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ISSUES FACING THE U.S. SPACE PROGRAM AFTER RETIREMENT OF THE SPACE SHUTTLE

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

FIRST SESSION

NOVEMBER 15, 2007

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CONTENTS

ISSUES FACING THE U.S. SPACE PROGRAM AFTER RETIREMENT OF THE SPACE SHUTTLE

THURSDAY, NOVEMBER 15, 2007

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 9:58 a.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. Well, good morning. Today, we're going to be discussing issues facing our Space Program and the question of the retirement of the Space Shuttle, the question of the new Constellation Program. We're going to be looking into the future.

We are very, very pleased to have Dr. Griffin, our Administrator, Mr. William Gerstenmaier, the Associate Administrator for Space Operations, and Dr. Richard Gilbrech, Associate Administrator for the Explorations Systems Mission Directorate. Welcome to you all.

I will submit a statement—opening statement for the record, and would invite Senator Hutchison to do the same.

[The prepared statement of Senator Nelson follows:]

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

Good morning and welcome to this hearing on NASA's plans for retiring the Space Shuttle and operating the International Space Station after 2010.

The President's *Vision for Space Exploration* and the NASA Authorization Act of 2005 lay out a plan for NASA to complete construction of the International Space Station before retiring the Space Shuttle and transitioning to our Nation's next generation launch vehicle. Today we examine NASA's plans for implementing these requirements and the implications for the International Space Station and the NASA workforce after the shuttle is retired.

I have three areas of concern regarding the transition that I would like to hear addressed today. First, I am concerned that NASA is improperly planning to retire the space shuttle on an arbitrary date in 2010, rather than completing the current manifest as required by both the President's Vision document and the authorization act.

Second, NASA's plan for cargo and human transportation to the ISS is woefully inadequate. NASA's baseline plan to purchase services from commercial providers is predicated on the wildly optimistic assumption that two small, start-up companies will successfully develop, launch, and test cargo- and human-rated rockets and space vehicles in the next 34 months. While I enthusiastically support the COTS program, it should only be an adjunct to a more reliable, proven approach. The cur-

rent plan B is to purchase additional launch services from the Russians. NASA should not assume that Congress will authorize additional expenditures to Russia. Nor will this senator support any plan that would allow Vladimir Putin to hold hostage a $60 billion U.S. national asset. NASA needs a better plan.

Third, to fulfill our oversight responsibility, this committee must understand the effects of the upcoming changes on NASA's workforce, both civil servants and contractors. All of the information we have received to date has been limited to generalities and platitudes. We need to see the numbers.

We are all aware that NASA is being asked to do much with too little. The President has not provided the funding necessary to implement his own *Vision for Space Exploration.* However, we must plan responsibly for the future, protecting and utilizing our current assets while developing new capabilities for the next generation of explorers.

Senator NELSON. And we'll put your opening statements in the record, as we previously discussed. And so, if it's with the pleasure of the witnesses, we'll just get into a discussion of this issue.

STATEMENT OF MICHAEL D. GRIFFIN, PH.D., ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, ACCOMPANIED BY WILLIAM H. GERSTENMAIER, ASSOCIATE ADMINISTRATOR FOR SPACE OPERATIONS, NASA; AND DR. RICHARD GILBRECH, ASSOCIATE ADMINISTRATOR, EXPLORATION SYSTEMS MISSION DIRECTORATE, NASA

Dr. GRIFFIN. Thank you, Senator. And entering—I'd be happy to enter my statement for the record and to defer making it at this time.

[The prepared statement of Dr. Griffin follows:]

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

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to appear today to discuss the various aspects of the Space Program after the Shuttle is retired, including the status of space transportation in support of the International Space Station (ISS). I would like to give you an update on our plans to ensure that space transportation capabilities remain available through the completion of ISS assembly and during the ISS post-assembly period after the Space Shuttle fleet has been retired in 2010. These capabilities are essential to successfully complete, operate and maintain the ISS, ensure productive utilization of this valuable national asset, and meet U.S. obligations to our international partners, including Canada, Europe, Japan, and Russia.

For the remainder of this decade, the Space Shuttle fleet will remain a highly capable and reliable system for assembling and servicing the ISS. The Shuttle, in concert with the consistent performance of our Russian partner's Soyuz and Progress vehicles, and the emerging cargo transfer vehicles from our European and Japanese partners, will ensure that the ISS will have adequate support for the remaining assembly period. The use of the Shuttle to deliver ISS components, essential spares and external stowage platforms is critical during this period.

Looking to the post-assembly period, NASA's next human spaceflight vehicle, the Orion Crew Exploration Vehicle, is on track to achieve Initial Operational Capability (IOC) in early 2015. The Constellation Program, of which Orion and its Ares I Crew Launch Vehicle are key components, has already made significant strides in the development and testing of system components.

The next decade, 2011 to 2020, will be an exciting period in the space transportation industry. There are many initiatives underway in both the public and private sectors to field new vehicles to serve the next generation of space exploration and development. It is important that NASA closely monitor the progress of individual development projects and actively manage risk so as not to jeopardize the viability of the ISS due to an inability to service it on a timely basis. Flexibility will be important to our success.

The capability to transfer crew to and from the ISS, and to ensure a safe and expedient return in the event of an emergency, is relatively limited in the near term. On the other hand, capabilities to transport cargo and crew should become more di-

verse in the next decade, and thus will involve detailed trades among cost, schedule, performance, and risk. NASA's policy is to employ U.S. commercial services for both cargo and crew exchange at the earliest available opportunity, while minimizing the technical risks of interrupting the U.S. crew presence on orbit, or having to leave the ISS in a state of disrepair because failed components cannot be replaced.

The Space Shuttle Legacy

The ISS was designed to employ the Space Shuttle fleet for assembly and ongoing servicing. With a capacity for launch and return of up to 16 metrics tons (Mt) of non-pressurized cargo and four Mt of pressurized cargo, the Space Shuttle's supply and return capability far exceeds that of all other domestic and foreign vehicles. In addition, the Space Shuttle provides ISS crew exchange, while also transporting the construction crew needed to conduct complex assembly operations in space. The Shuttle's robotic arm is essential to these tasks, as are the Shuttle-based capabilities for conducting extravehicular activities. When necessary, the Space Shuttle can be employed for ISS attitude control and re-boost. For these reasons, the ISS was designed to be assembled and maintained based on the Space Shuttle's capabilities. The transition from Shuttle-based space transportation to a mixed fleet of U.S. commercial spacecraft and international partner assets is challenging due to this design heritage, but NASA is committed to developing options to satisfy the requirements of the ISS after the retirement of the Shuttle.

Retirement of the Space Shuttle is on schedule for 2010 and critical to future Exploration plans. As we approach this date, we are hopeful that we can complete the ten remaining Space Station assembly flights, the servicing mission to the Hubble Space Telescope, and the two contingency Shuttle missions to the ISS within this timeframe. If it becomes clear that we will not complete the flight manifest by 2010, NASA will evaluate options and make adjustments consistent with not flying any flights beyond 2010. Continuing to fly the Shuttle beyond 2010 does not enhance U.S. human spaceflight capability, but rather delays the time until a new capability exists and increases the total life cycle cost to bring the new capability on line.

In the second half of 2006, NASA successfully completed three Space Shuttle missions which continued ISS assembly with the addition of the P3, P4, and P5 truss segments. In June 2007, ISS–13A (STS–117) added the S3 and S4 truss segments, boosting available power on the ISS to 63 kilowatts. All of these new systems continue to operate as designed, with the exception of the starboard solar array rotary joint. We need to determine the source of the contamination within this joint, but all of the rotational elements are replaceable and there is a high probability of repair. Analysis completed to date shows this problem will not impact the next assembly flight ISS–1E (STS–122).

The most recent mission, STS–120, landed safely at Kennedy Space Center on November 7, 2007, after having delivered the Node (Harmony) safely to the ISS. The Harmony will now be moved to its permanent location at the end of the U.S. laboratory. This activity will involve three spacewalks and two major robotic maneuvers. Harmony will be ready for ingress and final activation around November 24. Pending successful activation and relocation of Harmony, the Shuttle and ISS teams are set to complete four flights this year. This is remarkable considering that 2007 started with an external tank sustaining 2,000 hail damage hits and a three-month delay to flights.

The next ISS assembly flight 1E (STS–122) is scheduled to launch the European Columbus laboratory in early December 2007. With this flight, we will turn our attention to integrating the long-awaited elements of our international partners. It will be followed next year by deployment of the Japanese Kibo laboratory complex, and the Canadian Dextre, a special purpose dexterous manipulator for the ISS external robotics system. With the addition of these features, the ISS will emerge as a prominent example of the benefits of cooperation in science and technology for peaceful purposes. The ISS will house three premier research laboratories, one from the U.S., one from Europe, and one from Japan.

Future missions will enable us to increase the ISS permanent crew size from three to six and deliver critical system spares to the Station. A crew of more than three is needed if Space Station partners are to conduct a robust research program on board the ISS. Pre-positioning spares gives us the ability to ensure a prudent margin on systems performance, while allowing the U.S. commercial transportation capability to mature. This strategy was also one of the principal recommendations found in the February 2007 *Final Report of the ISS Independent Safety Task Force.*

The Space Shuttle will retire at the end of Fiscal Year 2010. After 2010, there is no mission requirement for the unique capabilities of the Space Shuttle. Flying the Space Shuttle past 2010 would carry significant risks, particularly to our efforts to build and purchase new transportation systems that are less complex, less expen-

sive to operate, and better suited to serving both ISS utilization and exploration missions to the Moon, Mars, and beyond. Already, Shuttle facilities are being closed or transferred to exploration, Shuttle contracts are being phased out, and Shuttle engineers are transitioning to exploration activities. If we were to take the costly step of reversing those changes to keep the Space Shuttle flying past 2010, at a cost of $2.5 billion to $4.0 billion per year, using the same facilities that Constellation needs to develop, test, and begin operating Ares I and Orion, we would only exacerbate the gap in U.S. human spaceflight and put at risk our Nation's preeminence in space exploration. NASA is committed to a transition and retirement process that is efficient, innovative, and that minimizes the gap in U.S. human spaceflight to the greatest extent possible. In support of this effort, we have modified the Space Program Operations Contract (SPOC) to create a strong bridge between Shuttle and Constellation operations.

Transition

NASA recognizes that the foundation of its success in conducting human spaceflight activities is the professional strength and dedication of its workforce. While the development of the Orion spacecraft and the Ares family of launchers will involve the integration of new technologies and procedures, many of the basic skills needed to create these are already resident at NASA's human spaceflight Centers. In an effort to maximize the benefit of the Agency's corporate knowledge and minimize potential disruption to the workforce from the transition from the Space Shuttle to Orion, NASA has placed emphasis on refocusing its human spaceflight workforce on activities supporting the Exploration program as Shuttle activities ramp down. We have also put in place a system which allows employees to have two charge codes, one for Constellation work and one for Shuttle and Station work. This gives the employees a chance to begin transition as they fly out Shuttle. Examples of NASA's efforts to retain Shuttle workforce for Constellation projects include:

- The Space Shuttle Program manages "Retention of Critical Skills" through the last Mission in 2010 as a "top program risk." The second Space Shuttle civil service employee survey closed July 13, 2007. As was the case with the 2006 employee survey, many employees wish to continue working on Space Shuttle until the end of the program, but they want to have more information about their specific job assignments after Shuttle has been retired. Results of the survey will assist NASA in crafting employee assignment and motivational strategies to best use our dedicated civil service workforce through the last Shuttle mission.
- NASA's Human Capital leads held a joint Government/Contractor Human Capital Forum in August 2007 to share best practices in communications. NASA is working with the Space Shuttle prime contractors on ways to optimize skilled employee retention. Since both government and contractor employees cite meaningful future Exploration work as a primary motivator to continue working on Shuttle, NASA can affect employee retention by competing and awarding the remaining Constellation contracts as that work is defined by the Government.

In addition to preserving the expertise of its work force, NASA is also committed to leveraging key facilities for the Orion and Ares projects, rather than letting them fall into disuse after the retirement of the Shuttle. To that end, we are examining our inventory of manufacturing, integration, assembly, and check-out facilities to determine whether they can be used to support the needs of the Exploration program; such facilities represent a significant investment by the taxpayer, and we will work to ensure that, where cost-effective, they are put to use effectively in the years ahead. Transition also provides with an opportunity to change and improve the way that we are operating. Some facilities no longer needed and with maintenance costs will be closed. Examples of NASA's efforts to turn over or retire Shuttle-related facilities include:

- The Space Shuttle Program has turned over the West Mobile Launch Platform Park Site at Kennedy Space Center to the Constellation Program. Echoing its use during Apollo and early Shuttle development, the Park Site will be used as a staging area for early construction and modifications at KSC as Constellation launch facilities are built up. At Stennis Space Center, the "A–1" Engine Test Stand turned over by the Space Shuttle Program in November of 2006 was outfitted with the first Power Pack Assembly for the Ares I Upper Stage J–2X liquid rocket engine and is soon to begin engine testing.
- NASA continues to retire Space Shuttle capabilities once they are no longer needed for the successful fly-out of the remaining Space Shuttle missions through 2010. NASA has begun removal of the Forward Reaction Control Sys-

tem (FRCS) rocket testing system at the White Sands Test Facility in New Mexico. At the Palmdale, California Boeing site, temporary building and tooling for the Space Shuttle have begun to be removed as part of a pilot project to assess the time and cost required to dispose of assets that are no longer required. Similarly, at the Michoud Assembly Facility in New Orleans, old Space Shuttle Orbiter tooling and spares no longer needed to meet the manifest are being excessed to clear out space needed for the Constellation Program's Ares I Upper Stage production.

Orion Crew Exploration Vehicle and Ares I Crew Launch Vehicle

NASA's Constellation program, which includes the Orion Crew Exploration Vehicle and the Ares I Crew Launch Vehicle projects, has made great strides this past year. The program has tested hardware, logged wind tunnel hours, conducted rocket firings, and hired contractors for almost all program elements. Constellation has an integrated schedule and is meeting its early milestones. The Ares I has passed its system design review and is on track for preliminary design review, with test flights slated for 2009. All major elements of Orion and Ares I will be under contract by the end of 2007, bringing the program closer to the IOC of Orion in March 2015 and full operating capability about 1 year later.

The Orion will translate the hopes and aspirations of explorers the world over into an operational system for the next generation in human space exploration. It is the first element in an evolving architecture that will one day carry people back to the Moon, on to Mars and beyond. The Orion will also have the capability to exchange crews on the ISS and serve as an emergency crew return vehicle. In this role, which it will serve if U.S. commercial services are unavailable, it will have a capacity for up to six crew members and a stay time on orbit of up to 210 days. Its associated command module will have a limited capacity for some pressurized dry cargo transfer.

International Space Station: Post-Assembly Transportation Requirements

Once ISS assembly is completed and the Space Shuttle fleet is retired in 2010, transportation requirements decline from the approximately 50–60 Mt per year associated with assembly to approximately 10–20 Mt per year needed to sustain the system and utilize the internal laboratories and external platforms. NASA is continuously evaluating these space transportation requirements to ensure that maximum operating efficiencies are gained and minimum maintenance and utilization needs are met. Cargo re-supply requirements fall into two broad categories: (1) items necessary to meet internal demands, such as consumable liquids and gases (*e.g.,* water, oxygen, and nitrogen), internal system spares, crew provisions, and internal scientific payloads; and, (2) items such as external system spares, ammonia tanks, and external scientific payloads.

NASA's analysis of post-assembly logistics demand and supply considers first the transportation assets available through the baseline ISS program. Initial analysis indicates that there remains a significant shortfall between the logistics demand to sustain and utilize the ISS and the logistics supply available through international agreements, contracts, and services owed. This shortfall corresponds to approximately 10 Mt per year after Space Shuttle retirement, or over 50 Mt through 2015. When one takes into consideration the packaging structure and carriers necessary to transport a net usable cargo of 50 Mt, the gross requirement approaches 80 Mt through 2015. Some options for addressing this challenge are detailed below.

In addition to cargo services, six crew members will permanently occupy the ISS in six-month rotations. Three of these crew members will be provided by Russia; the remaining three crew members will be from the U.S. and Canada, Europe, or Japan. The U.S. is obligated to provide bi-annual crew exchange, as well as emergency crew return capability and habitation accommodations, for these three crew members. Once the Space Shuttle is retired, the Russian Soyuz will be the only vehicle available for crew exchange and rescue services until a U.S. commercial crew service, or Orion, is available. NASA has contracted with Roscosmos to provide Soyuz and limited cargo services through the end of FY 2011, as permitted under the Iran and Syria Nonproliferation Act (P.L. 106–178, as amended by P.L. 109–112). NASA is monitoring the progress of potential domestic commercial providers to develop cargo and crew transportation services to the International Space Station (ISS), and the Orion project is on track to reach its Initial Operational Capability in March 2015. The Administration is considering options to maintain a U.S. crew presence aboard the ISS. Purchasing cargo and crew transportation services domestically is NASA's preferred method to meet the needs of the ISS. Another option may be to seek relief from the provisions the Iran and Syria Nonproliferation Act for additional Soyuz services to keep a U.S. crew presence on the ISS until either domestic commercial

crew transportation services, or Orion, become available. We will keep the Congress fully informed of our plans.

U.S. Commercial Orbital Transportation Services (COTS)

U. S. space policy directs pursuit of commercial opportunities for providing transportation and other services to low Earth orbit and beyond. Successful COTS partners may open new space markets and provide reliable, cost effective cargo and crew transportation services, ushering in a new era for commercial space. NASA is investing $500 million to stimulate the commercial space industry and to facilitate U.S. industry demonstration of commercial space transportation capabilities under Phase 1 of the COTS project. NASA plans to utilize the commercial space industry to re-supply the ISS after retirement of the Space Shuttle in 2010.

The COTS launch providers are not developing systems to be operated by the government or its contractors, but are demonstrating a capability that NASA and others can later purchase as a commercial service. Since these companies are developing vehicles that they intend to use commercially for other customers in addition to NASA, they are assuming a significant portion of the financial and programmatic risk.

As part of Phase 1 of the COTS project, the Agency signed two funded Space Act Agreements (SAAs) with emerging commercial launch providers or "partners" to facilitate the development and demonstration of the vehicles, systems, and operations needed to resupply, return cargo from, and transport crew to and from a human space facility, with the ISS providing the representative requirements for such a facility. Performance milestones culminate in a flight demonstration in which the partner's vehicle will launch, rendezvous and dock with ISS, and return safely to the Earth's surface. The partners are only paid a pre-negotiated, fixed amount if they successfully complete a milestone. If they do not complete the milestone to NASA's satisfaction, they are not paid. These milestones are both technical (*e.g.,* a successful design review or hardware test) and financial (*e.g.,* raising a certain amount of private funding). NASA has also entered into multiple unfunded SAAs with various emerging commercial launch providers to provide support in the development of a low Earth orbit transportation capability.

NASA assists the COTS partners' efforts by providing a network of Agency technical experts across all discipline areas—known as the COTS Advisory Team. Extensive NASA technical and facility resources are also available to the commercial partners through reimbursable SAAs.

On October 18, 2007, NASA terminated one of the two funded SAAs because the commercial partner had failed to perform under the terms of the agreement. NASA remains committed to the COTS project and to stimulating a robust commercial space industry, as demonstrated by the release of a competitive announcement on October 22, 2007, seeking a new round of Phase 1 proposals. Industry proposals for this new competition are due to the Agency on November 21, 2007.

NASA's Space Operations Mission Directorate, in cooperation with NASA's Exploration Systems Mission Directorate, will oversee procurement of commercial cargo services to and from the ISS. The President's 2008 Budget included $1.9 billion over 5 years in the Space Operations Mission Directorate for crew and cargo services, the majority of which will be available for commercial services. We continue to analyze the exact amount of funding required in this area. A government procurement of commercial cargo services is planned. NASA released a Commercial Space Transportation Services Request for Information (RFI) on July 7, 2007. Issuance of a Request for Proposals (RFP) is currently expected in FY 2008.

Japanese H–DII Transfer Vehicle (HTV)

Japan's HTV is an expendable, automated cargo transfer vehicle designed to launch on the H–IIB expendable rocket and rendezvous with the ISS. It will include both pressurized and non-pressurized carriers, thus allowing delivery of rack-mounted equipment, water and gases, and non-pressurized system spares. The HTV has completed its critical design review and is scheduled for demonstration in the mid-2009 period. The cargo capacity will be approximately 5.5 Mt and the lead-time to production is estimated to be three to 4 years. Japanese plans currently call for a production capacity of one HTV per year. This rate corresponds to Japan's commitment to fly one HTV per year over the period 2009–2015.

A portion of the HTV cargo capacity is owed to the ISS program based on Japan's share of common system operations costs and prior barter arrangements. This cargo capacity is important since it has already been factored into the ISS baseline program for cargo supply. Approaches to acquiring further HTV cargo delivery services, particularly in the area of non-pressurized system spares, are under evaluation in the event that COTS cargo services are delayed. If system sparing becomes critical

to maintain the station and U.S. commercial cargo services are delayed, it would be prudent to have the flexibility to execute a sound contingency plan.

European Automated Transfer Vehicle (ATV)

Europe's ATV is an expendable, automated cargo transfer vehicle designed to launch on the Ariane V expendable rocket and rendezvous with the ISS. It will have capability to deliver dry cargo at the sub-rack level, and external tanks for water, gases, and propellant. The cargo capacity will be approximately six Mt and the lead-time to production is estimated to be about 3 years. The first ATV, *Jules Verne,* is currently in final integration at the Guiana Space Center, Kourou, French Guiana (South America) and is scheduled for launch to the ISS in the first quarter of calendar year 2008. European plans call for production of five ATVs, corresponding to their commitment to fly five vehicles to the ISS over the period 2008–2013.

A portion of the ATV cargo capacity is owed to the ISS program based on Europe's share of common system operations costs. This cargo capacity is also important and has been factored into the ISS baseline program for cargo supply. In addition, the ATV is capable of performing ISS re-boost and attitude control, and propellant can be transferred to the ISS tanks for use after the ATV has departed.

