The Future of NASA: Space Policy Issues Facing Congress

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Summary

The National Aeronautics and Space Administration Authorization Act of 2010 (P.L. 111-267) authorized major changes of direction for NASA. Among these, it called for the development of a new, crew-capable, heavy-lift rocket, and it provided for the development of commercial services to transport NASA crews into low Earth orbit. However, under the Continuing Appropriations Act, 2011 (P.L. 111-242 as amended by P.L. 111-322), NASA continues to operate under a requirement to proceed with its previous human spaceflight program. Moreover, in a period of fiscal constraint, it is unclear whether future appropriations will match the growing NASA budgets envisioned by the 2010 act. Thus the 112th Congress is likely to continue to closely examine the future of NASA.

Before the 2010 act, NASA's priorities were governed by the Vision for Space Exploration. The Vision was announced by President Bush in January 2004 and endorsed by Congress in the 2005 and 2008 NASA authorization acts (P.L. 109-155 and P.L. 110-422). It directed NASA to focus its efforts on returning humans to the Moon by 2020 and some day sending them to Mars and "worlds beyond." The resulting efforts are approaching major decision points, such as the end of the space shuttle program and key milestones for the Constellation spacecraft development program intended to replace the shuttle. A high-level independent review of the future of human space flight, chaired by Norman R. Augustine, issued its final report in October 2009. It presented several options as alternatives to the Vision and concluded that for human exploration to continue "in any meaningful way," NASA would require an additional $3 billion per year above previous plans.

In February 2010, the Obama Administration proposed cancelling the Constellation program and eliminating the goal of returning humans to the Moon. NASA would instead rely on commercial providers to transport astronauts to Earth orbit, and its ultimate goal beyond Earth orbit would be human exploration of Mars, with missions to other destinations, such as visiting an asteroid in 2025, as intermediate goals. Operation of the International Space Station would be extended to at least 2020, and long-term technology development would receive increased emphasis. The 2010 authorization act incorporated many of these proposals, though it retained elements of Constellation and scaled back the proposed emphasis on commercial providers and technology development.

As the 112th Congress oversees NASA's implementation of the 2010 act and considers how to address the broad space policy challenges that remain, it faces questions about

- whether NASA's human exploration program is affordable and sufficiently safe, and if so, what destination or destinations it should explore;
- how to ensure that new spacecraft for human exploration, both government-owned and commercial, are developed effectively, despite budget constraints;
- how to manage the transition of workforce and facilities as the space shuttle program comes to an end during 2011;
- how best to manage and utilize the International Space Station; and
- how NASA's multiple objectives in human spaceflight, science, aeronautics, and education should be prioritized.

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Introduction and Legislative Context

The idea of human spaceflight beyond Earth orbit has captivated many Americans for more than half a century. As U.S. space policy has evolved, new opportunities have emerged, and new challenges have arisen. From 2004 to 2010, the priorities of the National Aeronautics and Space Administration (NASA) were governed by the Vision for Space Exploration. The Vision was announced by President Bush in January 2004 and endorsed by Congress in the 2005 and 2008 NASA authorization acts (P.L. 109-155 and P.L. 110-422). It directed NASA to focus its efforts on returning humans to the Moon by 2020 and some day sending them to Mars and "worlds beyond." The resulting efforts are now approaching major milestones, such as the end of the space shuttle program and design review decisions for the new spacecraft intended to replace the shuttle.

In May 2009, the Obama Administration announced plans for a high-level independent review of the future of human space flight, chaired by Norman R. Augustine.[1] Major components of the FY2010 NASA budget request were placeholders, to be revised following the results of this review. The Augustine committee released its final report in October 2009.[2] The report identified serious barriers to the implementation of the Vision and proposed several alternatives. Committees in the House and Senate held hearings to consider the proposals.[3] The Administration did not submit a revised FY2010 budget for NASA. In December 2009, Congress appropriated FY2010 funds for NASA at approximately the level in the President's original request. The appropriations conference report (H.Rept. 111-366) stated that the Augustine committee's report

> raises issues requiring thoughtful consideration by the Administration and the Congress.... It is premature for the conferees to advocate or initiate significant changes to the current program absent a *bona fide* proposal from the Administration and subsequent assessment, consideration and enactment by Congress.... It is the expressed hope of the conferees that the Administration will formulate its formal decision soon, submit its recommendations for congressional review and consideration, and budget the necessary resources.

In February 2010, as part of its FY2011 budget, the Administration proposed major changes to the Vision, including the elimination of a human return to the Moon as NASA's primary goal, the cancellation of NASA's Constellation spacecraft development program, a new effort to encourage the private sector to develop commercial crew launch services, and increased emphasis at NASA on technology development and science. The 111th Congress considered these proposals but ultimately did not pass a regular FY2011 appropriations bill for NASA. Under the Continuing Appropriations Act, 2010 (P.L. 111-242 as amended by P.L. 111-322), NASA is operating at FY2010 funding levels through March 4, 2011. Because the continuing resolution does not explicitly remove it, a restriction in the FY2010 appropriations act that requires NASA to continue the Constellation program remains in effect.

[1] For more details, see "Human Spaceflight: The Augustine Committee," below.

[2] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, October 2009, at http://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf.

[3] House Committee on Science and Technology, *Options and Issues for NASA's Human Space Flight Program: Report of the "Review of U.S. Human Space Flight Plans" Committee*, hearing September 15, 2009; and Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space, *Options from the Review of U.S. Human Space Flight Plans Committee*, hearing September 16, 2009.

The 111th Congress did pass a comprehensive NASA reauthorization bill, the NASA Authorization Act of 2010 (P.L. 111-267). This act mandates several major changes in direction for NASA. For example, it calls for the development of a new, crew-capable, heavy-lift rocket, and it provides for the development of commercial services to transport NASA crews into low Earth orbit. In the near term, NASA's ability to implement these changes may be constrained by operating under the continuing resolution.[4] The NASA Inspector General has estimated that if the continuing resolution is extended through the end of FY2011, without changes to the requirement to continue Constellation, NASA will likely have to spend $575 million during FY2011 on activities that it would otherwise no longer pursue.[5] In the longer term, fiscal constraints may also create barriers, if they result in future appropriations that do not match the growing NASA budgets envisioned by the 2010 authorization act.

As Congress considers these broad space policy challenges, the major issues it faces can be summarized as three broad questions:

- **What is NASA for?** Different analysts and policy makers give different answers to this question: making scientific discoveries, developing technologies with economic benefits, enhancing national security, enhancing international prestige, even fulfilling human destiny in space. How should these competing goals be prioritized?
- **What should NASA do?** In order to accomplish its broad goals, how should NASA balance its major programs in human spaceflight, robotic spaceflight, aeronautics research, and education? In the human spaceflight program, which is larger than all the others put together, should the agency's goal be exploration of the Moon, Mars, or some other destination? What should the top priorities be for NASA's science and aeronautics programs?
- **How?** Once these questions are decided, how should their answers be implemented? What new space vehicles are needed? Should they be government-owned or commercial? What should be done with existing programs, such as the space shuttle and the International Space Station?

This report analyzes these questions and some possible answers. It also addresses a number of cross-cutting issues, such as NASA's interactions with other federal agencies and the growing role of the commercial space industry.

What Is NASA For?

During the Eisenhower Administration, after the Soviet Union's launch of the first artificial satellite, Sputnik, but before the establishment of NASA, the President's Science and Advisory Committee identified four "principal reasons for undertaking a national space program":

[4] For more information about how operation under the continuing resolution is affecting NASA's implementation of the 2010 authorization act, see Elizabeth M. Robinson, Chief Financial Officer, NASA, testimony before the Senate Committee on Commerce, Science, and Transportation, December 1, 2010.

[5] Paul K. Martin, Inspector General, NASA, letter to the chairmen and ranking members of the House Committee on Science, Space, and Technology and the Senate Committee on Commerce, Science, and Transportation, January 13, 2011, http://oig.nasa.gov/readingRoom/Paul.pdf and http://oig.nasa.gov/readingRoom/Rock.pdf.

