and Education Program (MUREP) which is listed as a subset.
- GSRP cultivates research ties to the academic community to help meet the continuing needs of the Nation's aeronautics and space effort. This project seeks to increase the number of highly trained scientists and engineers in aeronautics and space-related disciplines and to broaden the base of students pursuing advanced degrees in science, mathematics, and engineering.
- Space Grant is a national network of colleges and universities that works to expand opportunities for Americans to understand and participate in NASA's aeronautics and space programs by supporting and enhancing science and engineering education, research, and public outreach programs.
- EPSCoR develops academic research enterprises that are long-term, self-sustaining, and nationally competitive by supporting states with modest research infrastructure to become more competitive in attracting research funding. Funding is awarded to lead academic institutions, fostering a STEM relationship with industries for research and development opportunities.
- A subset of the Higher Education Program, the Minority University Research and Education Program (MUREP) engages underrepresented populations through a wide variety of initiatives. Multiyear grants are awarded to assist minority institutions, faculty, and students in research pertinent to NASA missions. The program focuses on recruiting and retaining underrepresented and underserved students in STEM disciplines through completion of undergraduate or graduate degrees in support of their entry into the scientific and technical workforce. More information can be found at *http://www.nasa.gov/education.*

Question 17b. Include in the material the budget history for those activities from FY 2007 through the current budget runout to 2013.

Answer.

Undergraduate Student Research Project (USRP)						
FY 2007 Actual	FY 2008 Enacted	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
$2.3M	$4.0M	$4.1M	$4.0M	$4.0M	$4.0M	$4.0M
ISS National Laboratory*						
FY 2007 Actual	FY 2008 Enacted	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
$0.0M	$0.0M	TBD	TBD	TBD	TBD	TBD

*A budget has not been established for the ISS National Laboratory activity, as the project is in its formulation phase. Details regarding the contribution of funding across the Federal Government and management of the overall project have not yet been determined.

NASA Higher Education Program						
FY 2007 Actual	FY 2008 Enacted	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
$50.8M	$64.5M	$46.5M	$48.5M	$48.5M	$48.5M	$48.5M

NASA Minority University Research Education Program (MUREP)						
FY 2007 Actual	FY 2008 Enacted	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
$24.7M	$27.5M	$28.1M	$30.7M	$30.7M	$30.7M	$30.7M

Background

- The program/projects within the Higher Education Program that support NASA's Higher Education Outcomes and Objectives are: Space Grant; EPSCoR; USRP, GSRP, and MUREP which is listed as a subset.
- The NASA FY 2009 Budget Estimates document is the resource for the listed funding amounts for Higher Education Program and Minority University Research and Education Program. The Higher Education funding listed here includes the budgets of individual projects USRP, GSRP, as well as Space Grant and EPSCoR which are listed individually in the NASA FY 2009 Budget Estimates document.
- The FY 2008 Enacted Higher Education funding level includes $7M for Congressionally-mandated Global Climate Change Education which will address innovative opportunities for educating students on global climate change with a special component focusing on teacher education preparation (pre-service).

Question 17c. Please provide a separate summary of ISS-related activities that would appear to support the implementation of the objectives stated in the America COMPETES Act.

Answer. NASA's response document, "An Opportunity to Educate: ISS National Laboratory," presents a plan to validate the task force's strategy for using ISS resources and accommodations as a venue to engage, inspire, and educate students, teachers, and faculty in the areas of science, technology, engineering, and mathematics.

The document is being finalized for printing and submission to Congress in the coming weeks.

For the demonstration phase of the plan, eleven organizations submitted candidate demonstration projects which are varied and cover science, technology, and engineering. The candidate activities convey the possibilities inherent in the ISS National Laboratory concept.

Background:

In 2006, NASA asked a range of Federal agencies with responsibilities in education to participate in the ISS Education Coordination Working Group charged with developing a strategy for using the ISS as an educational asset. The initial report from the task force, delivered in December 2006, affirmed that there was a serious interest on the part of Federal agencies in use of the ISS.

ISS Education Coordination Working Group Members

PEIRCE HAMMOND
Department of Education
BERNICE ANDERSON
National Science Foundation
WANDA WARD
National Science Foundation
BILL VALDEZ
Department of Energy
JEFF DILKS
Department of Energy
ROBERT MCGAHERN
Department of Defense
TYSON TUCHSCHERER
Department of Defense
TOM TATE
U.S. Department of Agriculture
LINDELL WILLIAMS
U.S. Department of Agriculture
DAN BERCH
National Institutes of Health
BRUCE FUCHS
National Institutes of Health
SHELIA BAUER
Federal Aviation Administration

SANDRA L. BRUNER
U.S. Geological Survey

ROBERT RIDKY
U.S. Geological Survey

LOUISA KOCH
Nat'l Oceanic & Atmos. Admin.