Russian Progress and Soyuz Vehicles

The expendable Russian Soyuz rocket has over 1,700 successful launches in the past 40 years. In the ISS Program to date, it has been used to launch 15 Soyuz crew transfer vehicles, each having a capacity for three crew, and 26 expendable, automated Progress cargo transfer vehicles. Both vehicles rendezvous with the ISS. In the future, the Russian segment is planned to expand to accommodate two Soyuz and two Progress (or a Progress and an ATV) vehicles to support six crew. The Progress has the capability to deliver dry cargo and tanks for water, gases and propellant. Its cargo capacity is approximately 2.5 Mt. The lead-time to produce a unit is estimated to be a little over 2 years for both Soyuz and Progress. Russian plans currently call for the production of two to four Soyuz crew vehicles per year and three to five Progress cargo vehicles per year for missions to the ISS through at least 2015.

The ISS program has purchased approximately six Mt of cargo capacity from Russia for use during the FY 2009–11 period in order to help bridge any time between the Shuttle retirement and U.S. commercial cargo transfer availability. These services are considered important and have been factored into the ISS baseline program for cargo supply. In addition, Soyuz services have been purchased through the end of FY 2011 to provide crew rotation and rescue before U.S. commercial crew transfer, or Orion, services become available. These services have also been factored into the baseline program for crew exchange.

Conclusion

NASA is making excellent progress toward completion of the ISS assembly phase. In the coming year, popular awareness will expand dramatically around the world as the laboratories of Europe, Japan, and later, Russia, begin operations alongside the U.S. laboratory. The performance of on-orbit systems, transportation systems, and the flight and ground crews has been outstanding. The teams have successfully dealt with many challenges and will no doubt continue to face challenges; operating continually in space is an extremely difficult endeavor, but despite the difficulties, the ISS has now been continuously crewed for more than 7 years. This remarkable level of achievement is possible only because individually, and collectively, we have learned how to actively manage risk with maturity and prudence.

The future of space transportation is uncertain in detail, but clear in direction. The next decade will offer more opportunities, and choices, than did the last decade. We must continue to examine these choices if we are to be prepared for the next phase in the ISS program. While we focus our sights on enabling discovery and a new economy in space, we must also develop our transportation plans to withstand the risk of short-term setbacks that are inevitable in the development of new technologies for new frontiers. We have done the planning, understand the options, and are prepared. We appreciate your continued support to maintain the flexibility needed in order to be successful.

Thank you for the opportunity to appear before you today. I would be pleased to respond to any questions that you may have.

Senator NELSON. As I understand it, in previous conversations with you and your colleagues, Dr. Griffin, you're stating that the policy of NASA now is to have a hard date of September 30, 2010, in which to shut off the Space Shuttle. What happens if you

haven't completed the remaining 13 flights on the manifest by that point?

Mr. GERSTENMAIER. I'll answer that for you.

Again, we've laid out a plan to get the Space Station assembly complete. And, in that plan, we have, essentially, ten more flights remaining for assembly, and then two contingency flights. And we've put two contingency flights in to ensure that we could get all the Space Station assembled by that date.

And we're making pretty good progress along that plan. It looks like we're going to probably need those two contingency flights to fly some additional spares up to help us with the gap, but that all works out fine, and that's all laid out as our current plan. If we start getting toward the end of September 30, 2010, and it looks like we're not going to be complete with assembly, as soon as we start detecting some problems along those lines, we would come to you and let you know what problems we're seeing and talk to you about other options to go ahead and do some things differently.

Ultimately, we might be able to remove some of those flights if things go the right way. But, again, at this point, we really need those flights, from a sparing standpoint. We need to have the Station in a good, assembled configuration, and we're on a good track to go do that.

So, again, I think we have a good working plan that gets us there to September 30, 2010, and we're prepared to react and change if we need to, if we see something come along the lines that make it different.

Dr. GRIFFIN. And I think our last flight is scheduled for April of 2010, at this point; so, at this point, we've got 5 months of schedule margin in the system. So, we think our plan is in good shape, sir.

Senator NELSON. Well, the whole purpose for this hearing is to try to explore all the different possibilities, the different contingencies. And you are looking at a flight rate of four flights per year. What makes you think that you can maintain that rate in 2009 and 2010, when, at that point, you only have two orbiters left?

Mr. GERSTENMAIER. Again, if we look at our historic flight rate, we're able to achieve that flight rate pretty regularly. And that includes even if we've had some downtime because of things like the hail damage, et cetera. And, if you look at this year, for example, the first part of the year we had the hail damage on the Shuttle, and we didn't fly until later in the spring, but it still appears that we're going to be on track to get four flights done this year. We're also looking at options to continue to fly *Atlantis,* OV–104, for some additional flights. And so, the current planning shows two Shuttle flights in those out years, but I think this spring we'll talk about that again, and we'll probably go ahead and continue to fly *Atlantis* for maybe two more flights, and we'll add that into the manifest. So, again, we're still continuing to evaluate, but, based on our past flight performance and our recent performance here, in the last year and this year, I think four flights per year and the remaining manifest is very achievable, and it doesn't put a lot of strain on the system to accomplish those flights. They won't be easy, but our teams are ready, we're prepared, and we're ready to execute.

Senator NELSON. So, what I'm hearing you saying is that you don't have an absolute hard cutoff date on September 30, 2010, in

what you have just stated to me. And I would remind you that when Senator Hutchison was the chairman of this subcommittee, and we passed, under her leadership, the NASA Authorization Act, and, in it, in the *Vision for Space Exploration,* there is no mention of a hard cut-off date there. So, am I correct? I'm hearing you say no hard cut-off date?

Dr. GRIFFIN. No, sir. We are—the President has directed that the Space Shuttle be retired by the end of 2010, and our budgetary planning does show that we will finish our last Space Station flight in Fiscal Year 2010, and we have, at this point, 5 months of margin to do that. I believe we have a very solid plan to get there, as Mr. Gerstenmaier was just outlining and as we're—we, you know, have discussed, and are happy to discuss, with your committee staff. So, I think our plan is very solid.

Senator NELSON. I want to challenge that. I want to challenge that, Dr. Griffin, because I'm reading from the President's *Vision for Space Exploration,* and it says, "Retire the Space Shuttle as soon as assembly of the International Space Station is completed, planned for the end of this decade." So, where do you see that the President has—"required" is the word that you used?

Dr. GRIFFIN. I stand corrected, sir.

Senator NELSON. All right. And I want to further refer to the NASA Authorization Act of 2005, it requires that the International Space Station, "be assembled and operated in a manner that fulfills international partner agreements as long as the Administrator determines that the Shuttle can safely enable the United States to do so." And the law also requires that, "the Administrator shall ensure that the ISS can have available, if needed, sufficient logistics and on-orbit capabilities to support any potential period during which the Space Shuttle or the follow-on crew and cargo systems are unavailable, and can have available, if needed, sufficient surge delivery capability or pre-positioning of spares and other supplies needed to accommodate any such hiatus."

So, it sounds to me that the legal authority backing you up is basically a statement of law that we are to complete the International Space Station and have the capability of the logistics and follow-on crew and cargo systems.

Dr. GRIFFIN. Yes, sir. And I have been unambiguous in my statements, in the past and again today, that we will finish the International Space Station. I'm simply saying that that is scheduled to be accomplished within Fiscal Year 2010, and we believe we have margin to do that. But, I—you and I share the goal of intending to finish the International Space Station.

Senator NELSON. I just want to say, you know I am your biggest fan, and you all just do terrific work, and another example is, in real time, what you did in this last mission with the tear in the solar panel, and how, at some risk, you go out there and, in fact, are able to repair it. But those kind of things, all of us know in this room, will happen, and I want us to get in the frame of mind that what we have is a $50 or $60 billion asset up there in space that has got to be tended to, and it's got to be built. You've got the hardware, and you're planned for it, and it may not come by September 30, 2010.

Dr. GRIFFIN. Sir, I understand. I do understand your point very well. If we are not able to finish by 2010, and if we were required to keep flying the Space Shuttle, that comes at a cost of $2.7 billion in ownership costs for the Shuttle each year, and that will delay our deployment of the follow-on systems, Orion and Ares. And, of course, with the fixed budget that we have, we are very reluctant to delay our future systems. So, we are trying, with all our might and with every good intention, to finish the construction of the Space Station by the end of Fiscal Year 2010.

Senator NELSON. We'll get into the budget a little later on.

What I did was just put the opening statements in the record. It's your pleasure, whatever you would like to do, and let me just turn it over to you, Kay.

STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

Senator HUTCHISON. Well, thank you.

I do think that our Committee has been—I don't want to say "blessed," because that would be too strong a word, but "fortunate" to have leadership in the last few years where the Chairman and the Ranking Member have been in lockstep, both when I was Chairman and now as Ranking Member, and along with Senator Nelson, because we are solidly committed to a strong NASA program, and we are committed to the Space Station being finished, and also the Crew Exploration Vehicle, as a matter of national security, to be online, we believe, without a gap. That's not exactly realistic right now, I understand that, but our goal is to close that gap.

I believe you, yourself, Dr. Griffin, said that you thought if China or any other country—India or Russia—gets humans back to the Moon, before America does, that Americans are going to say, "Why?" I would just add that I think if we are not able to go into space at all in a gap period because our relations with Russia, which is providing transportation now, is not such that we would be able to go up, that the American people are going to wake up and say, "What happened? What happened to the leadership of our country, to the leadership in Congress, and to the leadership in NASA, that we would be in a hiatus from being able to go into space at a time when other countries are emerging and doing it?" So, I think we have to prepare for that. I hope we don't wait for the crisis to happen, and I know that my colleague, the Chairman, agrees with me.

[The prepared statement of Senator Hutchinson follows:]

PREPARED STATEMENT OF HON. KAY BAILEY HUTCHISON, U.S. SENATOR FROM TEXAS

I join the Chairman in welcoming Dr. Griffin, along with Mr. Gerstenmaier and Mr. Gilbrech to this hearing today.

This is an extremely important hearing, on a subject which is becoming of increasing concern, not only to Chairman Nelson, myself, and this Subcommittee, but to other Members of Congress as well, who have voiced their concerns to me.

Two years ago, this Subcommittee introduced its NASA Authorization Bill, S. 1281, which subsequently was enacted into law. The first version of that legislation included language which *prohibited* a gap between the retirement of the space shuttle and the initial operation of its successor vehicles.

At the urgent request of NASA and the Administration, we modified that language to say that, *as a matter of national policy, there should be no gap,* but that

NASA should tell us, within a year of the last scheduled Shuttle mission, what kind of gap might be expected, what the impacts of that gap would be, and what options existed to address those impacts.

In hindsight, we probably should have written that language so that such a report would be provided two or even 3 years before the last scheduled flight, because the early steps necessary to make the transition from shuttle operations to the Ares launcher and the Orion Crew Exploration Vehicle are already being taken.

Our concern is that some of those steps may close off some of our possible options for dealing with the gap. That is why this hearing today is so important. We need to understand the full consequences of the early transition steps, in order to know whether they have the potential of limiting our available options to ensure our historical leadership in space exploration is not undermined.

During consideration of the Commerce, Justice, Science and Related Agencies bill, recently, I spoke about the possibility of another "Sputnik Moment" as other nations, like China, the Europeans, India, and others, make greater strides in developing and using human spaceflight capability—while the U.S. is facing a gap in our own ability.

I believe that both our national security and our economic well-being as a nation will be greatly damaged if we do not take steps to avoid another "Sputnik Moment."

You have said in a recent speech, Dr. Griffin, that if another nation should get humans back to the Moon before the U.S., that the American people would not like it, and wonder how we let that happen.

I agree, and I also believe that if we were to end up completing the assembly of the International Space Station, and then be unable to get to it, and use it, and get a return on our very large investment, that Americans would have the same reaction and ask the same questions.

I hope this hearing will enable us to have a clearer idea of what we will need to do, as a nation, to make sure they don't.

Senator HUTCHISON. So, let me ask you, as a follow-on to what you were just saying—you have said that, within the constraints of the budget, you can finish the Shuttle Program, in the 2010 Fiscal Year, that that will complete the Space Station. But you also have said that money taken for the Shuttle also takes away from the development of the Crew Exploration Vehicle. My question is this, what would it take—and I'm reading from estimates that you provided for us earlier this year—to accelerate the Ares launcher and the Orion vehicle, to shorten that gap? I believe you said—and you can correct me—that you would need an additional $2 billion between FY 08 and FY 2010 in order to accelerate the production. Either correct me or tell me if anything has changed in that number that would cause you to revise that, because, of course, you know that I, along with Senator Mikulski, tried to put $1 billion into this year's appropriation, which, at this point, does not appear likely to be successful in the conference committee, but it is because we were trying to accelerate the Crew Exploration Vehicle production. So, could you give us revised or current estimates of what it would cost to accelerate and what could we expect, for that money, the timetable to be for the acceleration?

Dr. GRIFFIN. Thank you, Senator.

I will open by saying I agree completely with the concerns you have expressed about the primacy of the United States in the world—and in its relation to our position in spaceflight. And, as you know, from the time of my swearing in as Administrator, the length of the gap between retirement of Shuttle and deployment of the Orion Crew Exploration Vehicle has been a primary concern of mine. And I've been very public about that.

When I came onboard, it would have been possible, given the necessary budgetary resources, to deploy—to retire the Shuttle at the end of 2010, and to deploy Orion in 2012. Time has passed, and

that is no longer possible. The earliest date that we could technically do it today would be September of 2013, we believe, absent crash measures. I'm talking about normal programmatics to deliver a sound vehicle with sound program management styles. We could do it in September of 2013.

I will defer, in a moment, to Dr. Gilbrech to give you the funding schedule that that requires. But you are correct, it is substantially more than is being allocated in the budget today. Budgetary resources which are allocated today support a delivery of March 2015 for the Orion Crew Exploration Vehicle.

Rick, if you could give them a funding schedule required to make the September 2013 date come true.

Dr. GILBRECH. Certainly. And I just also wanted to open that this is my first hearing, it's a new experience for me. I've been in the job 6 weeks, but I'm real excited about it. And I also wanted to state my—I guess, my thanks for the support of this committee and the members for the great things that we've seen from your support in NASA.

But, yes, the funding profile now, to bring us back to 2014, would be a $350 million infusion in FY09 and a $400 million infusion in FY 10. To accelerate that another year, to September 2013, would require a billion dollars in FY 2009 and a billion dollars in FY10. And that's about as far, technically, as we can take it, because of the technical challenges we have. Right now, the J–2X engine is the pacing item on our initial operating capability, so that really sets the line in the sand, as far as what we can technically achieve.

Senator HUTCHISON. So, really, under the very best of circumstances, the earliest that we could have the acceleration to 2013 would be with a billion dollars in next year's budget and a billion dollars in the following budget, in addition to the core NASA budget——

Dr. GRIFFIN. That's correct, Senator. Or else, obviously, an agreement not to do a billion dollars of other work elsewhere in NASA in order to do this.

Senator HUTCHISON.—well, I would say that we will look at next year's budget as an alternative as we are going through the budget process in the Appropriations Committee, and perhaps there might be a way that we could look at a billion-dollar infusion, but possibly some of that be offsets in other programs, if we could come to an agreement on that. And I don't know, because I haven't looked at next year's—I don't have next year's projections. But I would like to look at that, because it's a worthy goal. And if we can highlight for the American people the consequences of not going forward and the additional almost 2-year gap between September 2013 and March 2015 a year and a half—I think that it would be a priority that perhaps our President and the American people would think is a worthy goal. And I certainly intend to try to make that my goal.

Let me ask one more question, and then I know the chairman has others.

Senator NELSON. Help yourself.

Senator HUTCHISON. And that is——

Senator NELSON. Take as much time as you want.

Senator HUTCHISON.—looking for other alternatives, to what extent could the European Automated Transfer Vehicle, the ATV, or the Japanese Transfer Vehicle, HTV, be able to assist in meeting cargo delivery requirements of the U.S. portion of the ISS in the future?

Mr. GERSTENMAIER. Again our plan is—we've laid out the schedule for the remaining Shuttle flights—to leave Station assembled and in good configuration, and we're prepared for contingencies—and, in those, we're going to pre-position some spares with the Shuttle onboard Space Station, so that will allow us to fly Space Station in a robust manner for a period of time with very limited delivery capability. And, as you discussed, we'll have available from our partners, because of their agreements with us earlier on in the Space Station as part of their contribution to Space Station, we'll have the Automated Transfer Vehicle to use to carry some cargo up. That will fly the first time next year, in the—early next year, in January or February. And then, the Japanese vehicle comes online in July of 2009. It has the added capability of carrying external spares, like equipment that can fit in the back of the Shuttle, so that adds—gives us a lot of capability to also keep flying Space Station. And, again, we have those laid in our basic plan. But then, on top of both of those, we're looking to commercial orbital transportation, essentially to fill in the lion's share of that cargo.

So, the way we've laid it out is, we have what our partners are already giving us for the Automated Transfer Vehicle and for the Japanese HTV vehicle, and then, on top of that, or what we really need, is commercial orbital transportation, and if that comes online, we'll fly about—roughly 10 metric tons per year or so of cargo up on those commercial vehicles that are online.

And we have robustness in our series that this hardware and vehicles don't need to be online immediately after Shuttle retirement. We have some ability with the spares pre-positioned onboard Space Station to keep Station viable for a period of time until commercial comes online or the ATV or HTV are available to help.

Senator HUTCHISON. Well, except that we do have to get our people up there in some way. So, would that be another option, beyond the Russian contract?

Mr. GERSTENMAIER. We're looking, as kind of a follow-on to the commercial orbital transportation, there is a—an activity that Rick is managing, and—the Commercial Orbital Transportation System, capability D, which could potentially bring commercial crew transportation, maybe in that time-frame. The first thing we think is important is for them to demonstrate the ability to carry cargo, to show that as a proven capability, that it can be available on a schedule and with the right reliability. Then, if those same systems would make sense to then transport crew, that could be another alternative to the Russian vehicles.

Senator HUTCHISON. Is there anything that we're doing, with either the Russian Space Agency or anything internally in our program with Shuttles, that is in any way detracting from the potential commercial development?

Dr. GRIFFIN. Senator Hutchison, in my opinion, no, NASA has set aside a substantial budget as an incentive for COTS providers—Commercial Orbiter Transportation System—COTS pro-

viders, if they meet their milestones. And we have stated repeatedly that we are—our budgetary baseline features the use of such commercial transportation, and that we can use all of it that can be supplied, even by the most optimistic projections of supply. So, we can and will use it if it comes online. There is nothing that we are doing with the Russians, frankly, or with the Shuttle, that would make those statements untrue.

Senator HUTCHISON. Do you have any estimate, at this time, that there is one or more commercial system that you could foresee as a realistic possibility, as of 2010, being an alternative for carrying either people and—certain types of cargo, spares, et cetera, or at least people?

Dr. GRIFFIN. I think, 2010 would be a bit optimistic. One of the winners of our earlier round of COTS agreements, Space X, is, I think, showing good progress for—toward cargo delivery in the post-2010 environment. People will inevitably come, later. I believe that they can get there. I do believe that they can get there, but it will not be immediately post-2010. We are in the middle of a second round of competition for a new COTS agreement, looking for another provider. I'm optimistic that that will bear fruit, as well, but not immediately after 2010. In the period between 2010 and the end of—between 2010 and 2012, our only option, as I see it, to put crew on orbit will be to buy seats from Russia. I regret that. I've stated many times that I regret that we are in a position as a nation where that is our only option. But that is, at this point, our only option.

After 20—after January 1st of 2012, we no longer have the legal authorization even to buy Soyuz seats from Russia. And so, at this time, the only option the United States will have to put its own astronauts onboard the Space Station will be via commercial means, if they materialize.

Senator HUTCHISON. Thank you.

Senator NELSON. All right. I want to follow up on the line of questioning of Senator Hutchison.

The NASA authorization bill, now law, of 2005 requires you to either pre-position International Space Station spares or maintain sufficient cargo launch capability during that gap, which we're now estimating to be at least 5 years, unless we get the additional funding.

Now, doesn't this make the two contingency flights, you've got ten flights to assemble the Station, you've got one to go to Hubble, and the remaining two are contingency flights, doesn't that make them mandatory and not optional?

Dr. GRIFFIN. My position all along has been that they are not optional, that we have labeled them "contingency flights" because they are less critical than the assembly of the basic Station. But my position has been that they are mandatory, for the reason that you state: we need to pre-position certain spares for the Station on orbit, and those spares are not capable of being brought up by Progress or by any other means of which we know, aside from the Space Shuttle. So, yes, sir, I would agree with you.

Senator NELSON. OK. Now, we talked earlier about four flights a year, particularly in 2009 and 2010, and, at that point, you only had two orbiters, so it's a pretty spotty kind of thing. You've indi-

cated that you think that you can do it. I think it's our obligation to point out, as the oversight committee, that it was in the losses of *Challenger* and *Columbia* that the investigations found that the schedule pressure was a contributing cause to the accidents. Therefore, I am just bringing up this hard cutoff date again.

Mr. GERSTENMAIER. Again, I think we're very aware of that, we're very conscious of that schedule pressure. We talk about it every day. And where we sit today, with being able to end in March of 2010, and then we still have until September 30, we have 6 months of margin in the system. When I talk to our team and we go look at things, we think we have enough margin to go pull this off. We know that there'll be some hurricane problems that'll cause some rollback. That's planned in there. We know there is going to be potential for other Shuttle delays for various situations. We may have some contingencies onboard Station, as we've just seen. And we've factored all that in as much as we can in our planning, and we're trying to be as robust as we can.

I would add, even the solar array repair that we just did, the thing that is unseen is how much preparation went into that activity before it actually occurred. You know, we had already analyzed the solar array in a partially deployed configuration, so we knew immediately we were in no jeopardy and we didn't have to do anything immediately when that array got hung in this intermediate condition. So, we had been prepared for that contingency. We had also analyzed the ability to cut the guidewire, which we did on the EVA, so we knew that that was an option, to go cut the guidewire, if it happened to snag. We had seen the wire, during retract, actually snarl a little bit, so that gave us a clue there might be a problem there. So, we actually spent all that time in preparation before the flight, and, during the flight readiness review, we actually showed a video of the deploy of the guidewire fitting through the grommets on the solar array, analyzing the situation, and we discussed all that analysis. So, again, we have enough time in the schedule to be fully diligent, to look at all the problems, to be prepared and be ready to react. We may get something that's big, and, if we do, we'll stand down and we'll do the appropriate thing and not go fly. So, I stress that to the teams all along. We don't know if we're going to make December 6 right now. We have two critical EVAs next week, on the 20th and 24th, and I don't see any pressure on the teams. If we don't get those done, we'll move the flight into January, and we'll see where we stand.