- "the compelling urge of man to explore and to discover";
- "defense ... to be sure that space is not used to endanger our security ... [and to] be prepared to use space to defend ourselves";
- to "enhance the prestige of the United States ... and create added confidence in our scientific, technological, industrial, and military strength"; and
- "scientific observation and experiment which will add to our knowledge and understanding of the Earth, the solar system, and the universe."[6]

To these objectives, analysts today add

- the potential for technologies developed for the space program to have direct and indirect ("spinoff") economic benefits;
- the opportunity to use space activities as a tool of international relations, through collaboration on projects such as the International Space Station; and
- the ability of the space program to inspire students and promote education in science, technology, engineering, and mathematics (STEM).

These goals form a foundation for U.S. space policies, but policy makers differ in how they should be balanced against each other. Is the urge to discover a sufficient reason to explore space, or must exploration also meet needs here on Earth? Should economic benefits be an explicit focus for NASA or just a positive side effect? To what extent should improving STEM education be a NASA function, as opposed to a consequence of its other functions? Should the emphasis of international space programs be competition or cooperation?

The priorities that Congress assigns to these objectives may determine how it balances the competing demands of NASA's programs. For example, if Congress believes that national prestige is a high priority, it could choose to emphasize NASA's high-profile human exploration activities, such as exploring Mars or establishing a Moon base. If scientific knowledge is a high priority, Congress could emphasize unmanned missions such as the Hubble telescope and the Mars rovers. If international relations are a high priority, Congress could encourage joint space activities with other nations. If economic benefits are of interest, Congress could focus on technological development, linking NASA programs to the needs of business and industry.

A report by the National Academies proposed goals similar to those listed above and recommended three criteria to use in balancing their competing demands for resources:[7]

- *Steady progress.* Each major area should be maintained at a level that allows sustained long-term progress with intermediate goals achieved at a reasonable pace.

[6] President's Science Advisory Committee, *Introduction to Outer Space*, March 26, 1958, http://www.hq.nasa.gov/office/pao/History/monograph10/doc6.pdf. For more information on the evolution of space policy since Sputnik, see CRS Report RL34263, *U.S. Civilian Space Policy Priorities: Reflections 50 Years After Sputnik*, by (name redacted).

[7] National Research Council, *America's Future in Space: Aligning the Civil Space Program with National Needs*, 2009, http://www.nap.edu/catalog/12701.html, pp. 46-48.

- *Stability.* Rapid downsizing and abrupt redirection should be avoided because they are disruptive, can take time to recover from, and can create risk as operations experience is lost.
- *Robustness.* Sufficient human resources and research infrastructure should be maintained so that the nation can ramp up selected activities quickly in response to changing national needs or scientific breakthroughs.

The Academies report did not, however, actually employ these criteria to prioritize the goals it proposed.

What Should NASA Do?

Based on this wide variety of objectives, NASA has established programs in human spaceflight, science, aeronautics, and education. The largest and most visible effort, in human spaceflight, has faced considerable uncertainty about its proper scope and aims. The content of the science, aeronautics, and education programs is less controversial but still faces questions about scope, balance, and other issues.

Human Spaceflight: The Vision for Space Exploration

The Vision for Space Exploration, announced by President Bush in a speech on January 14, 2004, directed NASA to focus its efforts on returning humans to the Moon by 2020 and eventually sending them to Mars and "worlds beyond."[8] (Twelve U.S. astronauts walked on the Moon between 1969 and 1972. No humans have visited Mars.) The Vision also directed NASA to return the space shuttle to flight status following the February 2003 *Columbia* disaster; to complete construction of the International Space Station (ISS) in accord with existing international commitments; and to conclude U.S. participation in the ISS by the end of 2015. The first post-*Columbia* shuttle flight was launched in July 2005. The other goals remain to be accomplished.

To advise NASA on implementation of the Vision, President Bush established a Commission on the Implementation of U.S. Space Exploration Policy, chaired by Edward C. "Pete" Aldridge, Jr.[9] The Aldridge Commission issued its report in June 2004.[10] In April 2005, NASA established an Exploration Systems Architecture Study (ESAS) to identify a strategy and technical architecture for implementing the Vision. The ESAS issued its final report in November 2005.[11] From then until 2010, the reports of the Aldridge Commission and the ESAS were the baseline for NASA's space exploration plans.

[8] President George W. Bush, speech at NASA headquarters, Washington, D.C., January 14, 2004, http://history.nasa.gov/BushSEP.htm. For more information on the original Vision and initial reactions to it by Congress and the public, see CRS Report RS21720, *Space Exploration: Issues Concerning the Vision for Space Exploration*, by (name redacted).

[9] Pete Aldridge was Under Secretary of Defense for Acquisition, Technology, and Logistics from 2001 to 2003. He previously held other senior positions in both government and the aerospace industry. In the 1980s, he trained as a shuttle astronaut, but his mission was cancelled following the *Challenger* disaster in 1986.

[10] Commission on the Implementation of U.S. Space Exploration Policy, *A Journey to Inspire, Innovate, and Discover*, June 2004, http://www.nasa.gov/pdf/60736main_M2M_report_small.pdf.

[11] National Aeronautics and Space Administration, *NASA's Exploration Systems Architecture Study: Final Report*, NASA-TM-2005-214062, November 2005, http://www.nasa.gov/pdf/140649main_ESAS_full.pdf.

In the NASA Authorization Act of 2005 (P.L. 109-155), Congress endorsed the Vision in broad terms and established several milestones for its implementation, including a statutory mandate to return to the Moon no later than 2020.[12] Nevertheless, it directed NASA to construct an architecture and implementation plan for its human exploration program "that is not critically dependent on the achievement of milestones by specific dates."[13]

The NASA Authorization Act of 2008 (P.L. 110-422) reaffirmed the Vision's broad goals, including the "eventual" return to the Moon and missions to other destinations in the solar system.[14] It expressed the sense of Congress that "America's friends and allies" should be invited to participate.[15] It directed NASA to take a "stepping stone approach" in which lunar exploration activities are designed and implemented with strong consideration to their future contribution to exploration beyond the Moon.[16] It directed that plans for a lunar outpost should not require its continuous occupation and that NASA should use commercial services for its lunar outpost activities "to the maximum extent practicable."[17]

Program to Implement the Vision

The program for implementing the Vision, as it stood before passage of the 2010 authorization act, addressed the conclusion of the space shuttle and International Space Station programs as well as the development and implementation of new vehicles for taking humans into Earth orbit and then back to the Moon. The major elements were as follows:

- Retire the space shuttle during 2011 (extended from the original deadline of the end of 2010). Rely on non-U.S. vehicles for human access to space until a replacement vehicle is developed.
- Terminate U.S. use of the International Space Station at the end of 2015.
- Under the Constellation program, develop new systems for space exploration:
  - the Ares I rocket to launch astronauts into low Earth orbit, where the International Space Station is located;
  - the Orion crew capsule, to be launched atop Ares I to carry astronauts into orbit and beyond;
  - the Ares V heavy-lift rocket to send astronauts and equipment to the Moon; and
  - the Altair lunar lander and various lunar surface systems.

Before the Administration's FY2011 budget proposals, no funds were projected for any shuttle flights after the end of 2010. No FY2016 funds were projected for deorbiting the space station. The first crewed flight (or "initial operating capability") of Ares I and Orion was scheduled for

[12] P.L. 109-155, Section 101(b).

[13] P.L. 109-155, Section 503.

[14] P.L. 110-422, Section 402.

[15] P.L. 110-422, Section 401.

[16] P.L. 110-422, Section 403.

[17] P.L. 110-422, Section 404.

early 2015. The first return to the Moon, using all the Constellation systems together, was planned for 2020, although NASA acknowledged that meeting that date would be difficult.