BERNICE ALSTON
NASA Headquarters

MABEL MATTHEWS
NASA Headquarters

ANNGIENETTA R. JOHNSON
NASA Headquarters, Chair

BRION AU
EarthKam

FRANK BAUER
NASA Goddard Spaceflight Cntr

CHARLES BRODELL
NASA Goddard Spaceflight Cntr

BRADLEY CARPENTER
NASA Headquarters

BRENDA COLLINS
NASA Ames Research Center

ELIZABETH DIAL
Department of Defense

LYNN HARPER
NASA Ames Research Center

AL HOLT
NASA Johnson Space Center

P.W. JENNINGS
National Science Foundation

ROBERT KELSO
NASA Johnson Space Center

MICHAEL MARLAIRE
NASA Ames Research Center

CINDY MCARTHUR
NASA Johnson Space Center

DAWN MERCER
NASA Marshall Spaceflight Cntr

DOTTIE METCALF-LINDENBURGER
NASA Astronaut Educator

JONATHAN NEUBAUER
NASA Johnson Space Center

JULIE ROBINSON
NASA Johnson Space Center

CARLA ROSENBERG
NASA Headquarters

ISS Education Coordination Working Group Consultants

R. LYNN BONDURANT
Aerospace Educator

FRANCIS (SKIP) FENNEL
President National Council of Teachers of Mathematics and Professor of Education, McDaniel College

CHARLES HILL
Associate Director, Systems Integration Texas A&M University

KEN HUFF
Chair, National Science Teachers Association (NSTA) Aerospace Advisory Board

MIKE HYNES
National Council of Teachers of Mathematics (NCTM) Professor, Teaching and Learning Principles, University of Central Florida (UCF)

HARRIETT G. JENKINS
Retired Federal Executive-Consultant

RONNIE LOWENSTEIN
Lowenstein Associates

JAMES RUBILLIO
Executive Director, National Council of Teachers of Mathematics

KENDALL STARKWEATHER
Executive Director, International Technology Education Association

HAROLD STINGER
President and CEO, Stinger Ghaff arian Technologies (SGT)

LAUREEN SUMMERS
Program Manager, American Association for the Advancement of Science

BONNIE VANDORN
Executive Director, Association of Science-Technology Centers (ASTC)

GEORGE WHITESIDE
Executive Director, National Space Society

MICHAEL WISKERCHEN
Director, California Space Grant

Question 17d. Please provide details regarding interagency activities or discussions related to the President's America's Competitiveness Initiative (ACI) in which you or your designated representatives have participated, pursuant to the direction of the Act authorizing that participation.

Answer. On June 6, 2007, NASA Assistant Administrator for Education Dr. Joyce Winterton participated in the U.S. House of Representatives Committee on Science and Technology Subcommittee on Research and Science Education hearing, "Federal STEM Education Programs." The purpose of the hearing was to review the K–16 STEM education activities of Federal agencies and to explore current efforts for the improvement of interagency coordination and evaluation of programs. The witnesses provided Subcommittee Members with their suggestions for how those agencies could best contribute to STEM education nationwide and strongly recommended closely collaborating with educators in the field when developing programs.

The Office of Education also represents the Agency on the Interagency Aerospace Revitalization Task Force, a group of Federal agencies with a vital interest in strategic planning for STEM education to strengthen the science and technology workforce.

NASA is also leading the interagency ISS Education Coordination Working Group, with its concept plan "An Opportunity to Educate: ISS National Laboratory," being finalized for submission to Congress. The Working Group is also in early discussions with other interested agencies that are not formal participants.

Background

- In an effort to identify the contributions of Federal agencies to improving STEM education, the Academic Competitiveness Council (ACC) was created in the Deficit Reduction Act of 2005 (P.L. 109–171) and charged with creating an inventory of STEM education programs across Federal agencies, identifying the effectiveness of those programs, determining areas of overlap or duplication among programs, identifying target populations served by the programs, and recommending processes to integrate and coordinate those programs.
- The Aerospace Revitalization Task Force Act (P.L. 109–420) establishes the Interagency Aerospace Revitalization Task Force and directs the task force to develop a strategy for the Federal Government for aerospace workforce development. P.L. 109–420 also directs the Task Force to develop: (1) cooperation among Federal agencies to provide a skilled workforce; (2) integrated Federal policies to promote and monitor public and private sector education and training programs for science, engineering, technology, mathematics, and skilled trades; and, (3) partnerships with industry, organized labor, academia, and state and local governments for occupational information and for workforce education, training, and certification resources, including grants, loans, and scholarships.