So, again, I think we have the right schedule laid out, there is not undue pressure on the teams, and we're being extra diligent to make sure we don't put undue schedule pressure on ourselves.

Senator NELSON. All right. Everything that you've said is true, but you know from history what happens and how delays happen. What I want you all, I want all of us, to focus on is, remember to what the President's *Vision for Space Exploration* said, "Retire the Space Shuttle as soon as assembly of the International Space Station is completed, planned for the end of this decade."

So, I think it's our obligation to remind you of the President's *Vision for Space Exploration,* of the past pressures that, were in part contributors to *Challenger* and *Columbia,* and that you've got a robust schedule with only two orbiters left in the last 2 years.

I think the point is made. Let me move on.

Now, it's one thing, on your manifest, to conclude, in those ten flights, the ISS infrastructure, but then you need to outfit the Station so that it can be what Senator Hutchison took the lead in determining and designating it as a National Laboratory. Especially when you consider the fact that we've spent $50 or $60 billion on this. I have shared this with you, Dr. Griffin, before, about my concern that there are science payloads that ought to be on the ISS, that have been built and tested at great expense, and thus far in the manifest that you've set out, they're to be left on the ground. One of those is the Alpha Magnetic Spectrometer, which cost a billion and a half dollars to build. Have you made any progress in finding a ride so that the AMS could be located and placed on the International Space Station?

Mr. GERSTENMAIER. Yes, again, the problem with that is, we need those flights for the spares that we're going to need to outfit Station to keep it in a robust flying configuration. So, they're—we've looked carefully at what's on those flights, and there is nothing we can remove from those flights to make room for the AMS to fit out in the cargo bay. Those spares that are on the flight and the cargo that's there, unless something dramatically changes in the future, that equipment is going to be needed on Station to keep the Station in a robust and spared configuration, as you talked about. So, they don't fit on those—AMS doesn't fit on those spare flights.

Now, we also have included some payloads and research equipment on those remaining flights. There are some combustion racks, some other large facilities that will go in the Space Station, that will enhance its ability to be a National Lab. So, we haven't—in the remaining flights, we haven't totally cut out all the science, as you've described; there are substantial large facility-class payloads that will fly in those remaining flights that are part of the manifest. So, we've done our best to protect the intent of where we want to head with the Space Station as a National Lab, and to use it effectively in the future. So, we've got a lot of internal equipment; the problem is, we have a shortage of external cargo-carrying capability.

Senator NELSON. And yet, the whole purpose of having an International Space Station designated as a National Laboratory, by Senator Hutchison, is to be able to do these extraordinary scientific experiments that hold purpose and promise, such as the Alpha Magnetic Spectrometer. And so, this is almost like cutting off our nose to spite our face.

Let me ask you this. NASA is on the hook to deliver 50 metric tons of cargo to the ISS during this gap. That includes 30 tons of carriers, or a total package of 80 metric tons. Is that correct? During the gap.

Mr. GERSTENMAIER. Yes.

Senator NELSON. And you've got that allocated out, that the Europeans have the responsibility for so much, the Japanese have the responsibility for so much, the Russians, so much, and America, what we just mentioned, has 50 metric tons of cargo.

Now, in your written testimony, NASA's baseline is to purchase cargo launch services from commercial providers, including, as you

mentioned, the COTS. Here we are, less than 3 years prior to the retirement of the Shuttle. Do we have any commercial carriers that have demonstrated this capability?

Dr. GRIFFIN. We don't have demonstrated commercial capability, at this point. Of course, we do have existing space transportation capability for unmanned spacecraft, in the form of the Atlas and Delta fleet. We are putting out, in 2009—and we are putting out for selection in 2009, an RFP for such commercial capability, and we expect to have people respond to it. In fact, I know that they will.

One of the requirements for such commercial capability is to deliver the cargo that we need in close proximity to the Space Station, such that it can be brought onboard. So, we believe that, in the time that we have available, that this capability to deliver cargo in an unmanned mode to the Space Station can be brought online and that we can meet our obligations in that fashion.

Senator NELSON. And so, if I can restate what you just said, and maybe you want to amplify, that you think, within this 3-year period, that you're going to be able to develop and qualify a launch vehicle and a transfer spacecraft that can dock with the ISS.

Mr. GERSTENMAIER. We currently, under the COTS Phase 1 activity, have a demonstration activity where we're going to take a vehicle to Space Station and actually demonstrate the ability to dock to Space Station under existing funded Space Acts. And that's the Space X Project that you've talked about. And that involves a series of several test flights, including a docking to Space Station in 2009. And that will demonstrate that that capability is available. So, we don't have it today, but we have a plan to proceed forward to demonstrate and show that that capability is there.

Senator NELSON. Within 3 years. I hope you're right. Now, let me ask you, how long did it take the Europeans and the Japanese to develop their transfer vehicles?

Mr. GERSTENMAIER. Well, it's taken substantially longer, as——

Senator NELSON. Like about 15 years?

Mr. GERSTENMAIER.—if you began at the very beginning, yes.

Senator NELSON. Well, as you know, as we've discussed privately, I support COTS, I have worked to make sure that the little glitches were ironed out at Cape Canaveral to get them a launch pad. I hope for the best, but realistically, to think that all of this is going to happen with an inexperienced company within 3 years is not really for us to plan totally on. So, as NASA does so well, what is your backup?

Mr. GERSTENMAIER. Again, what we've done is, we're looking at using the Automated Transfer Vehicle and the Japanese HTV Vehicle as a backup. And then the other piece is that we're going to pre-position spares that allow us to fly for a certain period of time, with essentially no logistics capability, to Station. So, it's—those three pieces are essentially the pieces of our backup.

Senator NELSON. Japanese, European, and no logistics, those are your three.

Dr. GRIFFIN. Well, the—when we say "no logistics," the phrase I would use is "pre-positioning the logistics." That's what the——

Senator NELSON.—by the two——

Dr. GRIFFIN.—by the two contingency——

Senator NELSON.—remaining——

Dr. GRIFFIN.—flights.

Senator NELSON.—contingency flights.

Dr. GRIFFIN. Right. So, to purchase additional HTVs from Japan or to purchase additional ATVs from Europe would be part of our backup plan.

Sir, I don't want to leave this hearing, or this Committee, with the impression that we are in a good position. We're not. As Admiral Gehman said in his report on the *Columbia* Accident Investigation, the failure to plan for a successor to the Space Shuttle and to bring it online in a timely way was a failure of U.S. strategic planning. No one agrees with that position more than the people at this table. We are not in the position that I would wish the United States to be in as we take stock of our program of spaceflight following the loss of *Columbia* and then moving forward to the finishing—to the completion of the Space Station and its utilization.

Senator NELSON. Well——

Dr. GRIFFIN. We are, with those facts on the table, I think, doing the best that can be done.

Senator NELSON. And that's the purpose of this hearing, to flesh this out. Now, let me ask you this. You've just testified that you have to have, as a backup the Japanese and the European's ATV vehicles, and, of course, they have their own responsibility for getting cargo to the ISS.

Dr. GRIFFIN. So, that would—our purchases would be in addition to their responsibilities on their end.

Senator NELSON. OK. Now, we've got less than 3 years before Shuttle is shut down. Are you sending money to the Japanese and to the Europeans now to start building those ATVs and HTVs?

Mr. GERSTENMAIER. No. Again, we've done the planning, where we've identified when we would need to start funding—or to make those purchases. We know when that latest date is.

Senator NELSON. And when is that?

Mr. GERSTENMAIER. 2009.

Senator NELSON. And that would give you the capability of getting——

Mr. GERSTENMAIER. That would give me an HTV——

Senator NELSON.—the cargo——

Mr. GERSTENMAIER.—that would give me a cargo HTV in 2012. And I can bridge the gap between 2010 and 2012 with the pre-positioned spares onboard Space Station, with a higher failure rate than we've observed today. So, I have margin in what I'm pre-positioning. I can fly that gap until 2012, and then utilize their ATVs and HTVs they're already providing us to help augment that same gap.

Senator NELSON. As long as your two contingency flights are able to pre-position that.

Dr. GRIFFIN. That's affirmative.

Mr. GERSTENMAIER. That's correct.

Dr. GRIFFIN. And that is the reason why we don't feel—I—no one is more sensitive than I to the position that we've taken, that we do not have a Shuttle flight available for the AMS, because, after all, that, too, was an international agreement. But to make a Shut-

tle flight available for AMS requires removing this cargo that we spoke of that is our plan on how we get through the gap on Station logistics.

Senator NELSON. Or possibly we could be planning for purchasing those additional ATVs from the Europeans and the Japanese, and free up one-quarter of, 25 percent of one of those cargo bays on a contingency flight and get an important scientific instrument up there.

Dr. GRIFFIN. Well——

Mr. GERSTENMAIER. I would——

Dr. GRIFFIN.—I'm sorry, you go first.

Mr. GERSTENMAIER. I would just say that the cargo that the Shuttle is carrying is unique to the Shuttle. It's external cargo that is of large magnitude—and I think we provided this in a written response to you—but it's large rotary couples, it's large joints, it's things that can only uniquely fly on the Shuttle. They don't fit well on an ATV; in fact, they will not fit on an ATV, because it doesn't have cargo-carrying capability, and most of them will not fit in an HTV's external cargo capability. So, we have—uniquely are using the Shuttle to carry the cargo that only it can carry. It also carries the large stowage platforms that are needed to be on the outside of Space Station so we can hang all these spares on the outside of Space Station. We need both of those from those Shuttle flights. So, the cargo that the Shuttle is uniquely carrying has to be carried by the Shuttle.

Senator NELSON. So, they're not contingency flights, then; they're necessary flights.

Dr. GRIFFIN. As I've stated, I believe that to be the case, yes, Senator.

Senator NELSON. Well, why are we calling them "contingency"?

Dr. GRIFFIN. I can't answer that. We started calling them "contingency flights" a couple of years ago, and maybe it wasn't a good name. We——

Senator NELSON. Well, let's call them——

Dr. GRIFFIN.—we need those flights, and I've been quite clear about that all along. I have—my position on that has never changed.

Senator NELSON.—flight 12 and flight 13.

Dr. GRIFFIN. Now, to——

Senator HUTCHISON. Could——

Dr. GRIFFIN.—I'm sorry. Yes, Senator? Go ahead.

Senator HUTCHISON. I didn't mean to interrupt you if you were continuing.

Dr. GRIFFIN. I was going to make the point that, if one wished to fly the AMS, that the more productive approach, rather than clearing cargo off the Shuttle and putting the AMS on, it would be more productive to think about putting the AMS on an expendable vehicle, at some point, and flying it up. And that, too, of course, would require more money, but could be done, technically, more easily than it would be possible to remove Shuttle cargo from the Shuttle.

Senator HUTCHISON. Bingo. That's exactly what I was just getting ready to ask you. From the line that——

Dr. GRIFFIN. Well, we've estimated——

Senator HUTCHISON.—Senator Nelson was going, I was going to ask you, is the AMS potentially a cargo that doesn't have to be—that isn't going to be on the Shuttle, as you have said, but could go into one of these other commercial delivery systems?

Dr. GRIFFIN.—well, some amount of rework would be necessary, because, of course, the AMS is, today, planned for Shuttle integration. So, some amount of rework would be necessary. But we did, over a year ago, in response to this Committee's and other requests, we did look at what it would take to put the AMS on an expendable vehicle. And in the neighborhood—I'm going to use a rough estimate, because we have a range of estimates, but in the neighborhood of $350 to $400 million would be required for the—to pay for the expendable launch vehicle and to do the reintegration necessary to fly it up. Now, that money is also not in our budget, just as the extra Shuttle flight to fly it another way is not in our budget. I'm speaking now merely of technical possibilities.

Senator HUTCHISON. OK.

Mr. GERSTENMAIER. And I would add, there is a significant amount of rework on the AMS side to enable that to occur, as Mike said. And I think we've progressed from when we did this first study, that the AMS is now built up in a more manufactured state, so there is actually even more rework than when we did the study, about a year ago, that would have to be undone to make it compatible with an expendable launch.

Senator HUTCHISON. Well, I hope that I'm not, then, misreading what you're saying, that there is a ray of hope that we might be able to get the AMS on the Space Station at some future point, because I think the hearings that this Committee has had—and I know that it is also the case on the House side—have given us the impression that there is a lot of potential with the study of cosmic rays as a major form of energy—well, a major, perhaps, key to unlocking the dark energy that is out there, and then maybe potentially having a connection with energy sources for the future, for the world to use. And if that is the case, then perhaps after, or at the same time, in conjunction with some of these other opportunities, that we might be able to have that also as a new use for the Space Station research. Am I getting that correctly?

Dr. GRIFFIN. I believe so, Senator. I am an engineer. We are engineers. I can't speak to the scientific merit of the AMS. I am content to rest on the judgment of the scientists who have originally approved the program.

The issues that we're speaking of here today, in flying or not flying the AMS, or any of the other options we have discussed about, come down to budgetary constraints. We know how to do that which is desired to be done, but the options that you have discussed today—flying the Space Shuttle longer, flying the AMS or not flying the AMS—come down to budgetary limitations.

Within the budget that is allocated to NASA, I believe—I firmly believe that we have given you the best program of activity to meet the goals of the Authorization Act that we can give you.

Senator HUTCHISON. As you know, I am the one who pushed—and Senator Nelson helped in doing that—to designate the U.S. portion of the International Space Station as a National Laboratory. My purpose in doing that was to try to get alternative sources

of funding for new potential research projects so that everything wouldn't have to come out of NASA because of the budget constraints that we have been hearing about for—ever since I've been in the U.S. Senate. It's certainly a bipartisan message, that we have gotten from every President I have served with, that there are budgetary constraints. So, I thought designating as a National Lab that U.S. portion of the ISS would provide a potential for opening that up to other agencies. I couldn't have been more excited than the day that you signed the Memorandum of Understanding with the NIH, because we know there has—there is so much potential in health research in the microgravity conditions. But I also believe, as I know Senator Nelson does, that there are other scientific capabilities in space, and we shouldn't just be studying the effects on humans in space, that there are other potentials, one of those being energy, from the testimony that we have had in hearings. So, I know you know that I am a very strong supporter of looking for alternatives for the AMS that might open doors to future energy research, and, as we are expending enormous sums of money and authorizing enormous sums of money to look for better sources of energy for our country, I hope that that is an avenue that we can continue to pursue in innovative and creative ways.

Let me ask you, Are there other Memorandums of Understanding, other agencies or organizations, now in the works for research to be done on the Space Station? I'm hoping that the National Science Foundation might be a potential, possibly the Department of Energy. Are those—what do you have on the drawing boards?

Mr. GERSTENMAIER. We're beginning some preliminary discussions with several other agencies. We've also put some requests out for information of some commercial folks that might be interested in utilizing Station, and we're getting—we're just kind of at the formulation phase, where we're starting to get some of those responses back, we're starting dialogue with them. We haven't progressed very far, in terms of an MOU kind of stage. We're still kind of in an understanding research stage. But I will tell you, there appears to be a lot of interest out there in utilizing Space Station, so this seems to be a very productive thing that's heading forward. We're sorting through our options, looking to see what makes sense, starting the dialogue, and beginning forward—to come forward. And I think next spring we should come forward with some more definitive discussions along those lines.

Senator HUTCHISON. And are you envisioning that there will be some offset in the transportation costs for putting experiments, and possibly people, in the Station for NASA, that we would be able to do some sharing of expenses for NASA projects, as well as others?

Mr. GERSTENMAIER. We're looking at that now, or at least starting some of those discussions. As we talked about, the Commercial Orbital Transportation System's coming online, if they can bring a reduced price to orbit, you know, we would help facilitate some of these commercial groups and other government agencies to go utilize some of the same systems that they were going to use to carry cargo to Space Station. So, we think that helps, you know, bring along the transportation market, so it's not only the NASA needs for that market, but now it's a broader, potentially commercial and

other government agency market to the transportation side. So, we're starting some of those discussions, again, with folks along the transportation lines, showing them what's available on the commercial transportation side to move forward.

So, again, we recognize that that's a concern that needs to be worked, transportation to Station. We're looking for the other providers to help with a large portion of that transportation piece. You know, we provide the basic sustaining engineering, operation of the research, but we're looking to them to pick up a larger piece of the transportation. But we're starting, again, those discussions and showing them what's available on the commercial transportation side.

Dr. GILBRECH. Yes, Senator, if I could add onto that, we also, by design, put this—the amount of funding NASA's investing so that they wouldn't be solely dependent on NASA, they would look to other customers and try to foster that market and spur that interest. And so, that was, by design, why we put some fundraising on their side of the coin, so they would go look for those types of markets to spur that.

Senator HUTCHISON. Well, that is certainly the purpose that I had in mind, not only to assure that we have the utilization of the Space Station for more than just the impact on the human body of being in space, but other viable—either commercial, university, or government agency projects, and to share the costs so that NASA would have some offsets and, therefore, be able to do more in its core responsibilities. So, that was the dual purpose, and it seems to me that, from the things that you have said, although neither Senator Nelson nor I am going to be happy with a gap in the Shuttle and the Crew Exploration Vehicle, but, nevertheless, if we can add the money for these priorities to close that gap and at least get to the 2013, which is going to be a priority for me, if we can get to that point, then it looks like you do have other options out there for both cargo and commercial capabilities—other countries and commercial capabilities for cargo delivery, and then, possibly down the road, even human capabilities. And I'm very, very encouraged about the potential for the AMS at some point to be a part of the Space Station, because I just think there is too much potential there for us to turn our backs on. I mean, the whole NASA experiment was a huge leap, it was a huge risk, and we took it, and we have reaped the rewards. And I think there is a potential here, in energy research, for the AMS and the use of the Space Station for another type of research. So, I'm encouraged.

And I guess I will just ask if the engineers, who never want to be encouraging, might say that, yes, there is a ray of hope out there, that maybe we can take NASA and the research and the Space Station to the next step. Dr. Griffin, like Senator Nelson, I've worked with you for a long time, I respect you, I think you have done enormous things for NASA, but you are not an encourager. So——

[Laughter.]

Senator HUTCHISON.—if I would—if I could just end by asking if perhaps there is the ray of hope that you do see that future that we have envisioned out there, with a lot of creativity on our part, backed up with the dollars that I know you need.

Dr. GRIFFIN. Yes, Senator, I'm sorry that I'm not an encourager. I want, never, ever, ever, to promise you something that I can't deliver. What I have tried to say today is that I share—we share the same vision that you do. It would be silly for this Nation to finish the Space Station and not to use it appropriately. That would be silly. What I have tried to say today is that, within the budgetary allocation that we have, that we believe we have prioritized our activities correctly. And I don't mean for that to be an arrogant statement. We believe that we have set the best priorities that we can within our budgetary allocation. If you and your staffs believe that—also, that we have set our priorities correctly, and if you then find shortfalls in what we are doing, then the only place I can turn is to say that we are doing all we can within the budget allocations that we have. And I believe that to be so. But I share the vision that you have, and I am—you know, I intend to be responsive to your priorities.

Senator HUTCHISON. Thank you.

Thank you, Mr. Chairman.

Senator NELSON. And you can see, Dr. Griffin, that this line of inquiry by both of us is not only bipartisan, it is nonpartisan. And I have always maintained that there shouldn't be anything having to do with partisanship in America's Space Program. It's a nonpartisan activity.

Again, I remind you that the purpose of this hearing is that we are looking ahead, beyond this Administration, which only has a little over a year left, because decisions that are being made now are going to have profound implications for the next Presidential Administration. If we're fortunate to have a future Administration that is wildly enthusiastic about our Space Program and just starts shoveling money to NASA.

Dr. GRIFFIN. Be still my thumping heart.

[Laughter.]

Senator NELSON. What we're concerned about is that there are, in fact, decisions being made today that are going to preclude some of those things, and I want to get into some more of them. Before Senator Hutchison has to depart, one of the concerns that I have about AMS not going on the Shuttle is the fact that it's so much more expensive for it to get a ride on an expendable vehicle, and then you've got to have a transfer vehicle to get it over to the Station; whereas, the Shuttle would take it straight to Station.

I don't have a dog in this fight. The lead university on this is Massachusetts Institute of Technology. There is a consortium of several universities, some of whom are in Florida, but what we're looking at is the science and the value to the country and the opening up of the heavens and understanding the development of the universe and all of this kind of stuff that an experiment like AMS would bring to us. And so, we keep trying to wrack our brains as to how, before it's too late, we can get this thing up to the Space Station.

Senator HUTCHISON. Well, I——

Dr. GRIFFIN. I don't have another Shuttle flight.

Senator HUTCHISON. Well, I was going to ask the question, but Mr. Gerstenmaier answered it, which was why you, in your priority list, didn't put AMS. And his answer that came before I asked the

question was that other pieces of the Station that couldn't be carried up in any other way had to be done first. But then, the hope for the future is that something, reconfigured, might be able to take it up—gave me some hope that it wasn't all lost. I just agree with Senator Nelson on the importance of it. I think it's a whole new area, this energy potential, and I am convinced by Dr. Ting at MIT, that it's worthy. And, to my knowledge, there is little or no Texas involvement. I just think that if we're going to have the vision of NASA to do what can't be done in the private sector, realistically, to take our country ahead of anyplace else in the world in the exploration, and the use of space, that we've got to do those things that I think are the priority. And you didn't put this in that priority list, but I certainly—if we had the capability to extend the Shuttle, certainly what Senator Nelson says makes a lot of sense. I really believe in this line of research for our country, and I hope that we can figure the way to do it, either on an extended Shuttle or in some way patching it so that it can go in a cargo delivery service.

Senator NELSON. We need to get Dr. Griffin to be an encourager.

Senator HUTCHISON. He is notoriously an engineer.

[Laughter.]

Senator HUTCHISON. Say no more.

Thank you.

Senator NELSON. Well, thank you for coming.

I'm going to go on and continue a few more thoughts here.