The 2010 authorization act extended U.S. use of the International Space Station through at least 2020 and replaced Constellation with programs to develop commercial services for launching astronauts into low Earth orbit (instead of Ares I); a multipurpose crew vehicle (similar to Orion); and a new heavy-lift rocket (possibly similar to Ares V). The transition from Constellation to these new programs, however, is constrained while NASA operates under the continuing resolution.

Issue for Congress: Cost and Schedule

Cost played a central role as congressional policy makers oversaw the Vision's progress and considered proposals to modify it. During the Bush Administration, NASA stressed that its strategy was to "go as we can afford to pay," with the pace of the program set, in part, by the available funding.[18] The original plan in 2004 proposed adding a total of just $1 billion to NASA's budget for FY2005 through FY2009 to help pay for the Vision, with increases thereafter limited to the rate of inflation. Subsequent Administration budgets more than eliminated this increase, and actual appropriations by Congress were even less. As a result, most funding for the Vision has been redirected from other NASA activities, such as the planned termination of the space shuttle program.

NASA has not provided a cost estimate for the Vision as a whole. In 2004, it projected that developing capabilities for human exploration, not including robotic support missions, would cost a total of $64 billion up through the first human return to the Moon.[19] The Congressional Budget Office (CBO) concluded that, based on historical trends, the actual cost could be much higher.[20] In its 2005 implementation plan, NASA estimated that returning astronauts to the Moon would cost $104 billion, not including the cost of robotic precursor missions or the cost of servicing the ISS after the end of the shuttle program.[21] In 2007, the Government Accountability Office (GAO) estimated the total cost for the Vision as $230 billion over two decades.[22] In April 2009, as directed in the 2008 authorization act, the CBO updated its 2004 budgetary analysis of the Vision. It found that NASA would need an additional $2 billion per year through FY2025 to keep the Vision activities on schedule, not counting probable cost growth in other activities.[23] In October 2009, the Augustine report stated that executing NASA's plans would require an additional $3 billion per year, even with some schedule delays.[24]

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[18] See, for example, Michael D. Griffin, Administrator, National Aeronautics and Space Administration, testimony before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Space, Aeronautics, and Related Sciences, February 28, 2007, http://commerce.senate.gov/public/_files/Testimony_MichaelDGriffin_NASA_FY2008PostureStatementFINAL22707.pdf.

[19] Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration*, September 2004, http://www.cbo.gov/ftpdocs/57xx/doc5772/09-02-NASA.pdf, p. xi.

[20] Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration*, pp. xi-xiv.

[21] National Aeronautics and Space Administration, *Exploration Systems Architecture Study: Final Report*, p. 676.

[22] Government Accountability Office, *High Risk Series*, GAO-07-310, January 2007, p. 75.

[23] Congressional Budget Office, *The Budgetary Implications of NASA's Current Plans for Space Exploration*, April 2009, http://www.cbo.gov/ftpdocs/100xx/doc10051/04-15-NASA.pdf, pp. 2-3 and 12-13. The statutory mandate for this study was in P.L. 110-422, Section 410.

[24] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great*
(continued...)

Schedule is closely related to cost. For example, the 2009 CBO analysis found that NASA could maintain its currently planned budget by delaying its return to the Moon by approximately three years.[25] The tradeoffs can be difficult to quantify, however. The Augustine report, unlike the CBO analysis, found that under NASA's budget plans at the time of the report, "human exploration beyond low-Earth orbit is not viable" and planned budgets would delay a return to the Moon "well into the 2030s, if ever."[26] Schedule delays were already evident. For example, the initial operating capability for Orion and Ares I, originally planned for 2012, had slipped to 2015; the Augustine committee concluded that 2017 was more likely.

Issue for Congress: Why the Moon?

Ever since the Vision was announced, some analysts questioned its choice of the Moon as the headline destination for NASA's human exploration efforts. Some felt that revisiting the destination of the Apollo missions of 1969-1972 was a less inspiring goal than a new target would be.[27] Some doubted the scientific rationale, suggesting that robotic missions to the Moon could accomplish as much or more at lower cost and without risking human lives, or that more could be learned by visiting another destination that has been studied less by previous missions. Some were simply concerned about the cost.

Supporters countered that the Moon is the closest destination beyond Earth orbit and could serve as a stepping stone for subsequent destinations. As Earth's nearest neighbor, the Moon is of great scientific interest. Missions to the Moon would provide an opportunity to develop and test technologies and gain experience working in space. According to some advocates, the Moon might literally be a staging point for future missions. For some in Congress, concerned about national security or national prestige, the prospect of a manned Chinese mission to the Moon was a strong motivation to reestablish a U.S. presence. For many who supported the Vision, completing it became important in itself; part of the Vision's original purpose was to set a goal for NASA that would give the agency direction and enhance its public support, and some supporters feared that changing the plan would weaken NASA, whether or not a better plan could be devised.

Issue for Congress: "The Gap" and Utilization of the Space Station

In order to fund the cost of the Vision and because of safety concerns following the *Columbia* disaster in 2003, NASA intended to end the space shuttle program in 2010 once construction of the ISS was complete. (Because of schedule delays and a congressional mandate for an additional flight, the program will end during 2011 rather than 2010.) The shuttle's successors, Orion and Ares I, were not expected to be ready for crewed flight until at least 2015. The difference between these dates is generally referred to as "the gap." Congressional policy makers and others

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Nation, pp. 15-17.

[25] Congressional Budget Office, *The Budgetary Implications of NASA's Current Plans for Space Exploration*, pp. 2-3 and 7-9.

[26] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 17 and 84.

[27] For example, Apollo astronaut Buzz Aldrin called returning to the Moon "not visionary." See Buzz Aldrin, "Time to Boldly Go Once More," *New York Times*, July 16, 2009.

expressed concerns about U.S. access to space during the gap. The NASA Authorization Act of 2005 declared it to be U.S. policy "to possess the capability for human access to space on a continuous basis."[28] Former NASA Administrator Michael Griffin, a strong advocate of the Vision, referred to the gap as "unseemly in the extreme."[29]

Under current plans, Russian spacecraft will be the only means of access to the ISS for humans during the gap. A variety of alternatives are being considered for cargo. These points are discussed further below in the section "Post-Shuttle Access to the ISS." The prospect of the gap has intensified congressional concerns about whether the capabilities of the ISS will be fully utilized.

Human Spaceflight: The Augustine Committee

The Review of U.S. Human Spaceflight Plans Committee was formally chartered on June 1, 2009. It was chaired by Norman R. Augustine, a former chairman and chief executive officer of Lockheed Martin Corporation and a member of the President's Council of Advisors on Science and Technology under Presidents of both parties. Other committee members included scientists, engineers, astronauts, educators, executives of established and new aerospace firms, former presidential appointees, and a retired Air Force general.[30] The committee reported jointly to the Administrator of NASA and the Director of the Office of Science and Technology Policy in the Executive Office of the President. The committee's charter defined its scope and objectives as follows:[31]

> The Committee shall conduct an independent review of ongoing U.S. human space flight plans and programs, as well as alternatives, to ensure the Nation is pursuing the best trajectory for the future of human space flight – one that is safe, innovative, affordable, and sustainable. The Committee should aim to identify and characterize a range of options that spans the reasonable possibilities for continuation of U.S. human space flight activities beyond retirement of the Space Shuttle. The identification and characterization of these options should address the following objectives: a) expediting a new U.S. capability to support utilization of the International Space Station (ISS); b) supporting missions to the Moon and other destinations beyond low-Earth orbit (LEO); c) stimulating commercial space flight capability; and d) fitting within the current budget profile for NASA exploration activities.[32]
>
> In addition to the objectives described above, the review should examine the appropriate amount of research and development and complementary robotic activities needed to make human space flight activities most productive and affordable over the long term, as well as appropriate opportunities for international collaboration. It should also evaluate what

[28] P.L. 109-155, Section 501.