ISS Research

Question 18. Subsequent to the announcement of the Vision for Exploration in January 2004, the Space Shuttle manifest then in place contemplated considerably more missions than were subsequently planned. How many missions were removed from the manifest scheduling and planning process that would otherwise have been scheduled if the 2010 Shuttle termination date had not been imposed?

Answer. Prior to announcement of the new U.S. Space Exploration Policy, there were 29 Space Shuttle missions remaining on the manifest. This included the STS–114 return-to-flight mission and the final servicing mission to the Hubble Space Telescope (HST). The STS–114 mission was conducted as planned, and the HST mission remains planned for later this year. Of the remaining 27 missions, 9 were canceled in order to complete ISS assembly by 2010, and 16 were left on the manifest, in addition to 2 logistics contingency flights that would be added to the manifest if they could be flown safely by September 2010.

Question 18a. Please identify how many of those missions would have flown in support of ISS assembly, outfitting, maintenance, logistics and utilization. Include all payloads initially intended for delivery to the ISS that were not included in the current manifest planning for the remaining Space Shuttle flights.

Answer. The nine canceled missions noted above would have flown in support of ISS assembly, outfitting, maintenance, logistics, and utilization. It is not practical to identify "all payloads initially intended for delivery" because this would range from major payload elements interfacing directly with the Space Shuttle cargo bay to literally thousands of secondary payloads being transported on ISS pressurized and un-pressurized logistics carriers and in Shuttle mid-deck lockers. However, the major elements and cargo categories that were de-manifested included:

- Centrifuge Accommodation Module (CAM);
- Alpha Magnetic Spectrometer (AMS);
- Russian Solar Power Module (SPM);
- Cupola (subsequently we were able to add it as part of Node 3);
- Originally Designed Express Pallets (un-pressurized carriers);
- Originally Designed External Stowage Platforms (un-pressurized platforms on the ISS);
- Un-pressurized logistics supplies, user payloads, and carriers; and,
- Pressurized logistics supplies, user payloads, and carriers.

Subsequently, new EXPRESS Logistics Carriers (ELCs) have been designed that will both transport un-pressurized logistics elements to ISS and serve as the on-orbit stowage platforms. This design was optimized for the cargo-to-carrier mass fraction in order to restore a limited capability for critical system spares.

Question 18b. Please also provide the rationale for non-inclusion, the process by which those decisions, where applicable, were presented and agreed to by our international partners, and what impact the non-availability of those payloads has on ISS research capabilities, directly or indirectly.

Answer. The rationale was to deliver, via the limited, remaining Shuttle flights, only those elements critical to the completion of the ISS in a sustainable configuration (*i.e.,* power/thermal truss elements, international laboratories, habitability systems to enable a six-crew capability for maintenance and utilization, and critical system spares and consumables). The process used to arrive at this solution was a review of the Shuttle/Station Configuration Options Team that performed the needed analyses during the May–June 2005 time-frame. We reviewed the new plans with our International Partners in a series of meetings. The partners were interested in seeing that we were developing a sustainable Space Station and not just flying their modules. Final consensus was reached that this overall transportation would result in a long term, viable ISS.

In the case of U.S. research payloads, the guideline was to focus research equipment capability on those objectives directly related to the Exploration mission. As a result, human biomedical research remained of paramount importance, while the remaining research was largely, although not exclusively, suspended or terminated. The impact of reducing the scope of previously planned NASA utilization of the ISS was to free up approximately half of the ISS utilization capacity for non-NASA uses. The ISS vehicle capability was not degraded; power/thermal resources, crew time, data management and communications, and availability of pressurized/unpressurized payload sites were not affected. This reduction has enabled the National Laboratory concept for ISS.

Question 18c. Also include a report on the status of de-manifested items, in terms of their readiness for flight, their continued viability and whether they could be flown, if deemed necessary, on alternative expendable launch vehicles, whether provided by U.S. vendors or foreign launch systems.

Answer. All de-manifested items were withdrawn from planning with two exceptions: the Alpha Magnetic Spectrometer (AMS) and the Cupola. Through subsequent analysis, NASA determined that the Agency could include the Cupola as part of Node 3. In the case of AMS, an extensive study of alternative launch capabilities was completed and provided to the Congress in February 2008.