Senator HUTCHISON. Thank you.

Senator NELSON. All right, thank you.

Let's look to the future. Mechanisms fail, things are damaged, et cetera. How do you plan to address repairs or replacement of large Station elements if we don't have a Shuttle?

Mr. GERSTENMAIER. Again, we're pre-positioning a large number of those components. We'll have several control moment gyros, which weigh about 350 pounds, pre-positioned on the outside of Space Station. Those will be available for change-out by the crew onboard Space Station, if they need to be. There's a large fluid rotating coupling that controls all the fluid flow from the large radiators you see back into Space Station. That device will be pre-positioned on Space Station to go ahead and be replaced. The—all the components that are on the outside that have replacement parts and pieces, we will have those pre-positioned. For the robotic arm onboard Space Station, some of the joints, those are all replaceable; we'll pre-position portions of those joints. We're going to fly up, next year, a special-purpose dexterous manipulator—it's a two-armed robot that will allow us to do some activities—today that we can only do EVA—we'll be able to do those activities robotically. We're going to actually fly a spare arm for that device, in case that arm breaks and has problems. So, again, if you look at what we've done, we've tried to anticipate with our best engineering analysis and best knowledge of anything and everything that can fail, and we've tried to pre-position pieces in space.

The other thing that we're doing here is, we're really learning how to operate for sustained periods of time away from the home planet, which is exactly what we need to do for Moon and Mars. If you remember, during the *Columbia* downtime, you know, the

treadmill that the crew runs on, one of the gyros—it's probably a 75-kilogram device that provides stability for the treadmill—it broke, and we didn't have the capability to fly that on the Shuttle, but we were able to fly up, essentially, a bearing and a bearing puller from a hardware store in Texas, and we were able to go ahead and pull that bearing, which weighed about 8 ounces, replace it, and restore full functionality back to that treadmill. We did the same thing with our spacesuits. A small pump, about the size of your fingernail, failed internally to that spacesuit. We didn't think it was possible to dismantle the spacesuit on orbit and replace that small pump, but we were able to do that and repair. So, again, we may be forced to do some ingenious things or repair in ways that we haven't anticipated, but that knowledge is critical to us when we go to the Moon to try to establish outposts, and when we go to Mars.

So, the Station provides not only the scientific platform you talked about, but it provides an engineering basis for us to extend our knowledge and our ability to live off the home planet for extended periods of time. So, we've spared the large components, and, with our creativity and ingenuity, we think we have the capability to grow and continue to learn to allow us to go do exploration like we intend to go do.

Senator NELSON. And, of course, that's one of the things that NASA does best, is the ingenuity that you bring to fixing problems. And you have our highest compliments on that.

Looking to the future, I want to talk about the gap. Dr. Griffin, you've testified that what is now expected to be 2015 before you could fly with humans, and that you could shorten that to 2013 if we could get you an additional $400 million in Fiscal Year 2008, just for the Constellation Program. In 2009, an additional $800 million; and in 2010, an additional $800 million. And that is what you have laid out.

Now, Senator Hutchison mentioned that her cut on the difficulty of getting it—I am wracking my brain, I'm working with Senator Shelby, Senator Mikulski, Senator Hutchison, as to how to get some additional money in, but we're confronting the hard reality that the White House has announced that it would veto it. I'm referring to an October 5th *Houston Chronicle* article, the whole thing was that we had gotten an additional billion dollars for NASA in the budget, and I quote from the article, "The White House budget office renewed the President's veto threat Thursday, issuing a statement saying the overall bill includes an irresponsible and excessive level of spending."

The long and short of it is, I don't know that we're going to be able to get, in this Fiscal Year 2008 that we now have entered. I don't know that we're going to be able to get the additional funding for the Constellation Program.

So, I've got to look to the future. And even if we get an Administration that would just start throwing buckets of money at NASA, you're saying that we're on down the road and that you can't catch up just by throwing more money at it, because you've got to have a lot of lead time for some of these things.

I have a responsibility, now putting on my parochial hat, of looking out for the interest of the employees at the Kennedy Space

Center. And, of course, that's going to be the Space Center that's going to be hit the hardest with regard to layoffs. So, I want to know how many jobs that you think, if we are on the present schedule of shutting down the Shuttle in late 2010 and not flying with humans until the early part of 2015. How many jobs are going to be laid off at the Cape? You've got basically 15,000 employees, which include NASA and contractors.

Mr. GERSTENMAIER. We don't have a specific number, but we've been laying out plans to try to capture our—we have two competing things. We need to continue to fly Shuttle safely all the way to 2010, as you described earlier, so we need to keep our workforce in place for that. And then we need to provide them some—a future vision of where they need to go work. And there is going to be some downsizing during this period, just because of the efficiencies. But, again, if you look at even flying in 2015, there is a lot of preparatory work that needs to go in front of that. We need to, you know, begin some simulations, begin training, modify some facilities, change some equipment, and we're laying all that in place. You know, we're trying to give our workers a sense of the future. For example, the Ares I–X test flight, which his going to occur in 2009, April, that flight will use some of our Space Shuttle workers today to go support that flight. So, they actually get a chance, while they're doing their Shuttle jobs, to actually support that test flight on Constellation. And we think that's a great chance to give our workers a sense of the future, to let them learn skills that will allow them to go work in Constellation. There are also some test flights that fall in that timeframe. There's an Ares I–Y flight that occurs in there. So, there is going to be activity at the Cape during that period. So, even though there is a gap, in the sense that we're not flying to Space Station, there is still a lot of activity that's there, and we're trying to lay in those detailed plans. But we don't have a specific number of how many employees will actually be retired during that.

We're also looking at moving some activities from other areas within NASA to the Cape to help augment some of that, so the cuts won't be as steep as we've seen. So, again, we're trying to balance, across all the agency, how it fits.

The problem, frankly, that we have is that there is no big single piece that we can put to fill in all that work, and we have to be more efficient. So, it's going to be small, little pieces, one at a time. For example, the—and Rick can elaborate more, as—you know, the Orion production facility down in the ONC building, that's an important activity. Some of the upper-stage work'll get defined, et cetera. So, there is a lot of work that we've got to put together to get those plans, and we really won't have a specific number for an extended period of time, but I think we can show the vision for the future to fill in that gap, as long as it's a finite period of time.

And, Rick?

Dr. GILBRECH. And——

Senator NELSON. If that gap is 5 years, when would you start that work on assembly of Orion and assembly of Ares?

Dr. GILBRECH.—well, some of the early production work on Orion actually kicks off in 2009, so we have to do a lot of planning with Lockheed Martin and the Cape folks to get that early work on-

board. And Bill and I are working very closely. We're 3 years away from the proposed last Shuttle flight, and we're very much attuned into this to try to minimize the impact to all of our workforce across our ten centers, but we recognize that Kennedy is especially—has potential to be impacted. We also have recently rolled out our lunar assignments, which is the first step in trying to define some of the work that we see going to the different field centers. And Kennedy has some significant new roles *in situ* resource utilization and some of the surface habitat work that will be new work for the Cape.

Senator NELSON. But that comes later.

Dr. GILBRECH. It comes later, but we also—it's the first step, for them to start projecting that. And, again, as I've said, this will kind of come in small steps, one contract at a time—we'll get a little more clarity as to what that content means for each of the centers—and one milestone that we go through at a time. So, I would like to give you a solid answer right now, but we just don't have enough clarity to be credible. As Mike says, we always want to be credible in what we tell you, so that's basically where we are.

Senator NELSON. Well, the word is out in NASA that, with a 5-year gap, after you shut down Shuttle, you are looking at the layoff of as many as 5,000 at the Kennedy Space Center. Is that true?

Dr. GRIFFIN. A variety of estimates have been produced that I've personally seen, and some of them go as high as that number, yes, Senator. I think that is on the high side of credible, but I do realize that some people have made that estimate.

Dr. GILBRECH. And, as well, I'm—I mean, my goal is to close the gap from my side to try to beat the March 2015. But, again, we're holding the line there, because, based on the content that we've drawn the floor at, technically, and the budget we have, that's where we feel like we can credibly deliver. We hope that, as design reviews are behind us and contracts are put in place, that we can come and move that date forward and close that gap, but we want to hold that credible confidence level as we go forward.

Other opportunities, too, the COTS program, if it's——

Senator NELSON. Let me just stop you there, and we'll get to COTS in just a second.

Well, first of all, I want you to understand that a layoff of 5,000 people hits me like a bolt of lightning, and would hit the Kennedy Space Center likewise. Of course, I am a part of all that is has met, and one of the things that it has met was in aftermath of the Apollo program, where there were the huge economic dislocations, the loss of corporate memory, the decimation of families in the layoffs that occurred in the course of the 1970s. And, of course, we were trying to do the new system, and there was that last Apollo flight, which was Apollo-Soyuz, and then it was another 6 years before we finally flew the Space Shuttle. You know a 5-year gap may turn into 6 years, and it could turn into 7 years, and that's all the more pain and threats to America's Space Program because of the loss of that corporate memory and so forth.

Here we are and it is what it is. The funding is here. Since we're looking to the future now, if we're able to convince the new administration to start shoveling some additional money, how much of that 5-plus-year gap can we make up?

Dr. GRIFFIN. Again, we—Senator, we share your concern. I think I've been very clear on that. And it's honest. We share that concern. We, too, want to protect our intellectual capability, our brainpower, our corporate memory. We don't want to be the source of economic dislocation in central Florida. I, too, lived through that period, and, with you, I can testify with complete honesty that it was very ugly. I have said, for two and a half years, I don't want to repeat it again—the earliest, at this point, at—given where we are, the earliest, at this point, that we could creditably promise a replacement capability for the Shuttle would be September of 2013. That would be a 3-year gap. Our budgetary resources today, apples to apples, same budgetary assumptions, support March of 2015.

Senator NELSON. What I would like to do so that we can put this whole thing into context as we look to the future—and I want to ask this question for the record, and I want the record to reflect this, if you all would respond to us in writing. What are the planned workforce levels, and that's both government and contractors, at each NASA center in those years of the gap, from 2010 to 2015? Part of the reason that I'm asking, and I want the record to reflect, is that all those other centers are not going to be hit, there is not going to be a reduction in the workforce there, as there is at the Kennedy Space Center, under this funding scenario where we can't get any additional money right now. If you all will provide that for the record.

[The information referred to is contained in the Appendix.]

Dr. GRIFFIN. We will, of course, sir.

Senator NELSON. OK.

Let me just end up with a couple of more thoughts here. And thank you all for your kindness in responding, and you've responded very forthrightly. I appreciate that. It is my responsibility to try to get our arms around this.

The one thing that we haven't talked about is human access to the International Space Station. And, Dr. Griffin, in your testimony, you state that, when the Shuttle is retired we have no choice but to pay the Russians for human access to the ISS. American taxpayers have invested close to $60 billion for this American National Laboratory that is now an International Space Station. Now we're going to have to pay millions of dollars to the Russians in order to be able to use it, to get human access. That is the plan, is it not?

Dr. GRIFFIN. Through the end of 20—or through the end of 2011, that is the plan, sir.

Senator NELSON. Say that again.

Dr. GRIFFIN. Through the end of 2011, that is correct, that is the plan, is to pay——

Senator NELSON. Well, what about from 2011 to 2015, until we have the new——

Dr. GRIFFIN.i—f commercial capability to fly crew between 2012 and 2015 emerges, then, of course, we, NASA, will purchase such capability.

Senator NELSON.—you're talking about the COTS.

Dr. GRIFFIN. I'm talking about COTS. If there is no commercial capability, then the administration would have to seek relief from the Congress on the provisions of ISNA, the Iran Syria Nuclear

Nonproliferation Act, in order to be able to get another exemption to buy seats on the Russian Soyuz system.

Senator NELSON. Do you have that exemption through 2011?

Dr. GRIFFIN. We have it through the end of 2011, at this point, from the Congress, yes, sir.

Senator NELSON. OK.

Now, that is the plan. That's the plan of NASA.

Dr. GRIFFIN. Yes, sir.

Senator NELSON. We have to get humans to the International Space Station, and you're talking about a 5-year gap. And I want to show you why I think that that is an enormously perilous plan.

Can anybody in America predict the geopolitics of Russia in the year 2012, particularly what we see are the actions of Vladimir Putin right now? *The Wall Street Journal,* in an article last May quote, "The deepening chill in relations between Washington and Moscow is threatening U.S. companies' chances of winning at least two multi-billion-dollar business deals in Russia, according to Russian officials." Continuing, "With the Kremlin increasing the state's role in Russia's economy," which has became clearly apparent since the writing of this *Wall Street Journal* article last May. Again quoting, "analysts say its ability to use business as a political lever is increasing. The boards at Gazprom and Aeroflot are dominated by government officials."

What is becoming painfully apparent all over Europe right now, I can tell you, having just returned from an Intelligence Committee mission to those capitals, the Russians are buying up all the gas pipelines going into Europe, and they're going to be able to turn the spigot off, and they're going to have that economic power over Europe. Clearly, this is the plan.

With regard to nonproliferation, look at the comments of Vladimir Putin as recent as his meeting with Nicholas Sarkozy, the President of France, of which he's making excuses for Iran and their nuclear program. And this is 2007. Can we predict what the geopolitics and Russia's stance is going to be in 2012, with what we will see has been the trends in the last couple of years in Russia? Particularly with Putin, who now everybody believes is going to stay in power, one way or another?

So, here we have a plan, set up by NASA, that is going to rely on us paying for Russian vehicles. At the same time that we're laying off maybe 5,000 people at the Kennedy Space Center, we're going to pay for Russian vehicles that we don't even know are going to be available to us as a result of the new geopolitics of a future Russia. Now, that doesn't sound to me like a good backup plan. Can you comment?

Dr. GRIFFIN. Yes, I can. I don't think it's a good backup plan, either. It is the only one of which we can avail ourselves, because today Russia has the only other human spaceflight capability for the Space Station that we can even consider. We are where we are as a result of prior decisions made by prior administrations and sustained by prior Congresses that have put NASA in a position where we can no longer promise to be able to deliver crew to Earth orbit after 2010. That is where we are. Given those facts on the ground, I have presented you with the best plan that I can conceive. I don't like it, and I would not like to leave this hearing with

you having the impression that I do like it. I don't like it. I consider it to be unseemly in the extreme, and unwise, strategically, for the United States to be dependent upon any other nation for any other thing. I could not be more clear on that. This is where we are, and I am doing the best I can to plot our course out of it. I did not get us into this position. I am doing the best I can to get out of it.

Senator NELSON. But——

Dr. GRIFFIN. And if you think I like it, you would be wrong.

Senator NELSON. And, of course, you know my personal affection for you and the good job that I think that you're doing. And you are. I just want to get it on the record so that everybody understands this is a discussion that is often down in the weeds. We have now spent $60 billion investing in an International Space Station that Senator Kay Bailey Hutchison helped name a National Laboratory, and we're possibly not going to be able to get there, because Vladimir Putin might deny us. Or that we deny ourselves, because people like me are going to resist shoveling money to the Russians with him jacking up the price to exorbitant levels in the year 2012, while at the same time we're cutting up to 5,000 jobs that have been launching American spacecraft. That doesn't sound like a good plan to me.

Dr. GRIFFIN. Nor to me, sir.

Senator NELSON. At the same time we've got a law on the books that says that if Russia is helping the proliferation of nuclear weapons in Iran or Syria, that we can't buy rockets from them. We've got three strikes against us right there, to utilize a $60-billion asset. And that just seems to me like a terrible plan.

So, what do I do besides pray?

[Laughter.]

Dr. GRIFFIN. I guess you need to hire somebody smarter than me, because I have not been able to figure out a better one. I take responsibility for the plan we have, going forward. I don't have a better one. I share your concern about it. We share your concern about it. I've been speaking on this point now for two and a half years. I don't have a better plan. I'm sorry.

Senator NELSON. I want you to know my personal appreciation for all of your public service. And I want you to know, Dr. Griffin, how much I appreciate the professionalism that you have brought in some very trying times to NASA in the aftermath of the loss of another Space Shuttle, in trying to bring back a culture of safety.

This is a little agency, and it's not being treated right. There is, within the bosom of most every American, the yearning to explore in space. We've got to give flight to that aspiration of Americans. That's why I wanted to focus on the future in this hearing today, on the decisions that we're making now because of budget constraints that are irrevocable with regard to the future of what we can accomplish and the consequences of these decisions now. For the future of our blessed little space program.

Dr. GRIFFIN. Yes, sir. And I would like—I would like to add to the concerns you've raised, that all of the dates that we have discussed, even—as Senator Hutchison would label me—even as unencouraging as they are, will become worse if we have a full-year continuing resolution again, as we had last year.

Senator NELSON. I don't think it will be as—well, Lord knows, it better not be——

[Laughter.]

Senator NELSON.—or else we are in a world of hurt. I think ultimately what's going to happen, since everybody's all wound around the axle up here in the Senate over Iraq funding all of that, and with the President just vetoing another appropriation bill, Labor, Health and Human Services, is you're likely to get a packaging together of a whole bunch of appropriations bills that the President is insisting go back to his level of $22 billion less than what the Senate Appropriations Committee has done. Now, that's $22 billion on all the agencies, other than Defense.

What that final figure is, I don't know, but, of course, this Senator will be fighting to make sure that at least what we have in the underlying bill of appropriation to NASA, which exceeds the President's request by a couple of hundred-million dollars, that that, at least, stays. But, of course, what we needed was that additional billion dollars to replace the $3 billion that you had to spend on the recovery from the destruction of the Space Shuttle *Columbia.* Money that, by the way, 20 years earlier, was replaced after the destruction of the Space Shuttle *Challenger.* So, therein is where we have the crux.

I would be remiss if I did not put one more thing on the record that we haven't talked about, but this is about the future: China going to the Moon. You made the statements in China that you think that they could get to the Moon before us, and I think you were truthful, and I happen to agree with you. We're set, under the President's plan, of getting there no earlier than 2020. Some people have talked that the Chinese will have the capability of getting there sooner. You apparently believe that. And so, if you would just offer that for the record, I would appreciate it.

Dr. GRIFFIN. I will provide you an expanded answer for the written record, of course, because the discussion gets to be a little complex to do verbally.

[The information previously referred to follows:]

March 2008

Assessment of Chinese Capabilities to Mount a Human Lunar Mission

Chinese space officials have openly discussed plans to conduct spacewalking demonstrations next year, orbital rendezvous and docking operations by 2010, and a robotic lunar landing mission by 2012. Based upon a careful review of open source information concerning the capabilities of the *Shenzhou* crew vehicle and the planned *Long March 5* rocket, it is my considered judgment that, although China's public plans do not include a human lunar landing, China will have the technical wherewithal to conduct a manned mission to the surface of the moon before the United States plans to return.

While initial Chinese mission(s) to the moon would not have the long-term sustainability of our own plans for lunar return, I believe China could be on the moon before the United States can return.

China is prosecuting a fully indigenous program of human spaceflight development. They have adapted the design of the Russian *Soyuz* vehicle to create their own *Shenzhou,* which is more spacious, more capable, and better suited for long duration space missions than its Russian antecedent. China plans to conduct its first spacewalks and orbital rendezvous operations in 2008 and 2010, and to build a small space station in the next few years. All of this has been openly announced. Their accomplishments so far give me no cause to doubt their ability to carry out these plans.

With the first manned *Shenzhou* flight in October 2003 China surpassed by itself the accomplishments of all six U.S. *Mercury* missions in the early 1960s. The second *Shenzhou* flight in 2005 demonstrated most of the accomplishments of the first three U.S. *Gemini* missions in 1965. They will soon demonstrate the rendezvous and docking capabilities pioneered by the U.S. in the Gemini program in 1966, by docking a *Shenzhou* spacecraft with another *Shenzhou,* or with an orbital module left by a prior mission.

These examples illustrate a fundamental difference between the development of the Chinese human spaceflight program, and that of the U.S. and Russia. Because China can follow established technical paths, they do not have to verify the basic feasibility of their approach. They need only to demonstrate that their systems work as designed to accomplish tasks which are by now well understood. Thus, each step in space can take them to a new capability plateau, eclipsing the equivalent of several pioneering but tentative steps in an earlier era. The United States required twenty-one human spaceflights to reach the moon in the 1960s. China should not need so many.

The second major initiative for which the Chinese have demonstrated significant progress is the development of the *Long March 5* launch vehicle. They have conducted several rocket engine tests over the past 2 years, and plan to conduct demonstration flights in 2008–11. The Chinese have advertised its capability as 25 metric tons (mT) to low Earth orbit (LEO), rivaling or surpassing the largest expendable launch vehicles available today, which have a capacity of approximately 20 mT, or slightly greater. I believe that China's concerted, methodical approach to the *Long March 5* development, along with recent construction of a new launch facility on Hainan Island, puts them on track to bring the *Long March 5* online by 2013–14, their stated intention. NASA's *Ares I* rocket, which will have similar capabilities, will not be fully functional until March 2015, according to current plans.

Third, China has developed and demonstrated a dual launch processing capability. This capability, together with the 25 mT-to-LEO capacity of the *Long March 5*, allows China to reach the "tipping point" critical to executing a manned mission to the Earth's moon. As one possible approach, this can be done by means of two dual-launch sequences.

The first *Long March 5* would place, in Earth orbit, a lunar lander similar in size and mass to the Apollo Lunar Module, about 14 mT, together with a lunar orbit injection (LOI) stage weighing 6 mT. With a second *Long March 5* launch, the lander and LOI stage would be joined in Earth orbit by a 25 mT Trans-Lunar Injection (TLI) stage. The two payloads would rendezvous and dock automatically, as the Russian *Soyuz* and *Progress* vehicles do at the International Space Station today. After docking, the TLI stage would send the combined payload to the moon. Injection into lunar orbit would be accomplished by the LOI stage, leaving the lander poised to wait for a few weeks—or even months if necessary—for the second launch sequence.