[29] For example, see Michael D. Griffin, Administrator, National Aeronautics and Space Administration, testimony before the before the House Committee on Science and Technology, February 13, 2008, http://www.nasa.gov/pdf/211844main_House_Science_Committee_Oral_13_Fe08.pdf.

[30] See *Meet the Committee*, http://www.nasa.gov/offices/hsf/members/index.html.

[31] *Charter of the Review of U.S. Human Space Flight Plans Committee,* http://www.nasa.gov/offices/hsf/about/charter.html.

[32] It was subsequently agreed that the committee would also consider options not constrained by the current budget profile, if necessary to satisfy the other objectives. Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 7.

capabilities would be enabled by each of the potential architectures considered. It should evaluate options for extending ISS operations beyond 2016.

Options Identified by the Augustine Committee

The committee released its final report in October 2009. It identified five options: two within the existing budget profile and three that would require about an additional $3 billion per year. In the committee's judgment, developing Ares I, Orion, and the other Constellation systems is likely to take longer than NASA currently plans, and the options presented by the committee reflect these expected delays. The options are as follows:[33]

- **Option 1: Current Budget, Current Program.** This option is the current program, modified only to provide funds for space shuttle flights in FY2011 and for deorbiting the International Space Station in FY2016. The first crewed flight of Ares I and Orion is no earlier than 2017, after the International Space Station has been deorbited. Ares V is not available until the late 2020s, and there are insufficient funds to develop Altair and the lunar surface systems needed for returning to the Moon until well into the 2030s, if ever.
- **Option 2: Current Budget, Extend Space Station, Explore Moon Using Ares V Lite.** This option extends use of the International Space Station to 2020 and begins a program of lunar exploration using a variant of Ares V known as Ares V Lite. It develops commercial services to transport humans into low Earth orbit. It delivers a heavy-lift capability in the late 2020s, but it does not develop the other systems needed for returning to the Moon for at least the next two decades.
- **Option 3: Additional Budget, Current Program.** Like Option 1, this option is the current program, modified to provide funds for space shuttle flights in FY2011 and to deorbit the International Space Station in FY2016. The first crewed flight of Ares I and Orion would still be after the International Space Station is deorbited. The additional funding, however, would permit a human lunar return in the mid-2020s.
- **Option 4: Additional Budget, Extend Space Station, Explore Moon First.** Like Option 2, this option extends use of the International Space Station to 2020 and uses commercial services to transport humans into low Earth orbit. The first destination beyond Earth orbit is still the Moon. There are two variants to this option. **Variant 4A** develops the Ares V Lite for lunar exploration as in Option 2. **Variant 4B** extends the space shuttle program to 2015 and develops a heavy-lift vehicle for lunar missions that is more directly shuttle-derived. Both variants permit a human lunar return by the mid-2020s.
- **Option 5: Additional Budget, Extend Space Station, Flexible Path for Exploration.** Like Option 4, this option extends use of the International Space Station to 2020 and uses commercial services to transport humans into low Earth orbit. Missions beyond Earth orbit, however, follow a "flexible path" of increasingly distant destinations—such as lunar fly-bys, rendezvous with

[33] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 15-16.

asteroids and comets, and Mars fly-bys—without initially attempting a lunar landing. A lunar landing would be possible by the mid to late 2020s. **Variant 5A** employs the Ares V Lite. **Variant 5B** uses a commercial heavy-lift rocket derived from the Evolved Expendable Launch Vehicle (EELV). **Variant 5C** develops a shuttle-derived vehicle for heavy lift as in Variant 4B. (These alternative launch vehicles are discussed further later in this report.)

Although the committee's report did not recommend any particular one of these options, it made a number of findings and comments that put the options into context:[34]

- Option 1 and Option 2 fit within the current budget profile, but "neither allows for a viable exploration program. In fact, the Committee finds that no plan compatible with the FY2010 budget profile permits human exploration to continue in any meaningful way." The additional funding contemplated in Options 3, 4, and 5 is necessary for "an exploration program that will be a source of pride for the nation."
- "The return on investment to both the United States and our international partners would be significantly enhanced by an extension of the life of the [International Space Station]. A decision not to extend its operation would significantly impair U.S. ability to develop and lead future international spaceflight partnerships."
- Commercial services to launch crews into Earth orbit "are within reach. While this presents some risk, it could provide an earlier capability at lower initial and life-cycle costs than the government could achieve."
- Of the heavy-lift alternatives, Ares V Lite is "the most capable." The commercial EELV derivative "has an advantage of potentially lower operating costs, but requires significant restructuring of NASA" including "a different (and significantly reduced) role." A shuttle-derived vehicle would "take maximum advantage of existing infrastructure, facilities, and production capabilities."
- Variant 4B, which extends operation of the space shuttle to 2015, is "the only foreseeable way to eliminate the gap in U.S. human-launch capability."
- "Mars is the ultimate destination for human exploration of the inner solar system; but it is not the best first destination. Visiting the 'Moon First' and following the 'Flexible Path' are both viable exploration strategies. The two are not necessarily mutually exclusive; before traveling to Mars, we could extend our presence in free space and gain experience working on the lunar surface."

Questions for Congressional Policy Makers to Consider

The Augustine committee identified five questions "that could form the basis of a plan for U.S. human spaceflight":[35]

- What should be the future of the space shuttle?

[34] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 16-17.

[35] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 22.

- What should be the future of the International Space Station?
- On what should the next heavy-lift launch vehicle be based?
- How should crew be carried to low Earth orbit?
- What is the most practicable strategy for exploration beyond low Earth orbit?

These five questions focus on designing a future program of human spaceflight. In keeping with the committee's charter, the questions do not address NASA's other programs, and they take it as given that a human spaceflight program *should* be implemented. Congress may therefore wish to consider additional questions such as these:

- Is human spaceflight beyond low Earth orbit worth the cost and risk?
- If not, are there alternatives that would accomplish some of the same goals?
- What is the future of NASA's other activities, such as robotic exploration, science, and aeronautics research?

Each of these issues is discussed in more detail later in this report.

Human Spaceflight: Administration Proposals

In its FY2011 budget request, the Obama Administration proposed cancelling the Constellation program and eliminating the return of humans to the Moon as NASA's primary goal.[36] Instead, NASA would encourage the private sector to develop commercial space transportation services to carry astronauts to and from the International Space Station. For spaceflight beyond Earth orbit, NASA would emphasize long-term technology development rather than near-term development of specific flight systems. Operation of the International Space Station would continue until at least 2020. When asked about destinations for future human exploration of space, NASA officials stated that Mars would be the ultimate goal, but that other intermediate destinations would come first. They described these proposals as consistent with the "Flexible Path" option identified by the Augustine committee.

Congressional and Public Reaction

For the most part, Congress and the public at large reacted negatively to the Administration's proposals. Their concerns included the potential negative impact of Constellation's cancellation on employment in the aerospace industry, the lack of a specific destination and schedule to replace the goal of returning humans to the Moon, and the risk that the private sector might not in fact develop commercial space transportation services that meet NASA's needs. In the media, attention focused on the proposed cancellation of Constellation, with less notice of the programs that would replace it, such as increased technology development and stimulation of commercial space transportation services. Press accounts often reported the Administration's proposals as cutting NASA's budget, or eliminating its human spaceflight program, even though the proposed FY2011 budget for NASA was actually an increase over previous plans and included other human spaceflight activities to replace Constellation.

[36] For more information on the FY2011 budget request for NASA, see CRS Report R41161, *Commerce, Justice, Science, and Related Agencies: FY2011 Appropriations*.