The second pair of *Long March 5* launches would place in Earth orbit a crewed *Shenzhou* vehicle and LOI stage with one launch, and a TLI stage with the other. As in the earlier sequence, the *Shenzhou* would rendezvous and dock with the TLI stage, which would send the combined stack to the moon. The LOI stage would decelerate the *Shenzhou* into lunar orbit, where it would then dock with the waiting lander. The *Shenzhou* would differ from today's Earth-orbital version in two respects. It would require larger propellant tanks to allow it to depart lunar orbit for the return to Earth, and it might require a thicker heat shield to withstand atmospheric entry upon return from the moon. Neither of these modifications presents a significant challenge. The lunar version of *Shenzhou* would weigh about 11 mT, considerably less than the 14 mT lunar lander, so the delivery of a lunar-capable *Shenzhou* to lunar orbit presents no difficulty.

After rendezvous, the *Shenzhou* crew would transfer to the lander, land on the moon's surface, remain for several days, depart, rendezvous again with the *Shenzhou*, and return to Earth. (Parameters and assumptions for this scenario are summarized in the attached Technical Notes.)

What is fundamentally different about the dual-launch capability that the Chinese have demonstrated, and could well develop for the *Long March 5*, is that it enables human lunar missions without requiring a 120 mT class vehicle like the Apollo-era *Saturn V,* or our planned Shuttle-derived *Ares V.* This technique is not particularly cost-effective and is not easily scaled to a sustainable operation, but it does offer a path to "boots on the moon" without the development of a heavy-lift launch vehicle.

Apart from the lunar lander itself, this approach requires for its implementation only modest developments beyond the existing *Shenzhou* and the *Long March 5* vehicles. The new elements for a lunar mission are the TLI and LOI stages, which would be essentially the same aside from the size of the propellant tanks employed,

and which would utilize the upper-stage engines from the *Long March 5*, with modest improvements. This is a minor developmental excursion from *Long March 5* technology.

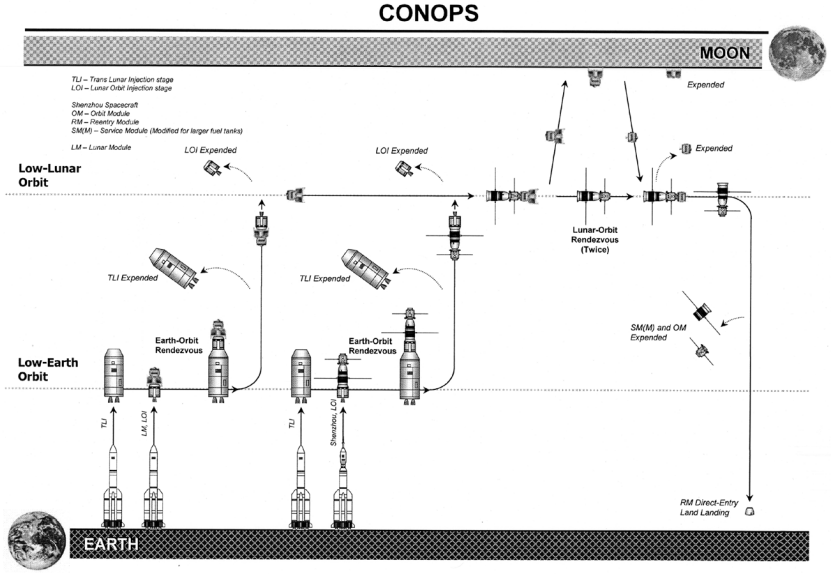
China has not announced any intention to develop a human lunar lander. However, I note that China recently launched its first robotic lunar orbiter mission, and has announced plans for a robotic lander by 2012 and a robotic sample return mission in the 2017–2020 timeframe. The developments in communications, tracking, guidance, navigation, and control required to execute robotic lunar orbital and lander missions are identical to those for a manned system, irrespective of whether or not the lander itself is scaleable to human missions. Inasmuch as the design parameters of the Apollo lunar lander are widely known and well within today's state-of-the-art, the development of a similar vehicle by the Chinese should not present a significant problem.

Pending development of a Chinese manned lunar lander, a fly-by or orbital mission around the moon could easily be executed with the *Shenzhou* spacecraft and a single pair of *Long March 5* launches, as outlined above. Indeed, as a matter of prudent engineering development, I would fully expect China to execute such a mission prior to a lunar landing. This would be completely analogous to the inspirational Apollo 8 mission during the Christmas season of 1968.

Technical Notes

Mission Parameters		
Translunar Injection V (km/s)	3.1	
Lunar Orbit Injection V (km/s)	1.0	
Trans-Lunar Injection		
TLI Stage Gross Mass (mT)	25.0	*Long March 5* payload to LEO
TLI Stage Mass Fraction	0.9	U.S. Centaur upper stage > 0.9
TLI Stage Empty Mass (mT)	2.5	
TLI Propellant Mass (mT)	22.5	
Specific Impulse ($I_{sp,}$ seconds)	450	Modest improvement of YF–75
Net Payload to TLI (mT)	20	
Lunar Orbit Injection		
Lunar Lander Mass (mT)	14	Apollo Lunar Module Mass
LOI Stage Gross Mass (mT)	6.0	
LOI Stage Mass Fraction	0.83	Conservative assumption
LOI Stage Empty Mass (mT)	1.0	
LOI Stage Propellant Mass (mT)	5.0	
LOI Injection Stage I_{sp} (seconds)	450	Same as TLI Stage
Lunar Shenzhou		
Earth Orbital *Shenzhou* Mass (mT)	8.0	
Lunar Departure V (km/s)	1.0	
Lunar Departure Propellant Mass (mT)	2.7	Hypergolic propellants, 310s I_{sp}
Additional Propellant Tank Mass (mT)	0.3	10% of propellant mass
Total Lunar *Shenzhou* Mass (mT)	11.0	Less than 14 mT lunar lander

NASA Concept of Notional Chinese Lunar Landing CONOPS



Dr. GRIFFIN. But, yes, I have stated—actually, I stated this in response to questions and answers following a speech I gave—that the best technical opinion I can give you is that China will be able to put people on the Moon before we will be able to get back. With the completion of their *Long March 5* development that they forecast for the 2012–2013 time-frame, and with the continued development of capability that they've already shown for dual-launch processing, they put themselves—they will put themselves—and, of course, they already have the *Shenzhou* spacecraft—they will put themselves in a position where the only item remaining for their accomplishment would be the construction of an Apollo-class lunar lander, and they would be able to do the job. I find their approach to the development of their space capabilities to be interesting and admirable. I admire what they have done. But I am concerned that it will leave the United States in its wake. And I have expressed that point. I do believe it to be technically—I believe it to be very solidly grounded, technically. I am sorry that, once again, it falls into the category of stuff that Senator Hutchison would label as not encouraging. But it is what it is.

I will give you a more complete answer for the record, sir.

Senator NELSON. Thank you. And since this hearing is about the future, I think it's appropriate to sound the claxon call of alarm that, on the basis of the agenda and schedule that we're going, is that China may well reach the Moon before we return. What does that imply? That could imply all kinds of things, including the defense of this country, particularly since they've already shown us that they can claim the high ground with an ASAT, an anti-satellite weapon that has taken out one of their satellites. And with them holding the high ground of the Moon before we would get

back there, is that a position that the United States of America wants to be in late in the next decade?

And I do not think so. I don't think that's what the American people want. But it's what is a trend, unless we change things.

So, thank you all, gentlemen, for being here today. Thank you for sharing this for the record. Have a good day.

And the meeting is adjourned.

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

A P P E N D I X

National Aeronautics and Space Administration

WORKFORCE TRANSITION STRATEGY INITIAL REPORT
SPACE SHUTTLE AND CONSTELLATION WORKFORCE FOCUS—*March 2008*

Table of Contents

1.0 Introduction

This report responds to direction in the Consolidated Appropriations Act of 2008 (P.L. 110–161):

> *"The Administrator of the National Aeronautics and Space Administration shall prepare a strategy for minimizing job losses when the National Aeronautics and Space Administration transitions from the Space Shuttle to a successor human-rated space transport vehicle. This strategy shall include: (1) specific initiatives that the National Aeronautics and Space Administration has undertaken, or plans to undertake, to maximize the utilization of existing civil servant and contractor workforces at each of the affected Centers; (2) efforts to equitably distribute tasks and workload between the Centers to mitigate the brunt of job losses being borne by only certain Centers; (3) new workload, tasks, initiatives, and missions being secured for the affected Centers; and (4) overall projections of future civil servant and contractor workforce levels at the affected Centers. The Administrator shall transmit this strategy to Congress not later than 90 days after the date of enactment of this Act. The Administrator shall update and transmit to Congress this strategy not less than every 6 months thereafter until the successor human-rated space transport vehicle is fully operational."*

The transition from Space Shuttle to Constellation over the next few years provides a rare opportunity to reinvigorate the Nation's space exploration capabilities. During that time, NASA's greatest challenge and top priority will be to safely fly out the Space Shuttle manifest, complete assembly of the International Space Station (ISS), and honor commitments to our international partners prior to retiring the Shuttle in 2010, all while developing the new Constellation space systems and preparing them for flight as soon as possible after the Shuttle's last mission.

Through this period, NASA's greatest asset will continue to be its people—the thousands of individuals across the country in both government and industry who conceive, design, build, operate, and manage an ambitious program of space exploration on behalf of the Nation. At the same time, our greatest challenge over the next several years will be managing this extremely talented, experienced, and geographically dispersed workforce as we transition from operating the Space Shuttle to utilizing the International Space Station and expanding our reach to the Moon, Mars, and beyond. This report describes NASA's strategy for meeting this challenge, integrated across programs, Centers, and our industry partners. Because this is a dynamic process, future versions of this report will provide updates to both this strategy and the underlying data which drives NASA's strategic and tactical plans.

NASA's most critical resource, and the one which will be most crucial to the success of this initiative, is the highly skilled workforce that will turn the Nation's space exploration policy into a reality. Today, a large portion of the Agency's skilled civil servant and contractor workforce is focused on the safety of ongoing mission

operations. Much of the experience and expertise within this workforce is required for the Constellation program to succeed. However, the effects of the transition will not be the same for everyone. While approximately 80 percent or more of NASA's budget will continue to pay for the purchase of contractor products, goods, and services, the nature of the work being done will change. NASA's human spaceflight workforce will shift from being focused primarily on operating spacecraft to a recurring cycle of spacecraft development and operations. NASA recognizes and values the dedication of its Space Shuttle workforce and will leverage this resource, where feasible, by engaging those men and women in challenging future work that capitalizes on their unique skills and abilities to the maximum extent practical.

All data in this report are NASA's best estimates as of March 2008. The maturity of the data will improve over time and will be updated in future versions of this strategy.

2.0 Background

NASA is managing human spaceflight workforce issues within the broader context of the U.S. Space Exploration Policy and the Agency's overall transition efforts. The *NASA Human Space Flight Transition Plan* (TCB–001) describes the processes by which the Agency manages and integrates all of the strategic and tactical aspects of transition, including workforce. To augment these transition processes and ensure close cooperation and partnering between NASA and industry, a Human Capital Council, comprised of human resources directors from the prime contractors and Centers, has been formed and meets quarterly. Supporting the efforts of the Human Capital Council, NASA and its prime contractors conduct frequent formal and informal Technical Interchange Meetings including a broad range of participants.

In addition to these standing Agency transition processes, NASA also tightly integrates transition workforce planning into its acquisition and budget development activities. NASA uses a strategic acquisition approach for make/buy decision and contracting. For example, a senior-level leadership forum reviews and approves Center acquisition strategies. Criteria during these reviews include any impacts of decisions on the health of the workforce at NASA's Centers, and any new programs, major program shifts, or major new institutional initiatives are coordinated through this process. Acquisition strategy planning decision meetings will occur semi-annually, synchronized to the President's budget development, as well as when any significant new mission element or program is proposed.

The annual Planning, Programming, Budgeting, and Execution (PPBE) process involves planning, analysis, recommending requirements, and developing decision packages as part of the Agency's development of the President's budget request. Transition workforce planning across the programs, the institutions, and Headquarters has shaped the last several budget development cycles and will continue to be a critical component of the budget process.

NASA's contractor workforce is vital to success. The Agency and its Space Shuttle prime contractors have developed and implemented a range of personnel management tools to help safely manage operations through retirement. It is important to note that while NASA directly plans and controls its civil servant workforce, the Agency does not determine the personnel levels of the contractor workforce. Instead, NASA purchases the products and services they provide as part of the national human spaceflight workforce and aerospace industrial and supplier base. NASA expects that many of its contractors will apply their human spaceflight workforce to the design, development, test, and integration of new human spaceflight and support systems. At the same time, containing workforce costs for exploration is key because NASA's new systems must cost less to produce, process, launch, and operate or the Agency will not have the resources to return to the Moon.

NASA Organization and Current Workforce Distributions

The Space Operations Mission Directorate (SOMD) oversees NASA's operational space capabilities, including the Space Shuttle, International Space Station, Launch Services, Space Communications and Navigation, and Rocket Propulsion and Test programs. The 2008 Space Shuttle workforce includes approximately 15,000 contractors and 1,700 civil servants in locations across the country (Figure 1).

NASA Organization and Current Workforce Distributions

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Figure 1: Major Space Shuttle Program Facilities

The Exploration Systems Mission Directorate (ESMD) oversees the Constellation, Human Research, Exploration Technology Development, and Lunar Precursor Robotic Programs, as well as the Commercial Orbital Transportation Services (COTS) project through the Commercial Crew and Cargo Program Office. Constellation Program work takes place across NASA's ten Centers and at prime contractor and subcontractor locations throughout the country. The Constellation Program project elements include the Orion Crew Exploration Vehicle (CEV), the Ares I crew launch vehicle, and extravehicular activity systems. NASA's first new Constellation human spaceflight capabilities will be Orion and Ares I, which will be followed by the development of the Ares V heavy-lift launch vehicle, the Altair lunar surface access module, and other systems necessary to support the exploration of the Moon, Mars, and beyond. Figures 2 and 3 highlight the Constellation Program Center work distribution.

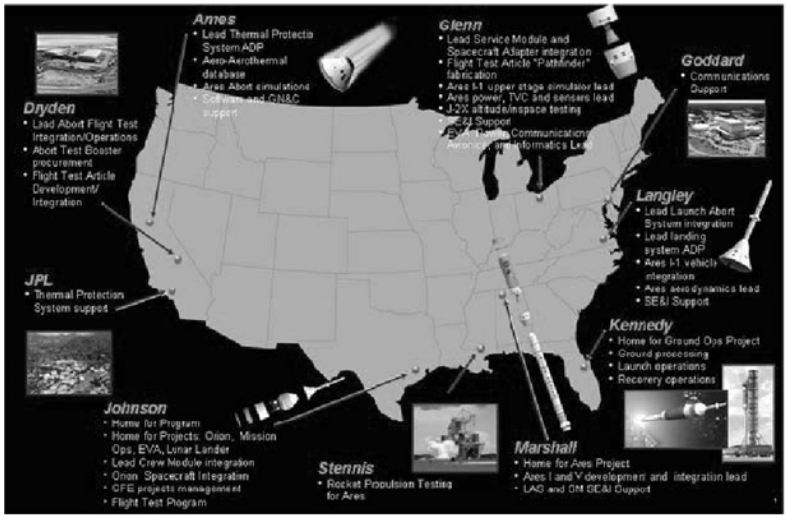


Figure 2: NASA Center Constellation Work

Figure 3: Constellation Work Distribution Nationwide

To manage an efficient and cost-effective transition of workforce, facilities, and contractor support from the Space Shuttle Program to the new Constellation Program, the NASA leadership team must ensure that our workforce skills are rebalanced to meet the evolved focus of the Agency, and effectively communicate our actions and goals to all of our stakeholders, most importantly our employees.

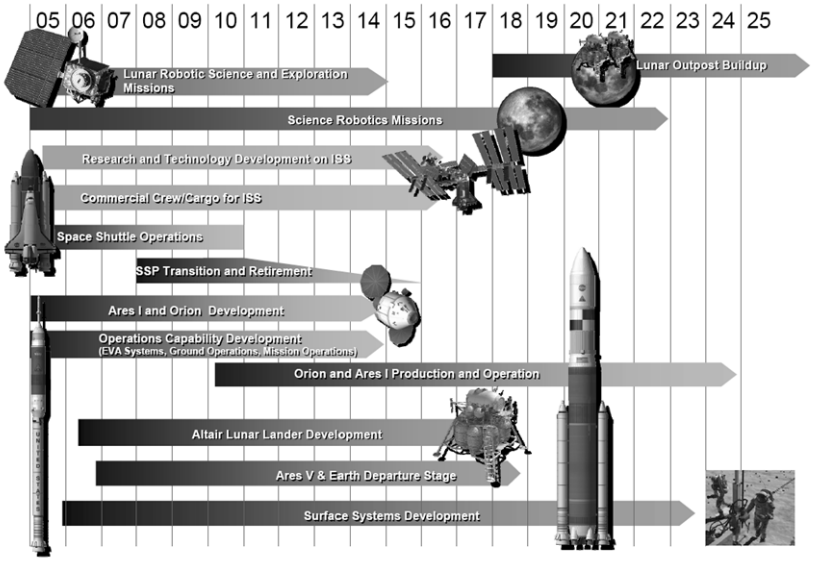


Figure 4: Space Shuttle's Legacy and Constellation's Future

While there will be a gap between flights of Shuttle and Ares I/Orion, a great deal of development activity is planned during this time, including Orion abort testing at White Sands Test Facility (WSTF), the Ares I–Y flight test at Kennedy Space Center (KSC), J–2X engine integrated development and testing at Marshall Space Flight Center (MSFC) and Stennis Space Center (SSC), and new testing and operations facility construction at SSC and KSC. NASA may schedule additional flight tests as requirements and program plans continue to mature. These and many other development and construction activities across all NASA Centers will provide the workforce with many opportunities to remain engaged with meaningful work between flights of Shuttle and Orion. Transition also provides an opportunity for NASA to forge a new line of business—to re-invent, re-invigorate, and re-vitalize the Nation's spirit and capacity for human space exploration.

Overall, NASA will spend the same amount on skilled labor as it has during the Space Shuttle era, but with a growing emphasis in the near term on the design of new vehicles to explore beyond Earth orbit. Further, NASA is committed to ensuring that all ten Centers remain fully capable of leveraging their unique resources and rich heritage by supporting Exploration work as well as NASA's scientific and research missions.

NASA's new systems must cost less to produce, process, launch, and operate or the Agency will not have the resources to further develop the vehicles and systems needed to return to the Moon. As NASA transitions, some of the workforce will move from Space Shuttle and ISS operational work to new vehicle design, development, test and evaluation (DDT&E) work. Regional workforce impacts of shifting from "vehicle processing" and "operations" to DDT&E activities are becoming clearer and will be outlined in subsequent sections of this report. Reducing the impacts to specific regions will require the assignment of specific Constellation development, test and manufacturing work to affected NASA Centers as the Space Shuttle is retired. Since upcoming Constellation contracts are competitively awarded, NASA cannot provide exact contractor workforce numbers or the location of the work performed beyond already awarded current work assignments. However, where possible, this report will provide forecast estimates for these assignments while still preserving the integrity of future acquisition activities.

As future procurements are conducted, contractors selected, and contracts awarded, a more comprehensive public assessment will become available during 2008 and 2009. For example, this past year, NASA announced the winning contractors for the

Ares I Upper Stage and Ares I Instrument Unit, but the contracts for the Ares V Core Stage, Earth Departure Stage, and for Altair have not yet been completed. Selection of contractors for these efforts will greatly influence contractor employment in the locations in which the work is performed. For those contracts that were awarded recently, NASA is still working with industry to refine contract related information, such as workforce levels. Further, the systems remain under development and the workforce requirements for the ground operations and launch processing for Orion/Ares at KSC are still being determined, with the program attempting to minimize the cost of operations of the new systems. As both requirements and plans solidify during the current and future budget cycles, NASA will have more precise information on the workforce impacts in particular areas.

NASA Transition Workforce Strategy

NASA's strategic approach to ensuring that critical skills are retained is fundamentally simple: provide a clear career path to challenging and exciting follow-on work in Constellation and on other programs, maintain NASA's quality workplace by providing a collaborative and creative environment, and support career development and learning opportunities. NASA is committed to transitioning the key Space Shuttle civil servant workforce to other Agency programs as is necessary using tools such as workforce synergy, matrixing, detailing, and retraining. In addition, Centers identify opportunities for the placement of employees with needed skills in other organizations.

Three key documents form the foundation for the NASA transition workforce strategy:

- *NASA Workforce Strategy,* 2006.
  http://nasapeople.nasa.gov/HCM/WorkforceStrategy.pdf.
- *NASA Human Capital Plan for Mission Execution, Transition, and Retirement of the Space Shuttle Program,* 2006.
  www.nasa.gov/pdf/218792main__SSP__human__capital__plan.pdf.
- *NASA Human Space Flight Transition Plan* (currently being updated as the NASA Transition Plan, 2008).
  http://spaceoperations.nasa.gov/tran__plan.pdf),

NASA has created seven goals focused on the human spaceflight workforce:

NASA's Human Space Flight Workforce Goals

1. Enable a capable and committed workforce to fly the Shuttle as safely as possible until its retirement in 2010 and complete the ISS in a manner consistent with NASA's International Partner commitments.
2. Make available the workforce required to advance Constellation to initial operating capability, both during the period of completing the Shuttle manifest through fiscal year 2010 and the period between the last Shuttle mission and the first Constellation mission.
3. Retain critical skills through the gap between the last Shuttle mission and the first Constellation mission.
4. Use the experienced, dedicated and skilled Shuttle and ISS industry workforce to the maximum extent required to implement Constellation.
5. Maintain ten "healthy" NASA Centers.
6. Identify and manage workforce geographic dislocation.
7. Maximize workforce efficiency and knowledge transfer through workforce sharing and synergy among NASA programs.

From these goals, NASA has created three specific workforce objectives:

NASA's Human Spaceflight Workforce Objectives

1. Retain the skills for Space Shuttle operations to safely execute the remaining Space Shuttle missions;
2. Manage the transition of appropriate Space Shuttle workforce into Constellation development; and
3. Retain the skills after Shuttle retirement that are needed to safely prepare for and execute the Constellation Initial Operational Capability (IOC) in 2015 and flight operations beyond.