Supporters of Constellation were particularly concerned about its status during FY2010. The FY2010 appropriations act prohibited NASA from using FY2010 or prior-year funds to terminate or eliminate "any program, project, or activity of the architecture for the Constellation program" or to create or initiate any new program, project, or activity.[37] Some analysts and policy makers expressed concern that NASA's contracting decisions and other actions during FY2010 violated this provision.[38] NASA officials replied that they were continuing to implement the Constellation program during FY2010 in full compliance with the law, even though they intended to terminate the program in FY2011. Two GAO opinions in May and July 2010 concluded that NASA had not violated the appropriations provision.[39] In June 2010, NASA announced that it would "prioritize" and "pace" (but not "terminate") contracts in the Constellation program because contract termination liabilities could result in a $1 billion "shortfall" in the program's FY2010 funding.[40]

Modifications to the Administration Proposals

On April 15, 2010, President Obama gave a speech at the Kennedy Space Center in Florida that attempted to answer some of these public and congressional concerns.[41] In this speech, he announced several modifications to the original FY2011 budget request proposals:

- Development of a modified Orion crew capsule would continue. The modified design would provide an emergency escape capability for the International Space Station, however, rather than transporting crews to and from the station on a regular basis.
- The next human mission beyond Earth orbit would be to an asteroid and would take place in 2025. This would be the first human mission to a destination more distant than the Moon. Subsequent missions to orbit Mars would take place in the mid-2030s. A human landing on Mars would remain the ultimate goal.
- NASA's increased technology efforts would focus on the development of a new heavy-lift rocket, with a decision in 2015 on a specific heavy-lift architecture for exploration of deep space.
- Independent of the FY2011 budget, an Administration task force will address economic development and the aerospace industry in the region of Florida known as the Space Coast.

[37] P.L. 111-117, Division B, Title III.

[38] See, for example, the letter from 27 members of Congress to NASA Administrator Charles Bolden, February 12, 2010, at http://www.posey.house.gov/UploadedFiles/LetterToBolden-CancellingConstellation-Feb15-2010.pdf.

[39] GAO, *National Aeronautics and Space Administration—Constellation Program and Appropriations Restrictions, Part I*, B-319488, May 21, 2010, http://www.gao.gov/decisions/appro/319488.pdf; and *Part II*, B-320091, July 23, 2010, http://www.gao.gov/decisions/appro/320091.pdf.

[40] NASA Administrator Charles F. Bolden, Jr., letter to Rep. Bart Gordon, Chairman, House Committee on Science and Technology, June 9, 2010, http://spacepolicyonline.com/pages/images/stories/Bolden_Letter_to_Hill_on_Constellation_June_2010.pdf.

[41] For a transcript of the speech, see "Remarks by the President on Space Exploration in the 21st Century," White House press release, April 15, 2010, http://www.whitehouse.gov/the-press-office/remarks-president-space-exploration-21st-century. See also two White House fact sheets provided in association with the speech: "A Bold Approach for Space Exploration and Discovery," http://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp-space-conf-factsheet.pdf, and "Florida's Space Workers and the New Approach to Human Spaceflight," http://www.whitehouse.gov/sites/default/files/microsites/ostp/nasa-space-conf-factsheet.pdf.

An Administration budget amendment in June 2010 proposed transferring $100 million from the Exploration account in NASA's FY2011 budget request to the Departments of Commerce and Labor "to spur regional economic growth and job creation along the Florida Space Coast and other affected regions."[42]

Human Spaceflight: The 2010 Authorization Act

In October 2010, Congress passed the NASA Authorization Act of 2010 (P.L. 111-267). The act authorizes funding for NASA for FY2011 through FY2013 at a level that matches the Administration's proposals. Its allocation of those funds within the agency, however, is quite different. New efforts in long-term space technology development are reduced by about half. This allows the addition of one extra space shuttle flight in FY2011 and additional funding for other human spaceflight programs in subsequent years. The human spaceflight program is to retain the full Orion crew capsule and develop a new, crew-capable, heavy-lift rocket. To pay for Orion and the new rocket, other elements of the human spaceflight program are to be scaled back significantly, including the Administration's proposals for technology demonstrations, robotic precursor missions, and development of commercial crew launch services.

As with any authorization act, these budgetary plans are subject to subsequent appropriations by Congress. Because the 111th Congress did not pass a regular FY2011 appropriations act for NASA, the 112th Congress will determine appropriations for all three years covered by the 2010 authorization act.

Other provisions of the NASA Authorization Act of 2010 are discussed throughout this report together with related discussion of the topics addressed.

Science

About two-thirds of NASA's budget is associated with human spaceflight. Most of the rest is devoted to unmanned science missions. These science missions fall into four categories: Earth science, planetary science, heliophysics, and astrophysics. The latter three are sometimes known collectively as space science.

In part because of concerns about climate change, both Congress and the Administration have recently placed increased emphasis on Earth science. In the FY2006 and FY2007 budget cycles NASA had no separate budget for Earth science, and supporters became concerned that this was adversely affecting the field. In late 2006, NASA reorganized the Science Mission Directorate, creating a separate Earth Science Division. The National Research Council recommended in early 2007 that the United States "should renew its investment in Earth observing systems and restore its leadership in Earth science and applications."[43] In response, Congress and the Administration increased the share of NASA's science funding devoted to Earth science from 26% in FY2008 to 32% in FY2010. In addition, NASA allocated 81% of the science funding it received under the American Recovery and Reinvestment Act of 2009 (P.L. 111-5) to Earth science. The Administration's requested budget for FY2011 would provide substantial increases for Earth

[42] http://www.whitehouse.gov/omb/assets/budget_amendments/amendment_06_18_10.pdf.

[43] National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, 2007, http://www.nap.edu/catalog/11820.html.

science funding, including a five-year, $2.1 billion global climate initiative. For FY2011 through FY2013, the NASA Authorization Act of 2010 authorized these increases.[44]

In recent years, Congress has sought to ensure that NASA's science program includes a balanced variety of approaches to R&D rather than focusing only on certain types of missions. For example, the NASA Authorization Act of 2008 stated that the science program should include space science missions of all sizes as well as mission-enabling activities such as technology development, suborbital research, and research and analysis (R&A) grants to individual investigators.[45] According to the National Research Council, "practically all relevant external advisory reports have emphasized the importance of mission-enabling activities," but determining their proper scale has been challenging "throughout NASA's history."[46] In the past few years, funding for planetary science technology has increased significantly, but funding for Earth science technology has increased only slightly; the astrophysics and heliophysics programs do not have dedicated technology subprograms. Funding for suborbital rocket operations increased from $51 million in FY2008 to $66 million in FY2010, but the trend is unclear as the latter amount was down from $77 million in FY2009.[47] Funding for R&A grants, which NASA controversially proposed to reduce significantly as recently as FY2007, has recovered as the result partly of the Administration's own initiatives and partly of congressional action on appropriations legislation. The NASA Authorization Act of 2010 reaffirmed the sense of Congress that "a balanced and adequately funded set of activities, consisting of research and analysis grants programs, technology development, small, medium, and large space missions, and suborbital research activities, contributes to a robust and productive science program and serves as a catalyst for innovation."[48]

In December 2009, the National Research Council recommended ways to make the mission-enabling activities of NASA's science programs more effective through more active management. These recommendations included establishing explicit objectives and metrics, making budgets more transparent, and clearly articulating the relationships between mission-enabling activities and the ensemble of missions they are intended to support.[49] The NASA Authorization Act of 2008 stated that the technology development program should include long-term activities that are "independent of the flight projects under development."[50] NASA may sometimes find it challenging to balance this independence against the goal of linking mission-enabling activities to the missions they support.

NASA's science programs have a history of periodic review by the National Academies. Such reviews typically take place every 10 years, so they are commonly known as decadal surveys. The NASA Authorization Act of 2005 mandated an Academy review of each division of NASA's

[44] P.L. 111-267, Sections 101-103.

[45] P.L. 110-422, Section 504.

[46] National Research Council, *An Enabling Foundation for NASA's Earth and Space Science Missions*, December 2009, http://www.nap.edu/catalog/12822.html, p. vii.