NASA is committed to working with the aerospace contractor community on workforce issues. The Agency's industry partners have a range of transition, retention, and staffing tools available to maintain critical skills to meet their contractual obligations required for safe Space Shuttle mission execution. Specific impacts will be unique to each contractor, depending in part on its role in future Constellation work and its skill set. NASA is also committed to the equitable distribution of tasks and workload among the Centers, leveraging the core technical capabilities of NASA's workforce and infrastructure, and limiting the impact of workforce changes to local communities of workforce changes. In the end, though, Constellation program requirements will drive Constellation's workforce size and skills needs.

NASA has provided the Space Shuttle prime contractors with a number of opportunities to help safely manage the Shuttle operations through FY 2010 and to prepare the contractor workforce for Shuttle retirement. This includes opportunities for employees to do work on several different NASA programs, acquire skills retraining, and in selected cases, receive retention bonuses. NASA remains committed to working with its industry, supplier, and research partners to craft and implement strategies to minimize disruption, upheaval, and economic impact, while maximizing support vital for Shuttle missions and program requirements.

NASA buys products and services from industry, and does not determine contractor workforce levels. However, the Agency has made a substantial investment in training an industrial human spaceflight workforce with unique skills. NASA believes that the highly skilled, experienced, and dedicated human spaceflight workforce of the Space Shuttle and International Space Station programs will be employed by successful bidders for future Constellation development work, but the 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 and the implications for the contractor workforce will become clearer.

While NASA maintains internal Government estimates for likely future contractor costs and workforce at NASA Centers for future contracts, these estimates are procurement sensitive and not released to the public. In some cases, NASA is still formulating the acquisition strategy and developing detailed procurement plans, including the division of work between civil servants and contractors and the Center at which the work will be conducted. Ultimately, Constellation program requirements will drive the workforce size and skills needs in the acquisition process. See Appendix C, "NASA Non-Sensitive Integrated Acquisition Roadmap", for more details.

3.0 Workforce Initiatives

NASA has undertaken a number of specific initiatives aimed at meeting its workforce goals. The total civil servant workforce level is expected to remain relatively constant through the transition from Space Shuttle to Constellation. NASA contractors are primarily responsible for implementing any initiatives needed to keep a skilled and robust contractor workforce in place and ready to perform its critical function of delivering products and services. NASA has been strongly engaged with its contractor partners in these activities at both the strategic and tactical levels.

Important milestones for NASA workforce planning include the design milestones for Constellation Program, the development contract start dates for Constellation, and the retirement of the Shuttle by the end of FY 2010. Constellation Design Reviews and the Space Shuttle manifest are shown on the NASA Multi-Program Integrated Milestones (MPIM) chart (Appendix D), and Constellation Procurement milestones are shown on the NASA Non-Sensitive Integrated Acquisition Roadmap (Appendix C). By completing the Constellation design reviews, NASA and its prime contractors determine in detail what work needs to be performed to develop Constellation vehicles, and by awarding the prime contracts for IOC, NASA determines who in industry is going to perform the work, where it will be performed, and what quantity of which skills are needed to deliver the products and services.

As NASA reaches the end of the Space Shuttle Program, specific Space Shuttle contract actions will be used to retain workers needed for Space Shuttle even as new Constellation work is competed with industry. NASA is assisting in the development and implementation of contract workforce retention plans for each Space Shuttle prime contractor, with a focus on communication and future work. In some cases, prime contractors are implementing monetary retention incentives. As appropriate, the contractor community is using a range of tools, such as cross-training, to demonstrate a future path for employees, as well as embedding personnel with operational experience in the design phases of Constellation's vehicles.

Additional initiatives will continue to be worked as part of the current budget development process, and NASA will provide updates to the status of these items in future updates to this report.

Space Shuttle Workforce Surveys

Background: The safety and success of the Space Shuttle Program depends on a skilled, focused, and motivated workforce. As the retirement of the Space Shuttle approaches, there is a large and growing need to ensure that there are enough skilled team members to support safe operations through the conclusion of the Space Shuttle Program. Annual surveys of the Space Shuttle civil servant and contractor workforce help NASA leadership monitor trends and refine communications and incentive activities aimed at retaining these critical workforce capabilities.

Status: The confidential 2007 Shuttle Employee Survey involved over 2,800 civil servant employees at KSC, JSC, MSFC, and SSC. The survey included employees who charged time to the Space Shuttle Program from October 2006 to May 2007. The survey was web-based and conducted between June 25 and July 13, 2007. Response rates from the four Centers were quite good, ranging from about 34 to 44 percent.

General observations from 2007's survey include:

- There continues to be a great deal of goodwill toward the Space Shuttle Program.
- Sixty-five percent of employees indicated that they will stay until the end of the program.
- Employees are nervous about the future, both their own and the Agency's. They are concerned about having meaningful work now and in the future, and about job security.
- Employees are concerned about the funding stability of the Constellation program.

These observations indicate a continuing need to improve communication at the Agency, Center, and program level. At the Agency level, NASA needs to continue to share the U.S. Space Exploration Policy, plans, and vision. At the Center level, the human spaceflight Centers must address workforce issues and concerns. At the program level, the three human spaceflight programs have to provide employees the status of Space Shuttle transition and retirement activities, plus information on new contracts and program progress.

Workforce Synergy, Matrixing, Detailing, and Cross-Training

Background: NASA uses the matrix form of management (or organizational structure) to support its multiple programs. In this approach, the functional skills (such as engineering, operations, etc.) are "sourced" within a Center and the program(s) tap into the expertise as needed. For example, the structural engineering function resides within the engineering organization allowing the managers and structural engineers to support not only the Shuttle Program, but potentially the Station and Constellation Programs as well. Not only does this allow for cross-training and broader skill development, but helps supervisors manage peaks and valleys in workload.

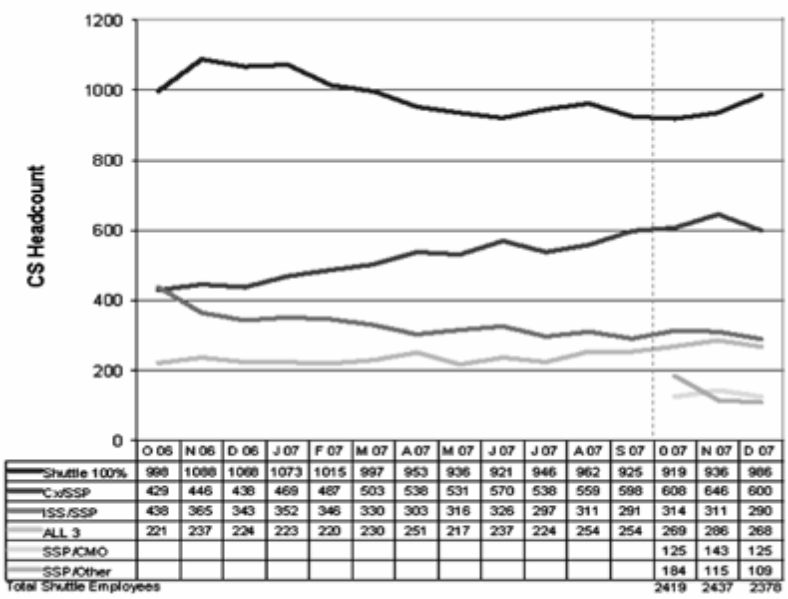
To build crossover skills for employees, NASA has made a concerted effort to share civil servant and contractor workforce across the programs (especially between Space Shuttle, ISS, and Constellation). This workforce synergy enables the Constellation Program to make steady progress toward its development and operational goals while ensuring the continuing availability of the critical skills necessary to safely and efficiently execute the remaining Space Shuttle missions. In addition, this synergy encourages transferring lessons learned, accounting for operations needs in spacecraft systems design, and showing employees the future of human spaceflight with the Constellation Program. NASA is providing the tools, training, and time for civil servant and contractor workers to gain experience and skills on new processes that NASA will implement for Orion and Ares. This hands-on experience will increase employee familiarity with the new techniques and qualify them for future work.

In addition, Centers are partnering with the programs to look for opportunities for retraining. For example, KSC identified several likely positions for Fuel Cell Engineers currently supporting the Shuttle Program to transition to Constellation in support of Cryogenic Systems or Environment and Crew Life Support Systems (ECLSS). Currently, the KSC training and development office is in the process of creating training plans that will identify the precise pathway for these individuals to transition to the new roles.

Status: NASA is tracking and comparing civil servant time spent on Space Shuttle, ISS, and Constellation. Based on the 2007 Shuttle Workforce Survey (the second year the survey has been taken), over 57 percent of those responding provide regular support to programs and projects outside of the Space Shuttle Program. The following data is for civil servant employees at each of the four main human spaceflight Centers that supported more than one program in 2007. The trends are showing increasing use of this effective practice, even with the unforeseen impacts of the additional work required to repair the Space Shuttle external tank damaged during the hail storm in 2007 and the engine cut-off (ECO) sensor challenges during STS–122. The following shows the percentage of civil servant employees at each of the four main human spaceflight centers that supported more than one program (Space Shuttle, ISS, and Constellation) in December 2007:

- Kennedy Space Center (KSC) 56 percent
- Johnson Space Center (JSC) 61 percent
- Marshall Space Flight Center (MSFC) 56 percent
- Stennis Space Center (SSC) 83 percent

Figure 5 shows the number of civil servants working full-time for Space Shuttle, ISS, Constellation, Center Management and Operations (CM&O), "Other", as well as the number of employees who split their time between multiple programs. The data is current as of January 2008.



	O 06	N 06	D 06	J 07	F 07	M 07	A 07	M 07	J 07	J 07	A 07	S 07	O 07	N 07	D 07
Shuttle 100%	998	1088	1068	1073	1015	997	953	936	921	946	962	925	919	936	986
Cx/SSP	429	446	438	469	487	503	538	531	570	538	559	598	608	646	600
ISS/SSP	438	365	343	352	346	330	303	316	326	297	311	291	314	311	290
ALL 3	221	237	224	223	220	230	251	217	237	224	254	254	269	286	268
SSP/CMO													125	143	125
SSP/Other													184	115	109
Total Shuttle Employees													2419	2437	2378

Figure 5: Transition of Civil Servant Employees

Based on workforce synergy metrics, from October through June of 2007, the number of civil servants charging to both the Space Shuttle and Constellation programs increased by 33 percent, while the number charging to both the ISS and Constellation increased by 23 percent. In addition, Shuttle contractor workforce has been used for Constellation Program tasks. Examples of synergy across the programs include the following:

- On STS–118, Shuttle Orbiter *Endeavor* was powered up before its mission using a new "paperless" process as a test of future procedures for the Orion spacecraft.
- For STS–120, a single Solid Rocket Booster was stacked one segment at a time to gather engineering information for the Ares I–X launcher, which will also use segmented solid rockets stacked singly. The Space Shuttle Program has also begun demonstrating new paperless, electronic procedures for processing solid

rocket motors in the Rotation, Processing, and Surge Facility (RPSF) and the Vehicle Assembly Building (VAB).

- The United Space Alliance (USA) Space Programs Operation Contract (SPOC) workforce is being used by Constellation to process the Ares I–X vehicle for the first Constellation test flight (scheduled for April 2009). The first Constellation flight of Ares will be conducted by many contractor personnel from the Space Shuttle workforce.
- Pratt & Whitney-Rocketdyne's Space Shuttle Main Engine employees across all sites spend approximately 20 percent of their time on other programs. Some examples of areas where this is occurring are combustion devices engineering, manufacturing engineering, electrical engineering, software engineering and business operations in support of J–2X development for Ares I and Ares V.
- Constellation's Orion project is defining a Relative Navigation Sensors Development Test demonstration, which would be conducted on a Space Shuttle flight in 2009 or 2010. This test would demonstrate operation of Orion navigation sensors on the Shuttle as it navigates near the ISS, similar to Orion's initial missions planned to the Station.
- To help retire the risk of Ares I first stage thrust oscillations, a Space Shuttle reusable solid rocket booster will be instrumented to simultaneously measure pressure, sound pressure level and acceleration in 2009 and 2010.

NASA has also assigned specific work tasks to Space Shuttle Government and contractor organizations to prepare their staffs for future positions, while providing work needed today for Constellation. Expanded industry workforce skills can be developed in a variety of ways under Space Shuttle contracts. In some cases, Constellation tasks are added to Shuttle contracts and Shuttle workers are able to broaden their skills applicability to Constellation work by performing actual contract tasks.

Workforce Skills Mapping

Background: The purpose of the Space-Shuttle-to-Constellation Workforce and Skills Mapping activity is to provide the requisite baseline data necessary to facilitate Agency management of personnel and skill needs across the portfolio, develop appropriate transition strategies, uncover potential problems, and test assumptions about mitigation actions.

Status: Phase I of the mapping activity, completed in the fall of 2007, focused on the civil servant work force. In this phase, the four traditional human spaceflight centers (JSC, KSC, MSFC, and SSC) compared Constellation's project needs with Shuttle workforce becoming available after the Shuttle Program ends, and assessed how well this demand and supply matched at a skills level. The Phase I assessment was designed to help the Agency uncover issues related to migration of workforce from Shuttle to Constellation after 2010, so that Centers and programs could add or refine human capital strategies for the placement and training of civil servant workforce in time for the major transition years of 2010 and 2011.

Although Constellation workforce demand projections at each Center used in Phase I were considered preliminary (particularly the projections for Fiscal Years 2013 through 2015), the study nonetheless resulted in the identification of a few skill mix issues at each Center that would likely remain even as Constellation demand is further refined. Furthermore, Phase I yielded more detailed information about how the Centers were planning to migrate specific skills to the Constellation program post-2010, and identified a set of issues for each Center that required specific near-term actions or special attention during the Fiscal Year 2010 budget planning cycle.

Phase II, currently underway and nearly complete, focuses on contractor data for on, near, and off-site contractor personnel, and expands the scope to all ten NASA Centers from the previous four human spaceflight operations centers. The purpose of this phase is to bring more quantitative rigor and detail to contractor workforce supply and demand projections. Phase III, scheduled for the third and fourth quarter of Fiscal Year 2008, will refresh the Phase I civil servant data with new information available from the Fiscal Year 2010 planning cycle, assess the validity of initial findings, and check progress of mitigation actions undertaken as a result of Phase I. The Agency will continue to refresh both civil servant and contractor data as part of the budget planning cycle each year between now and 2011.

Communications

Background: NASA's workforce surveys have indicated that communication is the key to managing the workforce during transition. NASA and its prime contractors are engaged in a robust communications effort at all levels to ensure that the work-

force is kept informed of current programs and future plans. The Agency is utilizing many tools and media options to make this possible, and the effectiveness of these tools is continually evaluated in both surveys and by monitoring various media metrics.

Status: The recent establishment of the external Space Shuttle transition website at *www.nasa.gov/transition* is an important step toward providing ready and open access to key NASA transition information. Additionally, a host of internal secure websites, newsletters, supervisor talking points, and monthly news articles add new elements to the NASA toolkit for communicating with the work force. Notable among the tools in use are *Rendezvous* magazine and other periodical publications.

In addition, a number of other communications methods and products are used, such as manager talking points, program websites, feedback groups, all-hands meetings, Transition "road shows," and quarterly program updates. Public briefings at symposia, conferences, and industry events are also frequently conducted to ensure the widest audience possible.

Figure 6: Examples of NASA Publications to Communicate with Shuttle Workforce

4.0 Distribution of Workload and Tasks to Centers

Background: New work assignments from ESMD have been distributed across the various Centers to not only leverage resident capabilities and expertise, but also mitigate some of the effects of Space Shuttle retirement. Analysis of current and projected workforce needs resulted in the following considerations being viewed as primary drivers behind workforce and workload allocation:

- geographical location of the work and workforce demographics;
- acquisition approach;
- degree of heritage system or support infrastructure composition in new vehicle architecture;
- unique skill set requirements or resources available;
- dynamics in work assignments and future assignment allocations;
- Operations/Development/Sustaining Engineering definitions, budgeting and mission splits, and transition funding;
- contractor-unique workforce issues; and
- NASA's repeated cycling from predominantly operations to development work as new systems are developed and fielded.

A sound baseline of data from which to build is fundamental to the success of NASA's evolving workforce strategy, and the results of the current workforce initiatives are central to any equitable evaluation of re-distribution, tailoring, or modifications to existing or projected Agency workload. However, each NASA Center has specific and unique capabilities and resources to execute their core competency mission areas. Awarding lunar contracts as soon as possible provides evidence of emerging opportunities, reduces workforce concern about the end of the Shuttle Program, and facilitates workforce strategy development and mitigation plans.

Status: NASA has made Exploration lunar lead and support role and work assignments that leverage expertise across the NASA Centers and facilities. These work assignments are provided in the table in Appendix A.

NASA is analyzing the costs and refining the method of retiring the Space Shuttle after its last mission in 2010. Space Shuttle Transition and Retirement work plans have been approved though the end of the Space Shuttle Program in 2010, but plans and costs for the remaining work to be conducted after 2010 are still being studied and are expected to be defined at the time the President's 2010 Budget Request is submitted in Congress in February 2009.

The following Center breakdown highlights the trends and major Transition-related activities that are and will be occurring that impact workforce utilization and future projections.

Johnson Space Center

JSC continues program management and mission operations for the International Space Station after the Space Shuttle's last mission in 2010. Management of Orion development continues, as well as mission operations capability development to enable Orion's first piloted spaceflight. Design and development of the Altair Lunar Surface Access Module does not begin on a large scale until 2011 and beyond. JSC's projected contractor workforce level is slightly lower in FY 2011 after the completion of the Space Shuttle Program.

Marshall Space Flight Center

MSFC continues management and sustaining engineering of the Space Shuttle's propulsion systems until completion of the last Space Shuttle mission in 2010. MSFC continues the design and development of the Ares I Crew Launch Vehicle from 2005 to 2015, while design and development of the Ares V Cargo Launch Vehicle will take place in 2011 and beyond. MSFC's projected contractor workforce level is approximately level over the years, due to more Ares V design work commencing right after Space Shuttle completes its last mission.

Kennedy Space Center

KSC completes Space Shuttle launch and landing work in 2010. In 2007, NASA started the construction of facilities modifications to KSC to prepare for the Ares I–X test flight in 2009, as well as for the later launch of Ares vehicles. NASA does not gather comprehensive workforce information for construction of facilities work, so not all of this work is included in Agency projections. NASA is still studying the tasks and contracts required for ground processing of the integrated Orion/Ares I vehicle, and only Government internal estimates are available for budget and work force. A Request for Information (RFI) for Constellation Ground Processing Services was released in February 2008, which will be followed by industry brief in the late summer of 2008 and a Request for Proposals in spring 2009. Contract selections and awards are expected in 2010. Analysis of the results from this RFI and follow-on activity is expected to have a significant impact on workforce planning at KSC and will be documented in future updates to this plan. KSC's contractor workforce is expected to decrease from FY 2010 to FY 2011. Work required at KSC to retire the Space Shuttle after 2010 is still being refined and is not included in these estimates. These estimates also do not include work still under negotiation between NASA Centers or prime contractors and subcontractors which will probably be reallocated to the launch site.

Stennis Space Center

SSC is transitioning from support of Space Shuttle Main Engine propulsion testing to propulsion test development for Constellation's new J–2X and RS–68B engines. Significant construction of facilities activities, including the A–3 Test Stand, is currently underway.

Michoud Assembly Facility

The Michoud Assembly Facility (MAF) will complete production of External Tanks for the Space Shuttle in 2010. Starting in 2008, MAF will begin preparations to start production assembly of upper stage tanks by Boeing for the Ares I launch vehicle. Lockheed Martin plans to use MAF for selected Orion Launch Abort System developments. NASA will select a new multi-program Facility Operations and Maintenance contractor in early FY 2009; NASA is still studying the scope and work required to conduct that function for all the NASA programs which will use MAF, so those estimates are not included. Production and test of the Ares V Core Stage and Ares V Earth Departure Stage begin ramping up in FY 2011; NASA is still studying the tasks and contracts for Ares V work, so these elements are not included in the estimates for MAF. NASA is considering early Ares V risk reduction and skill reten-

tion manufacturing tasks at MAF, but in 2008 these are only being evaluated for a later decision. Work required at MAF to retire the Space Shuttle External Tank production after 2010 is still under study and is not included in these estimates.

5.0 Workforce Projections

Background: NASA's projections for Center civil servant and contractor workforce levels are based on data from the Space-Shuttle-to-Constellation Workforce Mapping activity and updates to civil servant full-time equivalent (FTE) and contractor work-year equivalent (WYE) requirements from the Agency budget planning process. This is an evolving effort and will be updated accordingly as the data and information are further refined.

Status: NASA's bottom-up estimates in 2007 and early 2008 show a lower number of contractor work-year equivalents in FY 2011 than in FY 2010 because:

1. Space Shuttle work, which ends in FY 2010, is well defined, with predictable contractor workforce information provided by the existing contractors based on extensive experience.

2. As a mature, operational program, Space Shuttle budget maintains a low level of annual budget reserve. The direction of budget reserve to solve problems (by paying staff overtime or surge skills) does not drive gross change in the workforce distribution between various sites.

3. Given that the Constellation Program's Ares I and Orion projects are still in their early phases, work to be conducted at the production, assembly, and launch sites is still not fully defined, nor are contractor work-year equivalents fully mapped to the correct work location (see KSC estimates, below).

4. NASA is planning the work to be contracted for vehicle processing and operations. Once the planning is competed and providers selected, the industry workforce levels will be clearer. NASA's internal assessment is that less vehicle processing and operations labor will be needed to launch two Orion/Ares I missions each year to the International Space Station than that required to maintain the Space Shuttle for flight.

5. Current estimates are that several thousand fewer contractor positions may be required at KSC for that work after FY 2010, but more accurate information will not be available until vehicle processing contact work planning is better defined. These numerical estimates are based on work assigned to KSC during the FY 2009 formulation process negotiated with companies to provide these contracted products and services, these numbers will be based on internal government estimates.

6. Because the Constellation Program is still early in development and has not yet gone through Preliminary Design Review, budget reserves in later fiscal years (starting FY 2011) are not yet allocated to specific work, as the final allocation will be based on what challenges occur during development; these will not be identified for several years.

7. The Constellation lunar work for Ares V and Altair—including early technology development for these efforts—is in the early stages of planning, so the work allocation and time phasing are still internal government estimates until the final phasing is confirmed. This leads to less work being explicitly defined in FY 2011 and beyond than that supported by the budget; these data will be better defined over the next year.