[47] The NASA Authorization Act of 2010 directed NASA to designate an individual who is responsible for all suborbital research in the Science Mission Directorate and to report annually on the number and type of suborbital missions it conducts. (P.L. 111-267, Section 802)

[48] P.L. 111-267, Section 803.

[49] National Research Council, *An Enabling Foundation for NASA's Earth and Space Science Missions*, p. 4.

[50] P.L. 110-422, Section 501.

science directorate every five years.[51] The NASA Authorization Act of 2008 also mandated periodic reviews and directed that they include independent estimates of the cost and technical readiness of each mission assessed.[52] The NASA Authorization Act of 2010 directed NASA to "implement, as appropriate ... within the scope of the funds authorized," the missions identified by the Earth science decadal survey, and to "take into account" space science decadal surveys when submitting the President's annual budget request.[53] Decadal surveys by the National Academies are generally well received by NASA and are widely respected in the science and science policy communities. On the other hand, the expertise of the National Academies is primarily scientific. It is unclear whether their analysis of mission cost and readiness will be considered equally authoritative.

Aeronautics

After human spaceflight and science, NASA's largest activity is research on aeronautics, the science and technology of flight within Earth's atmosphere. There is a history of disagreement in Congress about the appropriate role of this program. Supporters argue that the aviation industry is vital to the economy, especially because aircraft are a major component of U.S. exports. They claim that government funding for aeronautics research can contribute to U.S. competitiveness and is necessary in light of similar programs in Europe and elsewhere.[54] Opponents counter that the aviation industry itself should pay for the R&D it needs. Against the background of this debate, NASA aeronautics programs have focused increasingly on long-term fundamental R&D and on research topics with clear public purposes, such as reducing noise and emissions, improving safety, and improving air traffic control.

In 2005, Congress directed the President to develop a national policy for aeronautics R&D.[55] The National Science and Technology Council (NSTC), part of the Executive Office of the President, issued this policy in December 2006.[56] The policy established general principles and goals for federal aeronautics activities, laid out the roles and responsibilities of NASA and other agencies, and directed the NSTC to issue a national aeronautics R&D plan at least every two years. The NSTC released the first national aeronautics R&D plan in December 2007 and the second in February 2010.[57] The NASA Authorization Act of 2008 stated that NASA's aeronautics research program should be "guided by and consistent with" the national aeronautics R&D policy.[58]

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[51] P.L. 109-155, Section 301.

[52] P.L. 110-422, Section 1104.

[53] P.L. 111-267, Sections 704 and 805.

[54] In 2005, a NASA-funded report found that European government support for aeronautics R&D was growing and that European countries "support civil aeronautics research on the basis of industrial policies." (Hans J. Weber et al., "Study of European Government Support to Civil Aeronautics R&D," August 15, 2005, http://www.aeronautics.nasa.gov/docs/tecop_europe_aero_r&d.pdf.) The report also found that European aeronautics R&D was increasingly guided by a 2001 European Union report that called for European countries to invest about $100 billion in the topic over 20 years. See *European Aeronautics: A Vision for 2020*, http://www.acare4europe.org/docs/Vision%202020.pdf.

[55] P.L. 109-155, Section 101(c). A similar but less detailed provision was previously included in Section 628 of the Science, State, Justice, Commerce, and Related Agencies Appropriations Act, 2006 (P.L. 109-108).

[56] Executive Office of the President, National Science and Technology Council, *National Aeronautics Research and Development Policy*, December 2006, http://www.aeronautics.nasa.gov/releases/national_aeronautics_rd_policy_dec_2006.pdf.

[57] Executive Office of the President, National Science and Technology Council, *National Plan for Aeronautics Research and Development and Related Infrastructure*, December 2007, http://www.aeronautics.nasa.gov/releases/
(continued...)

In June 2006, in response to a congressional mandate, the National Research Council of the National Academies released a decadal strategy for federal civil aeronautics activities, with a particular emphasis on NASA's aeronautics research program.[59] Along with other recommendations, the report identified 51 technology challenges to serve as the foundation for aeronautics research at NASA for the next decade. In the 2008 authorization act, Congress directed NASA to align its fundamental aeronautics research program with these technology challenges "to the maximum extent practicable within available funding" and to increase the involvement of universities and other external organizations in that program.[60] It also mandated periodic Academy reviews of the NASA aeronautics program and directed that they include independent estimates of the cost and technical readiness of each mission assessed.[61] As noted above with respect to its decadal surveys of NASA science, while the National Academies are widely respected for their scientific expertise, it is unclear whether their analysis of cost and technical readiness will be considered equally authoritative.

The aeronautics program's heavy use of shared facilities and capabilities, such as wind tunnels and supercomputers, has sometimes created challenges. For example, when NASA introduced full-cost accounting in the FY2004 budget request, the stated cost of the aeronautics program increased significantly because facility costs had previously been budgeted in another account. At least partly in response to these concerns, NASA subsequently established a separate Aeronautics Test Program in the aeronautics directorate and a Strategic Capabilities Assets Program outside the directorate. It has also sometimes been difficult for NASA to balance its stewardship of unique aeronautics facilities, often used by other agencies and by industry as well as by NASA itself, against the cost of maintaining those facilities. In 2005, Congress directed NASA to establish a separate account to fund aeronautics test facilities, to charge users of NASA test facilities at a rate competitive with alternative facilities, and not to implement a policy seeking full cost recovery for a facility without giving 30 days' notice to Congress.[62] To accompany the national aeronautics R&D plan, the Aeronautics Science and Technology Subcommittee of the NSTC developed a national aeronautics research, development, test, and evaluation infrastructure plan.[63] The infrastructure plan will be updated periodically in response to the biennial updates of the R&D plan.[64]

There is ongoing congressional interest in the relationship between NASA's aeronautics program and related efforts by the Federal Aviation Administration (FAA) and the Department of Defense (DOD). One aspect of this relationship is the interagency Joint Planning and Development Office (JPDO), which oversees the development of a Next Generation Air Transportation System

(...continued)

aero_rd_plan_final_21_dec_2007.pdf, and *National Plan for Aeronautics Research and Development*, February 2010, http://www.whitehouse.gov/sites/default/files/microsites/ostp/aero-rdplan-2010.pdf.

[58] P.L. 110-422, Section 301.

[59] National Research Council, *Decadal Survey of Civil Aeronautics: Foundation for the Future*, 2006, http://www.nap.edu/catalog/11664.html. The congressional mandate was in P.L. 109-155, Section 421(c).

[60] P.L. 110-422, Section 303.

[61] P.L. 110-422, Section 1104.

[62] P.L. 109-155, Section 205.

[63] Executive Office of the President, National Science and Technology Council, *National Aeronautics Research, Development, Test, and Evaluation (RDT&E) Infrastructure Plan*, January 2011, http://www.whitehouse.gov/sites/default/files/microsites/ostp/NSTC-Approved-IPlan-04Jan2011.pdf.

[64] Ibid., p. 7.

(NGATS) for improved airspace management.[65] Congress has directed NASA to align the Airspace Systems program of its Aeronautics Research Directorate with the objectives of the JPDO and NGATS.[66] The NASA Authorization Act of 2010 directed NASA to continue to coordinate its aeronautics research with DOD and the FAA.[67]

Education

In 2008, a congressionally mandated National Academies review of NASA education programs found that even though NASA is uniquely positioned to interest students in science, technology, and engineering, its education programs are not as effective as they could be.[68] The report found that NASA has no coherent plan to evaluate its education programs, and few of them have ever been formally evaluated. It recommended that NASA develop an evaluation plan and use the results of the evaluations to inform project design and improvement. It found that the operating directorates, rather than the Office of Education, fund about half of the agency's primary and secondary education activities. It recommended that the Office of Education focus on coordination and oversight, including advocacy for the inclusion of education activities in the programs of the operating directorates. Congress directed NASA to prepare a plan in response to the recommendations of the National Academies, including a schedule and budget for any actions that have not yet been implemented.[69] NASA issued this plan in January 2010.[70] In the NASA Authorization Act of 2010, Congress directed NASA to submit a report on outcomes of its education programs.[71]

Unlike the Department of Education or the National Science Foundation, NASA does not have a lead role in federal education programs. As a result, some analysts may view NASA's education activities as secondary to its primary efforts in spaceflight, science, and aeronautics. Congress, however, is typically supportive of NASA education programs and often provides more funding for them than NASA requests. This imbalance between Administration and congressional priorities, the dispersed nature of NASA's education activities outside the Office of Education, and the tendency for congressional funding increases to be dedicated to specific one-time projects rather than to ongoing programs, may make it difficult for NASA to plan and manage a coherent, unified education program.