8. NASA has not yet authorized the exact work which will be conducted to close-out and retire the Space Shuttle after FY 2010, primarily at KSC, MAF, and Shuttle Prime Contractor sites. That work will be better defined later in 2008 as part of the current budget process.

9. NASA does not uniformly gather data from contractors conducting construction of facilities projects, as these are not long-term, contracted efforts involving R&D. However, modification of facilities to support future Constellation development and operations has already started. Work will continue on construction of facilities for this through the gap in flights between Shuttle and Constellation. Some estimates are included, but these are not inclusive.

10. NASA does not gather data from companies participating via Space Act Agreement in the Commercial Orbital Transportation Services (COTS) activity, nor will NASA collect data from the follow-on Commercial Cargo services for ISS, as these are purchased services. After the last Space Shuttle mission, NASA will increase the percentage of budget going to procure these services and they will likely comprise part of the overall NASA contractor figures.

Specific Workforce Information by Center/Location

Note on contractor workforce estimate numbers: In order to project probable contractor workforce levels in the future, NASA gathers information from contractors on their current work, makes internal government estimates, and estimates allocation of future budget reserves not yet assigned to any contract. These can include NASA estimates of future budget reserves according to pro-rata distributions or technical risk assessments, as well as estimates of the percentage of funds used to design and develop new and unique products versus raw materials or purchased services. Contractor workforce projections for these years therefore may contain data which are the sum of: (a) defined, approved work on contract; (b) the government's estimate of work not yet awarded or negotiated (*i.e.,* procurement-sensitive information); (c) an informed estimate for budget reserves allocated to mitigate not-yet-identified future technical problems; and (d) potential work not yet assigned by the government but under internal consideration. The details of these estimates cannot be made public, as potential bidders could use that information to determine the government's "should cost" estimate, or existing contractors could use that information to propose work up to that level. Additionally, many of the specific contractual details are still being refined as NASA continues to develop the appropriate acquisition strategies to meet its mission objectives at best value to the Nation.

Pursuant to P.L. 110–161, Table 1 provides specific annual civil servant and contractor workforce projections for the four human spaceflight Centers (as well as MAF) that are most affected by the Shuttle-to-Constellation transition, including a low and a high range based on the variability in data inputs discussed above.

Space Shuttle and Constellation Workforce Estimates - as of March 2008

NOTE CAVEATS BELOW

Category	FY08	FY09	FY08-09 Delta	FY10	FY09-10 Delta	FY11	FY10-11 Delta	FY12	FY11-12 Delta	FY13	FY12-13 Delta
Nationwide											
Shuttle + Constellation FTEs	4,700	4,400	-300	4,200	-200	4,100	-100	4,200	100	4,300	100
Shuttle + Constellation WYEs (low)	20,900	20,200	-700	18,700	-1,500	12,500	-6,200	14,100	1,600	15,100	1,000
Shuttle + Constellation WYEs (high)	21,000	20,300	-700	19,100	-1,200	13,800	-5,300	15,700	1,900	17,000	1,300
Kennedy Space Center											
Shuttle + Constellation FTEs	1,000	1,000	0	1,000	0	1,000	0	1,000	0	1,000	0
Shuttle + Constellation WYEs (low)	8,000	7,300	-700	6,400	-900	1,600	-4,800	2,200	600	2,400	200
Shuttle + Constellation WYEs (high)	8,000	7,400	-600	6,700	-700	2,300	-4,400	3,100	800	3,800	700
Johnson Space Center											
Shuttle + Constellation FTEs	1,400	1,400	0	1,400	0	1,200	-200	1,200	0	1,300	100
Shuttle + Constellation WYEs (low)	5,900	6,000	100	6,000	0	3,700	-2,300	3,800	100	3,500	-300
Shuttle + Constellation WYEs (high)	5,900	6,200	300	6,600	400	5,500	-1,100	5,700	200	5,800	100
Marshall Space Flight Center											
Shuttle + Constellation FTEs	1,200	1,200	0	1,200	0	1,200	0	1,300	100	1,300	0
Shuttle + Constellation WYEs (low)	2,700	2,900	200	2,900	0	2,800	-100	3,000	200	3,100	100
Shuttle + Constellation WYEs (high)	2,700	3,100	400	3,500	400	4,400	900	5,100	700	5,500	400
Stennis Space Center											
Shuttle + Constellation FTEs	100	100	0	100	0	100	0	100	0	100	0
Shuttle + Constellation WYEs (low)	300	300	0	300	0	200	-100	200	0	100	-100
Shuttle + Constellation WYEs (high)	300	300	0	300	0	200	-100	200	0	100	-100
Michoud Assembly Facility											
Shuttle + Constellation WYEs (low)	1,900	1,400	-500	800	-600	600	-200	600	0	600	0
Shuttle + Constellation WYEs (high)	1,900	1,400	-500	800	-600	1,100	300	1,100	0	1,100	0

Increasing Uncertainty

Caveats:

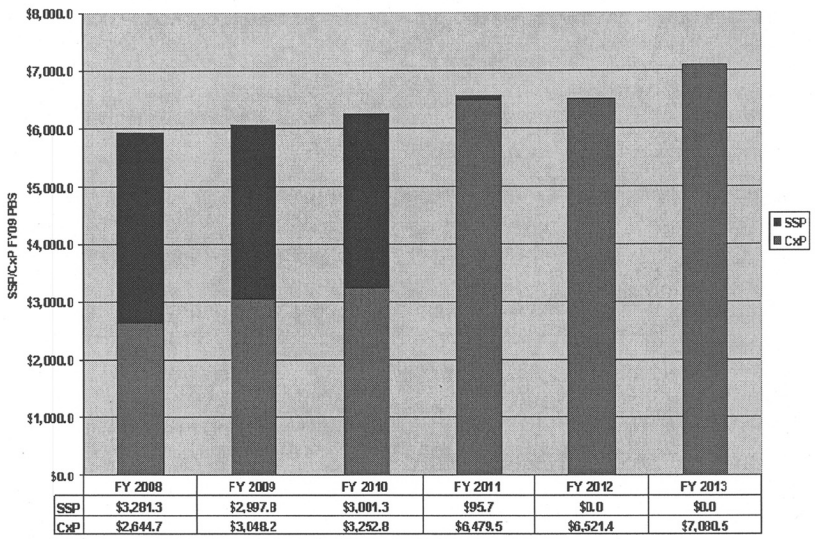
1) This table covers civil service and contractor personnel working on the Space Shuttle and Constellation programs at the Centers noted; it does not display the total Center workforce, and it does not include students involved with the programs.
2) "Nationwide" workforce estimates include personnel working on the Shuttle and Constellation programs beyond the Centers noted in the table.
3) FTE = Civil Servant Full Time Equivalent.
4) WYE = Contractor Work Year Equivalent.
5) See pages 19 - 20 of the March 2008 Workforce Transition Strategy, "Workforce Projections", for further notes on this table.

Table 1: Human Spaceflight Center Workforce Trends (Shuttle and Constellation Only) FY 2008 – FY 2013

NASA has focused its analysis to this point on the retirement of the Shuttle, which primarily affects the four human spaceflight Centers. As part of the FY 2010 budget formulation process and Shuttle-to-Constellation Workforce Mapping activity, estimates are being developed for transition impacts to other NASA Centers and future Constellation work package assignments. However, the number of civil servants and prime contractors supporting Shuttle today at the other Centers is small. While the Shuttle workforce at these Centers is declining toward zero in FY 2010, the overall impact of Shuttle retirement at these Centers will be relatively minor. For example, in FY 2008 there are approximately 25 civil servants and prime contractors that support Space Shuttle at Ames Research Center in California, 36 at Dryden Flight Research Center in California, 6 at Glenn Research Center in Ohio, 33 at Goddard Space Flight Center in Maryland, and 14 at Langley Research Center in Virginia. Though mature estimates will not be available until the FY 2010 budget formulation and Workforce Mapping activities later this year, Constellation work at these Centers is likely to exceed present Shuttle demand.

The data in Table 1 (including estimates of Constellation workforce at all ten Centers) will continue to be updated in future versions of this strategy.

Focusing on the Shuttle and Constellation elements alone, nationwide, NASA plans to spend roughly the same amount of money on the purchase of products and services from its contractors as before. Presently, the budget and workforce distributions are well known for the existing Shuttle program, while the Constellation aspects are continually being refined as previously discussed. Requirements maturation, budget allocations, future contract awards, and reserve expenditures on currently unknown future cost, schedule, technical, and safety risks will better define the precise workforce, skill, and locational needs of the projects.



	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013
SSP	$3,281.3	$2,997.8	$3,001.3	$95.7	$0.0	$0.0
CxP	$2,644.7	$3,048.2	$3,252.8	$6,479.5	$6,521.4	$7,030.5

Figure 7: Space Shuttle and Constellation Budget Systems FY 2009 Budget

As the Space Shuttle Program begins to phase out, the Shuttle prime contractors project that contractor workforce will begin to be drawn down. Using these data, NASA estimates that the total contractor reductions across all NASA Centers will be between 1,000–2,000 people in FY 2009 and between 2,000–3,000 people in FY 2010. These are the same projections that were presented as part of the President's FY 2009 budget roll-out and are consistent with the original Shuttle phase-out plan.

During the same period, Constellation work requirements will increase. Contractor workforce synergy and Constellation work definition have served to lessen overall contractor workforce reductions. NASA is attempting to capture a portion of the Shuttle workforce for required Constellation work. NASA believes that many experienced Shuttle workers will be employed in the new Constellation contracts.

As of the time of this report, not all of the Constellation work content that is expected to follow Orion/Ares I initial and full operational capability has been included in the Space Shuttle Workforce Mapping effort. It is anticipated that future content will be updated in future updates to this plan at the time of the President's FY 2010 Budget Request.

While the above estimates represent progress in defining workforce requirements at NASA Centers, the requirements should be considered preliminary and subject to change as work is better defined and contracts are awarded. Though student and Co-Op employees are not included in the FTE estimates, NASA expects that the number of student and Co-Op workers will remain relatively constant. Contractor workforce needed for Space Shuttle transition and retirement, as well as COTS launch workforce, is not included in the above projections, given the uncertainty related to the work requirements at this time and the nature of the relationship between the Agency and its COTS partners. Facility construction work is also not included in these estimates. A full list of caveats is noted on pages 19 and 20 of this report. NASA will provide Congress with civil servant and contractor workforce projections in future updates to this plan.

NASA has workforce estimates from 2007 which were used to generate the President's 2009 Budget to Congress. These were preliminary and subject to change—these estimates only portray the work assigned to NASA Centers and industry as of late 2007. NASA is analyzing updated information as the Agency prepares the Presidents 2010 Budget Request. The President's 2009 Budget Request provides a preliminary look at how workforce would change from FY 2007 to FY 2012 if NASA does not assign additional design, development, manufacturing, test, integration or operations work to be conducted at KSC or MAF.

6.0 The Road Ahead

In a short span of years, NASA has 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 the solar system. The Agency is continuing to transition from the Space Shuttle to new Exploration Systems; this transition is the largest and most daunting since the end of the Apollo Program and the beginning of the Space Shuttle Program. To implement it, NASA is 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. This joint effort between the Space Operations and Exploration Systems mission directorates includes the utilization and disposition of resources, including real and personal property, personnel, and processes, to leverage existing Shuttle and Space Station assets for future Exploration activities, including the Orion Ares I, and Ares V projects. Formalized Transition Boards are working to successfully achieve this outcome, and, to date, NASA has met all of its milestones and disposition targets. Acquisition, budget, and workforce planning are closely integrated and will continue to mature over the upcoming years.

The Agency will continue to keep the Congress informed of progress on Transition activities, and will provide biannual updates to this report.

APPENDIX A: CONSTELLATION WORK ASSIGNMENTS TO NASA CENTERS

Ames Research Center, Moffett Field, California	
ESMD	Manage Lunar Crater Observation and Sensing Satellite Project; support Exploration life support; lead radiation dosimetry and medical sensor technology development; support space human factors standards; support ISS Exploration experiment development; lead piloted spacecraft handling qualities.
Constellation	In program integration, support for program planning and control including data systems support; safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Mission Operations	Provide tools for flight controllers; develop new applications for the Constellation training program; support multiple mission operations planning and development tasks.
Orion	Lead thermal protection system advanced development; support aero/aerothermal database development; support flight software and guidance, navigation and control.
Ares I	Lead integrated systems health management; aborts lead including blast analysis for Ares abort; lead for launch abort system software requirements, interface and verification; launch abort system flight instrumentation and health management; provide high fidelity aero/aerothermal models and analysis and simulated assisted risk assessments.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation Program system engineer; build mission operations simulation capabilities; lead Ares V integrated health management; support Ares V payload shroud development at NASA's Glenn Research Center; subsystem lead for lunar lander and lunar surface systems integrated health management; support concepts for lunar surface extravehicular activity suit lock and concept trade studies for Moon suit; support lunar surface mobility; support lunar *in situ* resource utilization systems.

APPENDIX A: CONSTELLATION WORK ASSIGNMENTS TO NASA CENTERS—CONTINUED

Dryden Flight Research Center, Edwards, California	
ESMD	Support NASA's Ames Research Center on piloted spacecraft handling qualities.
Constellation	In program integration, support test and evaluation.
Ground Operations	Support definition and planning for Orion ground operations including launch abort and landing and recovery tests, re-entry and landing profiles, and range safety requirements.
Orion	Lead abort flight test integration and operations; abort test booster procurement; flight test article and abort test booster integration; flight test article design, assembly, integration and test; independent analysis and oversight of flight test articles.
Constellation Work Announced 10–30–07	Support mission operations simulation capabilities; support ground and flight test operations for lunar projects.
Glenn Research Center, Cleveland, Ohio	
ESMD	Lead cryogenic fluid handling, propulsion, fission power and energy storage projects; support Exploration life support; support Exploration medical capability and exercise technologies development.
Constellation	In program integration, support for safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
EVA Systems	Manage power and communications avionics informatics subsystems for low Earth orbit and lunar extravehicular activities; support extravehicular activity systems power, avionics and software disciplines.
Orion	Lead service module and spacecraft adapter integration; produce service module and spacecraft adapter flight test articles and pathfinders; support integration analysis and system engineering and integration; vehicle environmental qualification at Plum Brook.
Ares I	Lead upper stage thrust vector control subsystem development; lead upper stage electrical power and power distribution system development; lead developmental flight instrumentation package; support upper stage system engineering and integration; J–2X thermal and vacuum testing at Plum Brook; support vehicle integrated design analysis; lead upper stage module development for Ares I–X test flight.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation Program system engineer; lead Ares V power, thrust vector control and payload shroud development; lead Earth departure stage orbital environments testing at Plum Brook; subsystem lead for lunar lander ascent stage propulsion; and ascent and descent stage power generation, management and energy storage systems; lead lunar lander environmental testing at Plum Brook; support for lunar lander project integration and descent stage propulsion subsystems; lead lunar surface systems power generation and management, energy storage systems and element environmental testing; subsystem lead for passive thermal systems and surface element communications; support lunar surface in situ resource systems and surface mobility systems.

APPENDIX A: CONSTELLATION WORK ASSIGNMENTS TO NASA CENTERS—CONTINUED

Goddard Space Flight Center, Greenbelt, Maryland	
ESMD	Lunar Reconnaissance Orbiter Project management and integration.
Constellation	In program integration, support safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Orion	Communications and tracking support.
Constellation Work Announced 10–30–07	Lead program requirements for unpressurized cargo carriers; lead Orion unpressurized cargo carrier; support lunar architecture work for Constellation Program system engineer; subsystem lead for lunar lander avionics; support lunar surface systems avionics and surface element communications; provide extravehicular activity tools and equipment.
Jet Propulsion Laboratory, Pasadena, California	
ESMD	Navigation support for Lunar Crater Observation and Sensing Satellite; lead Advanced Environmental Monitoring and Control Project.
Constellation	In program integration, support safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Orion	Support thermal protection system advanced development.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation Program system engineer; lunar lander project support including spacecraft design; guidance, navigation and control; life support systems, and avionics; lead specific robotic surface mobility; support environmental monitoring and control and surface system local element communications.
Johnson Space Center, Houston, Texas	
ESMD	Human Research program management and integration; Commercial Orbital Transportation Services Project (COTS) management and integration; lead autonomous landing and hazard avoidance technology; in situ resource utilization; thermal, surface and extravehicular activity systems, and life support projects.
Constellation	Program management and integration; extravehicular activity systems project management and integration; extravehicular activity hardware development including suit, vehicle interface, tools and ground support equipment; manage life support, pressure garment and crew survival subsystems; mission operations project management and integration including Mission Control Center and training and mockup facilities.
Ares I and Ares V	Support program and mission operations interface.
Orion	Project management and integration; lead crew module and vehicle integration, government-provided hardware, flight test execution and parachutes.
Constellation Work Announced 10–30–07	Lunar lander and lunar surface systems project management and integration including lunar architecture work; element lead for lunar lander crew module/ascent stage; lead crew habitation and environmental control and life support subsystems; subsystem support for ascent stage propulsion, propulsion testing, and project avionics and structures; lead lunar surface crew habitation, environmental control and life support systems, and human mobility systems; support lunar surface in situ resource utilization systems.