Balancing Competing Priorities

Ever since the announcement of the Vision, NASA's emphasis on exploration has created concerns about the balance between human spaceflight and NASA's other activities, especially

[65] The establishment of JPDO was mandated by Section 709 of the Vision 100 – Century of Aviation Reauthorization Act (P.L. 108-176). For more information on NGATS, see CRS Report R40410, *Federal Aviation Administration (FAA) Reauthorization: An Overview of Legislative Action in the 111th Congress*, coordinated by (name redacted).

[66] P.L. 109-155, Section 423.

[67] P.L. 111-267, Section 903.

[68] National Research Council, *NASA's Elementary and Secondary Education Program: Review and Critique*, 2008, http://www.nap.edu/catalog/12081.html. The mandate for this review was in P.L. 109-155, Section 614.

[69] P.L. 110-422, Section 701.

[70] NASA, *NASA Report Regarding Response to the National Research Council Review of the NASA Elementary and Secondary Education Program*, January 2010.

[71] P.L. 111-267, Section 1001.

science and aeronautics. Because most funding for the Vision has been redirected from other NASA activities, advocates of science and aeronautics have feared that their programs will be cut in order to pay for human exploration activities. Congress, while fully supporting the Vision, has been clear about the need for balance. The NASA Authorization Act of 2005 directed NASA to carry out "a balanced set of programs," including human space flight in accordance with the Vision, but also aeronautics R&D and scientific research, the latter to include robotic missions and research not directly related to human exploration.[72] The NASA Authorization Act of 2008 found that NASA "is and should remain a multimission agency with a balanced and robust set of core missions in science, aeronautics, and human space flight and exploration" and "encouraged" NASA to coordinate its exploration activities with its science activities.[73] In January 2010, NASA Administrator Charles Bolden assured a group of scientists that "the future of human spaceflight will not be paid for out of the hide of our science budget."[74]

Balancing these competing priorities depends on answering questions, raised earlier in this report, about NASA's purpose. More than 50 years ago, President Eisenhower's advisors were aware that a space program was justified both by "the compelling urge of man to explore and to discover" and by "scientific observation and experiment which will to add to our knowledge and understanding." Today, there is still no consensus about how to balance these purposes. Some policy makers believe that a space program can best be justified by tangible benefits to economic growth and competitiveness. Others believe that its most important role is to be a source of national pride, prestige, and inspiration.

Space Shuttle Program

Since its first launch in April 1981, the space shuttle has been the only U.S. vehicle capable of carrying humans into space. After a few remaining flights during 2011, the space shuttle program is scheduled to end. Although some advocates and policy makers would like to extend the program, technical and management issues are making that ever more difficult as the scheduled termination approaches. Congress's attention is increasingly on managing the transition of the shuttle workforce and facilities and on addressing the projected multi-year gap in U.S. access to space between the last shuttle flight and the first flight of its successor.

Why the Shuttle Program Is Ending

The oldest shuttle is approaching 30 years old; the youngest is approaching 20. Although many shuttle components have been refurbished and upgraded, the shuttles as a whole are aging systems. Most analysts consider the shuttle design to be based, in many respects, on obsolete or obsolescent technology. The original concept of the shuttle program was that a reusable launch vehicle would be more cost-effective than an expendable one, but many of the projected cost savings depended on a flight rate that has never been achieved.

[72] P.L. 109-155, Section 101(a)(1).

[73] P.L. 110-422, Sections 2 and 409.

[74] NASA Administrator Charles F. Bolden, Jr., address to a meeting of the American Astronomical Society, January 5, 2010, http://www.nasa.gov/pdf/415511main_Bolden_AAS_Remarks_010510.pdf.

Over the years, NASA has attempted repeatedly, but unsuccessfully, to develop a second-generation reusable launch vehicle to replace the shuttle. In 2002, NASA indicated that the shuttle would continue flying until at least 2015 and perhaps until 2020 or beyond. The *Columbia* disaster in 2003 forced NASA to revise that plan.

Within hours of the loss of the space shuttle *Columbia* and its seven astronauts, NASA established the Columbia Accident Investigation Board to determine the causes of the accident and make recommendations for how to proceed.[75] The board concluded that the shuttle "is not inherently unsafe" but that several actions were necessary "to make the vehicle safe enough to operate in the coming years."[76] It recommended 15 specific actions to be taken before returning the shuttle to flight. In addition, it found that

> because of the risks inherent in the original design of the space shuttle, because the design was based in many aspects on now-obsolete technologies, and because the shuttle is now an aging system but still developmental in character, it is in the nation's interest to replace the shuttle as soon as possible as the primary means for transporting humans to and from Earth orbit.[77]

The board recommended that if the shuttle is to be flown past 2010, NASA should "develop and conduct a vehicle recertification at the material, component, subsystem, and system levels" as part of a broader and "essential" Service Life Extension Program.[78]

The announcement of the Vision for Space Exploration in 2004 created another reason to end the shuttle program: money. Before the shuttle program began to ramp down, it accounted for about 25% of NASA's budget. Making those funds available for the Vision became a primary motivation for ending the program.

Possible Extension of the Shuttle Program

Despite the safety risks identified by the Columbia Accident Investigation Board and the need to reallocate the shuttle's funding stream to other purposes, some policy makers and advocates remain eager to extend the program. For example, the NASA Authorization Act of 2008 directed NASA not to take any action that would preclude a decision to extend the shuttle program past 2010.[79] One of the options put forward by the Augustine committee (Variant 4B) included extending the shuttle program to 2015. The NASA Authorization Act of 2010 provided for an additional shuttle flight no earlier than June 1, 2011, and directed NASA to preserve its capability to launch space shuttles through FY2011.[80]

A decision to extend the program would create challenges relating to cost, schedule, and safety. With the planned termination date approaching, some contracts for shuttle components have

[75] For more details, see CRS Report RS21606, *NASA's Space Shuttle Columbia: Synopsis of the Report of the Columbia Accident Investigation Board*, by (name redacted).

[76] Columbia Accident Investigation Board, untitled report, August-October 2003, http://caib.nasa.gov/, vol. 1, p. 208.

[77] Columbia Accident Investigation Board, vol. 1, pp. 210-211.

[78] Columbia Accident Investigation Board, vol. 1, p. 209.

[79] P.L. 110-422, Section 611(d).

[80] P.L. 111-267, Section 503(e)-(f), with funding for the additional flight authorized in Section 101(2)(B).

already run out, and some contractor personnel have already been let go.[81] Reestablishing the capability to operate the program would likely incur costs and delays, and this potential will grow as the planned termination date approaches. The recertification process recommended by the Columbia Accident Investigation Board could be costly and time-consuming, although the board itself gave no estimate of either cost or schedule. At this point, completing a recertification in time to maintain a continuous flight schedule might already be difficult. Congressional policy makers or the Administration could simply decide to continue flying anyway, in parallel with the recertification process—in effect, NASA has already done this to some extent with the decision to allow a few flights originally planned for 2010 to slip into 2011—but policy makers might suffer political repercussions from such a choice if another serious accident occurred.