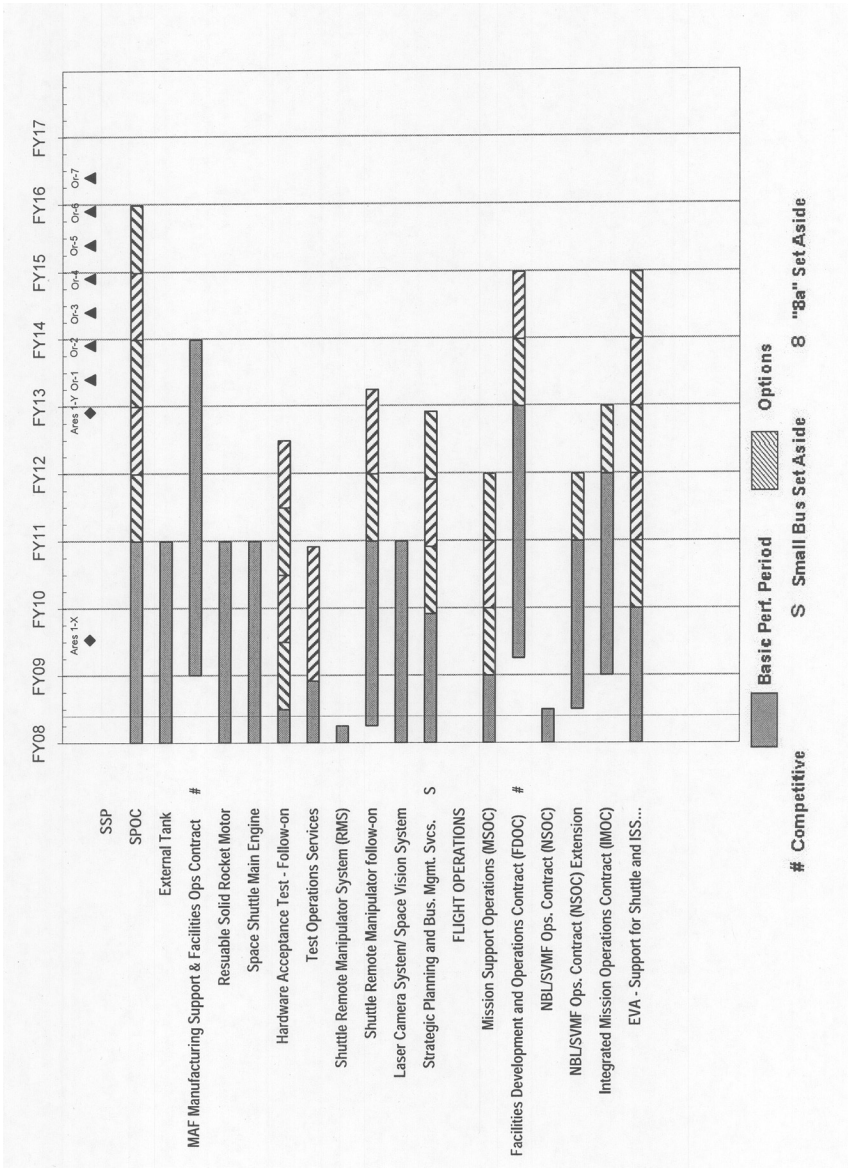
APPENDIX A: CONSTELLATION WORK ASSIGNMENTS TO NASA CENTERS—CONTINUED

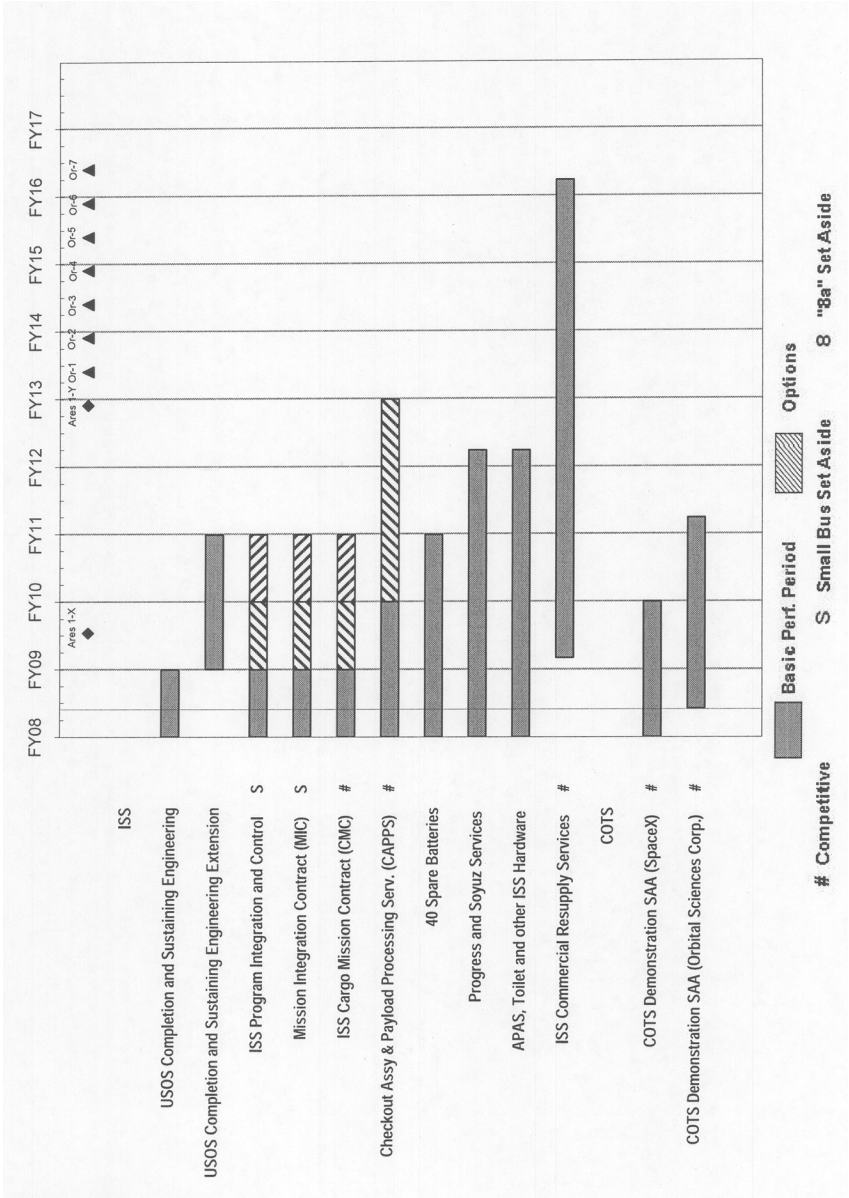
Kennedy Space Center, Kennedy Space Center, Florida	
ESMD	Support Exploration experiments on the ISS.
Constellation	In program integration, support safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Ground Operations	Project management and integration; responsible for achieving all Agency ground operations objectives allocated to the launch and landing sites; lead design, development, test and engineering and logistics activities for all ground processing, launch and recovery systems; lead ground processing, launch and landing operations planning and execution.
Orion	Ground processing including ground support equipment; launch operations; and recovery support during design, development, test and engineering; prime contractor oversight and independent analysis.
Ares I	Ground processing, launch operations, and recovery support during design, development, test and engineering; lead launch operations planning and execution for Ares I–X and other flight demonstrations.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation program system engineer; ground operations and assembly for Orion Block 1 and Ares I low Earth orbit operations phase; Ares V ground processing, launch operations and recovery support during design, development, test and engineering; final assembly of and ground processing support for human lunar lander; lunar surface habitat management and integration; lead for lunar surface in situ resource utilization systems; support surface systems logistics concepts.
Langley Research Center, Hampton, Virginia	
ESMD	Exploration Technology Development Program management and integration; lead structures, mechanisms and materials and supportability projects; support autonomous landing and hazard avoidance technology project with lead for sensors; deputy management for radiation protection element.
Constellation	In program integration, support safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Orion	Lead launch abort system integration and crew module landing system advanced development; produce flight test and pathfinder articles for crew module, launch abort system and separation rings; support aero/aerothermal; guidance, navigation and control; avionics software; and displays and controls; independent analysis and system engineering and integration support.
Ares I	Lead aerodynamic characterization of integrated launch vehicle stack, aerodynamic database development, and aeroelasticity test and analysis; support structural design and analysis; guidance, navigation and control development; flight mechanics and trajectory analyses; support systems engineering and upper stage design, development, test and engineering; lead vehicle integration activities and crew module and launch abort simulator design and fabrication for Ares I–X.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation Program system engineer; lead Ares V aerodynamics; support Ares V systems engineering, structures and materials engineering, and payload shroud structures; build mission operations and simulation capabilities; subsystem lead for lunar lander structures and mechanisms including ascent and descent stages; support lunar lander project integration; support lunar lander and lunar surface systems crew habitation (radiation protection); lead lunar surface systems structures and mechanisms including support to habitat, mobility and in situ resource systems.

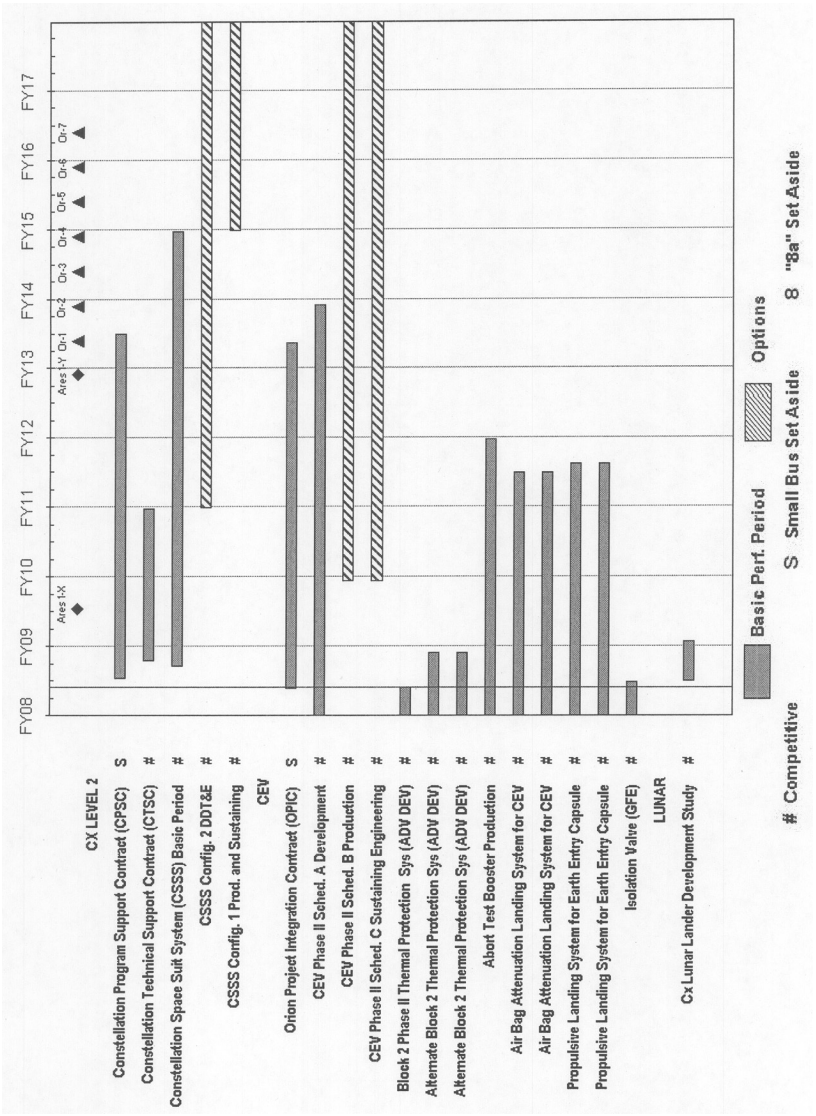
APPENDIX A: CONSTELLATION WORK ASSIGNMENTS TO NASA CENTERS—CONTINUED

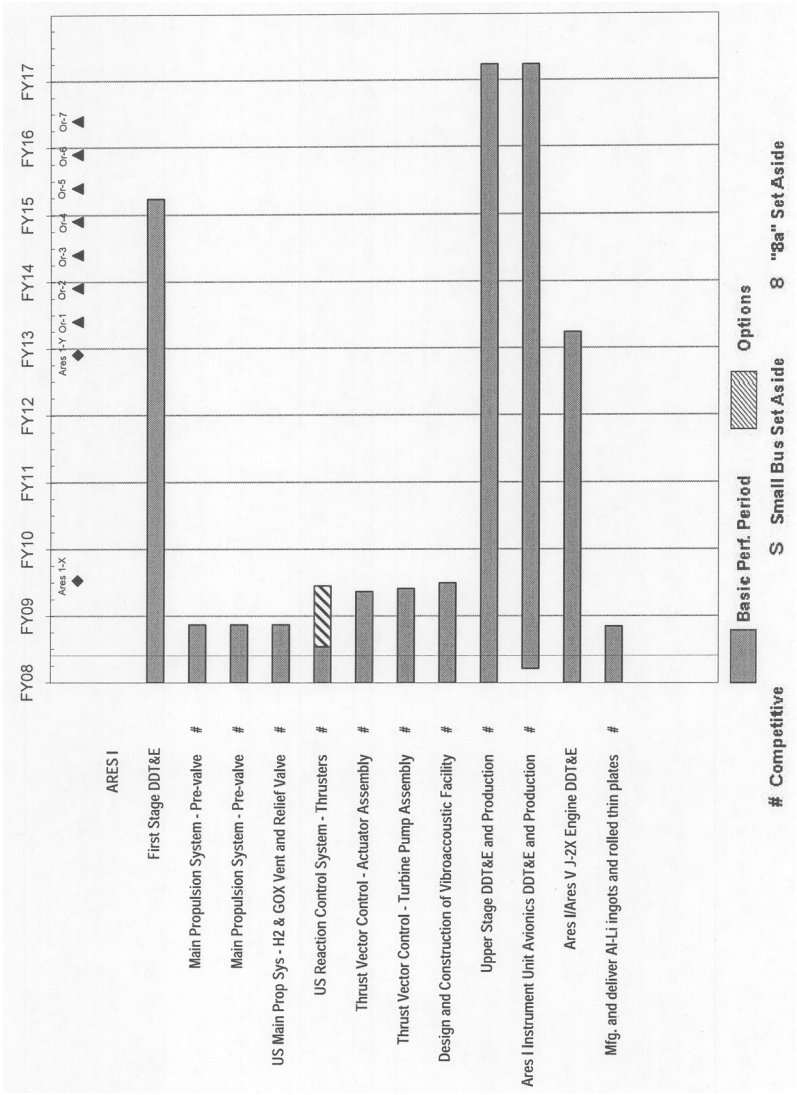
Marshall Space Flight Center, Huntsville, Alabama	
ESMD	Lunar Precursor Robotic Program management and integration.
Constellation	In program integration, support program planning and control; safety, reliability and quality assurance; system engineering and integration; and test and evaluation.
Orion	Support launch abort systems and service module; support abort test booster requirements development and validation.
Ares I and Ares V	Project office management and vehicle integration for Ares I and Ares V; Ares I first stage development and management and Ares V first stage management; Ares I upper stage design and development; J–2X engine development and management; manage upper stage production contracts at NASA's Michoud Assembly Facility; lead Ares I–X avionics, roll control system, and first stage modifications; Ares V Earth departure stage development, test and oversight; core stage development, test and oversight; core stage (RS–68) engine management.
Constellation Work Announced 10–30–07	Support lunar architecture work for Constellation Program system engineer; element lead for lunar lander descent stage; subsystem lead for lunar lander descent stage propulsion; subsystem support for lunar lander ascent stage propulsion, propulsion testing, project avionics, life support, and structures; support project integration; support lunar surface systems life support, habitat, structures and in situ resource systems.
Michoud Assembly Facility, New Orleans, Louisiana	
Constellation	Manufacturing of Ares I upper stage, Ares V stages, and Orion structure.
Stennis Space Center, Stennis Space Center, Mississippi	
Constellation	In program integration, support system engineering and test and evaluation.
Ground Operations	Support design, development, test and evaluation of propellant test and delivery systems; ground engine checkout facility simulation and analysis; engine and launch facility planning and development.
Ares I	Focused program management and integration for rocket propulsion testing; lead sea-level development, certification and acceptance testing for flight upper stage assembly, upper stage engine and main propulsion test article including facility modifications and test operations; lead altitude development and certification testing for upper stage engine.
Constellation Work Announced 10–30–07	Lead Ares V liquid rocket systems and stage testing at sea level and altitude; support lunar lander descent stage propulsion testing.
White Sands Test Facility, Las Cruces, New Mexico	
Constellation	Orion Abort Test Booster Test Site.

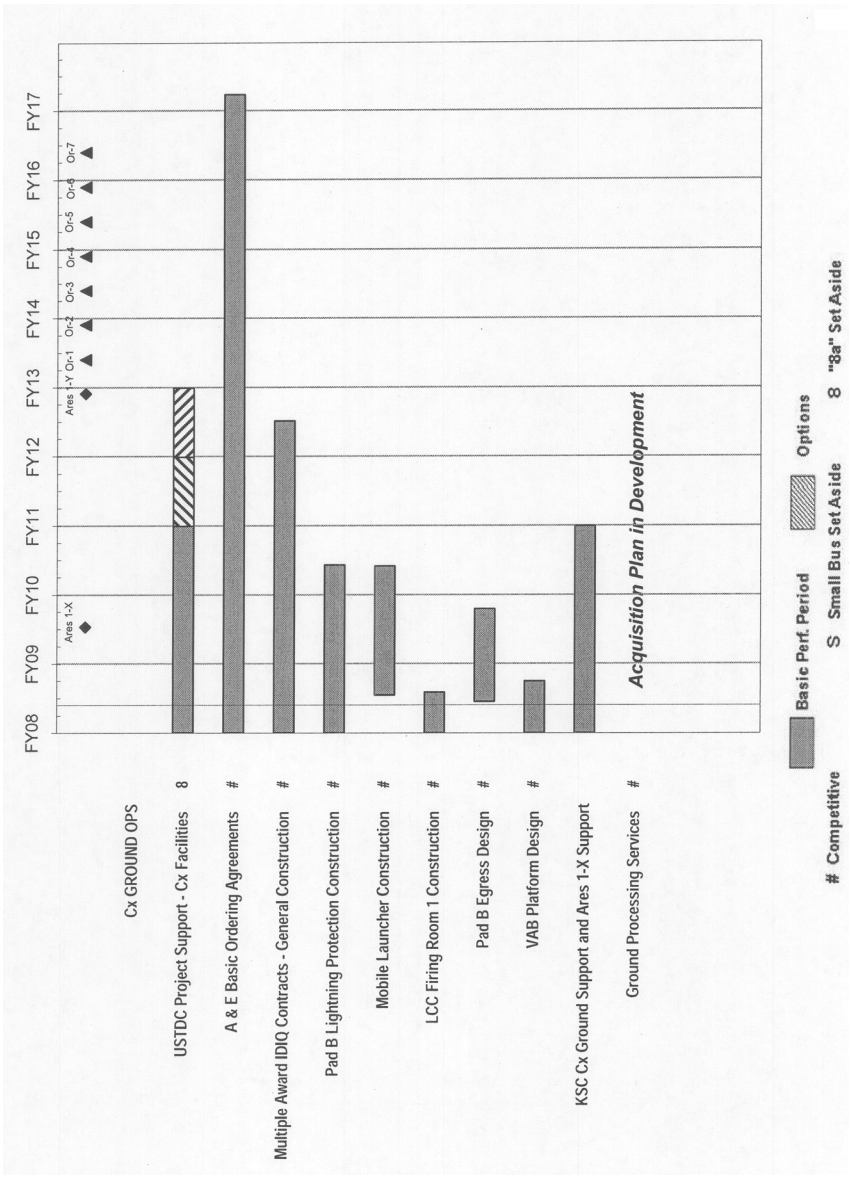
APPENDIX B: NASA NON-SENSITIVE INTEGRATED ACQUISITION ROADMAP



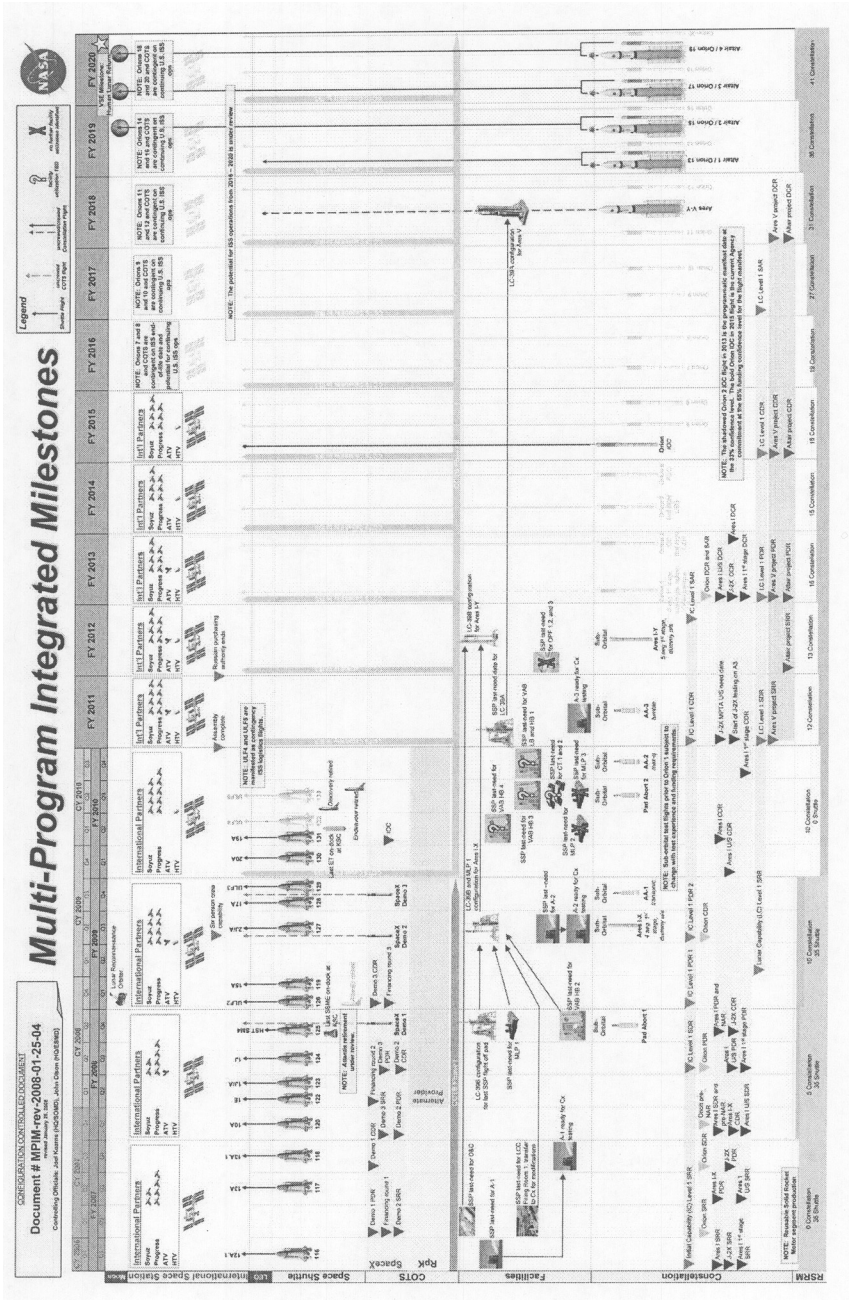

FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
Ares 1-X
Ares 1-Y
Opt-1
Opt-2
Opt-3
Opt-4
Opt-5
Opt-6
Opt-7
ISS
USOS Completion and Sustaining Engineering
USOS Completion and Sustaining Engineering Extension
ISS Program Integration and Control S
Mission Integration Contract (MIC) S
ISS Cargo Mission Contract (CMC) #
Checkout Assy & Payload Processing Serv. (CAPPS) #
40 Spare Batteries
Progress and Soyuz Services
APAS, Toilet and other ISS Hardware
ISS Commercial Resupply Services #
COTS
COTS Demonstration SAA (SpaceX) #
COTS Demonstration SAA (Orbital Sciences Corp.) #
Basic Perf. Period
Options
Competitive
S Small Bus Set Aside
8 "8a" Set Aside


FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
Ares 1-X
Ares 1-Y
Or-1
Or-2
Or-3
Or-4
Or-5
Or-6
Or-7
CX LEVEL 2
Constellation Program Support Contract (CPSC) S
Constellation Technical Support Contract (CTSC) #
Constellation Space Suit System (CSSS) Basic Period #
CSSS Config. 2 DDT&E #
CSSS Config. 1 Prod. and Sustaining #
CEV
Orion Project Integration Contract (OPIC) S
CEV Phase II Sched. A Development #
CEV Phase II Sched. B Production #
CEV Phase II Sched. C Sustaining Engineering #
Block 2 Phase II Thermal Protection Sys (ADV DEV) #
Alternate Block 2 Thermal Protection Sys (ADV DEV) #
Alternate Block 2 Thermal Protection Sys (ADV DEV) #
Abort Test Booster Production #
Air Bag Attenuation Landing System for CEV #
Air Bag Attenuation Landing System for CEV #
Propulsive Landing System for Earth Entry Capsule #
Propulsive Landing System for Earth Entry Capsule #
Isolation Valve (GFE) #
LUNAR
Cx Lunar Lander Development Study #
Basic Perf. Period
Options
Competitive
S Small Bus Set Aside
8 "8a" Set Aside


FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
Ares 1-X
Ares I-Y
Or-1
Or-2
Or-3
Or-4
Or-5
Or-6
Or-7
ARES I
First Stage DDT&E
Main Propulsion System - Pre-valve #
Main Propulsion System - Pre-valve #
US Main Prop Sys - H2 & GOX Vent and Relief Valve #
US Reaction Control System - Thrusters #
Thrust Vector Control - Actuator Assembly #
Thrust Vector Control - Turbine Pump Assembly #
Design and Construction of Vibroaccoustic Facility #
Upper Stage DDT&E and Production #
Ares I Instrument Unit Avionics DDT&E and Production #
Ares II/Ares V J-2X Engine DDT&E
Mfg. and deliver Al-Li ingots and rolled thin plates #
Basic Perf. Period
Options
Competitive
S Small Bus Set Aside
8 "8a" Set Aside


FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
Ares 1-X
Ares 1-Y
Op-1
Op-2
Op-3
Op-4
Op-5
Op-6
Op-7
Cx GROUND OPS
USTDC Project Support - Cx Facilities 8
A & E Basic Ordering Agreements #
Multiple Award IDIQ Contracts - General Construction #
Pad B Lightning Protection Construction #
Mobile Launcher Construction #
LCC Firing Room 1 Construction #
Pad B Egress Design #
VAB Platform Design #
KSC Cx Ground Support and Ares 1-X Support
Ground Processing Services #
Acquisition Plan in Development
Basic Perf. Period
Options
Competitive
S Small Bus Set Aside
8 "8a" Set Aside

APPENDIX C: MULTI-PROGRAM INTEGRATED MILESTONES (AS OF JANUARY 25, 2008)



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