During the 2009 presidential transition, the GAO identified the pending retirement of the space shuttle in 2010 as one of 13 "urgent issues" facing the incoming Obama Administration.[82] The GAO also stated that "according to NASA, reversing current plans and keeping the shuttle flying past 2010 would cost $2.5 billion to $4 billion per year."[83]

Transition of Shuttle Workforce and Facilities

The transition of assets and personnel at the end of the shuttle program is of great interest to many in Congress and represents a major challenge for NASA. The shuttle workforce is a reservoir of unique expertise and experience that would be difficult for NASA and its contractors to reassemble once dispersed. NASA managers are particularly concerned to maintain key human spaceflight expertise and capabilities. In certain communities, the loss of the shuttle workforce will have a significant economic impact. For individuals, the loss of specialized, well-paid employment that has been relatively stable for many years can be especially disruptive at a time when the job market is already unusually difficult. Finding the best alternative use of facilities and equipment is important for getting the best value for the taxpayer.

NASA's transition management plan, issued in August 2008, establishes a timeline for the post-shuttle transition, defines organizational responsibilities for various aspects of the transition, establishes goals and objectives, and outlines planning and management challenges such as management of human capital and disposition of infrastructure.[84] As it notes, the scope of the transition is huge:

> The SSP [space shuttle program] has an extensive array of assets; the program occupies over 654 facilities, uses over 1.2 million line items of hardware and equipment, and employs over 2,000 civil servants, with more than 15,000 work year equivalent personnel employed by the contractors. In addition, the SSP employs over 3,000 additional indirect workers through Center Management and Operations and service accounts. The total equipment acquisition value is over $12 billion, spread across hundreds of locations. The total facilities replacement cost is approximately $5.7 billion, which accounts for approximately one-fourth of the value

[81] For example, see Tariq Malik, "NASA Begins Job Cuts for Shuttle Retirement," Space.com, May 1, 2009.

[82] http://www.gao.gov/transition_2009/urgent/.

[83] http://www.gao.gov/transition_2009/urgent/space-shuttle.php

[84] National Aeronautics and Space Administration, *NASA Transition Management Plan for Implementing the U.S. Space Exploration Policy*, JICB-001, August 2008, http://www.nasa.gov/pdf/202388main_Transition_Mgmt_Plan-Final.pdf.

of the Agency's total facility inventory. There are over 1,200 active suppliers and 3,000 to 4,000 qualified suppliers geographically located throughout the country.[85]

Congress has addressed a number of these issues through legislation:

- In the NASA Authorization Act of 2005, Congress directed NASA to use the personnel, capabilities, assets, and infrastructure of the shuttle program "to the fullest extent possible consistent with a successful development program" in developing the vehicles now known as Orion, Ares I, and Ares V. It also required the development of a transition plan for personnel affected by the termination of the shuttle program.[86]
- In the Commerce, Justice, Science, and Related Agencies Appropriations Act, 2008, Congress directed NASA to prepare a strategy, to be updated at least every six months, for minimizing job losses as a result of the transition from the shuttle to its successor.[87] The strategy report was first issued in March 2008 and was updated in October 2008 and July 2009.[88] As well as strategic information, it provides annual workforce projections for each NASA center and a summary of recent relevant actions by NASA and its contractors.
- In the NASA Authorization Act of 2008, Congress directed NASA to submit a plan for the disposition of the shuttles and associated hardware and to establish a Space Shuttle Transition Liaison Office to assist affected communities.[89] It provided for temporary continuation of health benefits for personnel whose jobs are eliminated as a result of the termination of the program.[90] It directed NASA to analyze the facilities and personnel that will be made available by the termination of the shuttle program and to report on other current and future federal programs that could use them.[91] The resulting report summarized the "mapping" process that NASA is using to align the civil servant and contractor shuttle workforce and the shuttle facilities at each NASA center with the needs of other programs.[92]
- In the Commerce, Justice, Science, and Related Agencies Appropriations Act, 2010, and in previous NASA appropriations acts for several years, Congress prohibited NASA from using appropriated funds to implement reductions in force (RIFs) or other involuntary separations, except for cause.[93]

Before the release of the Administration's FY2011 budget, many of the personnel employed in the shuttle program were expected to transition to the Constellation program. The new direction for

[85] NASA, *Transition Management Plan*, pp. 7-8.

[86] P.L. 109-155, Section 502.

[87] Consolidated Appropriations Act of 2008 (P.L. 110-161), Division B.

[88] For the most recent update, see *NASA Space Shuttle Workforce Transition Strategy Pursuant to FY 2008 Consolidated Appropriations Act (P.L. 110-161), July 2009 Update*, http://www.nasa.gov/pdf/372110main_7-21-09%20Workforce%20Transition%20Strategy%203rd%20Edition.pdf.

[89] P.L. 110-422, Section 613.

[90] P.L. 110-422, Section 615.

[91] P.L. 110-422, Section 614.

[92] National Aeronautics and Space Administration, *Aerospace Skills Retention and Investment Reutilization Report*, July 2009.

[93] Consolidated Appropriations Act, 2010 (P.L. 111-117), Division B.

NASA's human spaceflight program established by the NASA Authorization Act of 2010 introduces new uncertainty into these plans.

International Space Station

The ISS is composed of crew living space, laboratories, remote manipulator systems, solar arrays to generate electricity, and other elements. Launched separately, these elements were assembled in space. Rotating crews have occupied the ISS, each for a period of four to six months, since November 2000.[94]

When the space station was first announced, its assembly was to be complete by 1994. In 1998, when construction actually began, it was expected to be complete by 2002, with operations through at least 2012. Completion is now scheduled during 2011. In 2003, NASA briefing charts showed operations possibly continuing through 2022. Under the Vision, announced in 2004, U.S. utilization was scheduled to end after 2015. The NASA Authorization Act of 2010 extended U.S. utilization through at least FY2020.[95]

The framework for international cooperation on the ISS is the Intergovernmental Agreement on Space Station Cooperation, which was signed in 1998 by representatives of the United States, Russia, Japan, Canada, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. The intergovernmental agreement has the status of an executive agreement in the United States, but is considered a treaty in all the other partner countries. It is implemented through memoranda of understanding between NASA and its counterpart agencies: the Russian Federal Space Agency (Roskosmos), the Japanese Aerospace Exploration Agency (JAXA), the Canadian Space Agency (CSA), and the European Space Agency (ESA).[96] The United States also has an ISS participation agreement with Brazil, independent of the 1998 framework.

Because of cost growth and schedule delays, the scope and capabilities of the ISS have repeatedly been downsized.[97] The original concept was not just a laboratory, but also an observatory; a transportation node; a facility for servicing, assembly, and manufacturing; and a storage depot and staging base for other missions.[98] By 1989, only the laboratory function remained, and even that was smaller and less capable than in the original plans. In 1993, Russia joined the space station partnership, a move that added foreign policy objectives to the program's goals. By 2001, following further downsizing, NASA saw three goals for the station: conducting world-class research, establishing a permanent human presence in space, and "accommodation of all international partner elements."[99] Following the announcement of the Vision in 2004, learning to

[94] For more details, see the ISS website, http://www.nasa.gov/mission_pages/station/main/index.html.

[95] P.L. 111-267, Section 503(a).

[96] The text of the bilateral memoranda of understanding can be found at http://www.nasa.gov/mission_pages/station/structure/elements/partners_agreement.html.

[97] For more information on the evolution of the space station's purposes and capabilities, see (name redacted), Congressional Research Service, "NASA's Space Station Program: Evolution of its Rationale and Expected Uses," testimony before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space, April 20, 2005, http://commerce.senate.gov/pdf/smith.pdf.

[98] James Beggs, Administrator, National Aeronautics and Space Administration, testimony before the House Committee on Appropriations, Subcommittee on HUD-Independent Agencies, March 27, 1984.

[99] Daniel Goldin, Administrator, National Aeronautics and Space Administration, testimony before the House (continued...)

live and work in space became a key justification for the ISS program, and ISS research was to be focused on the long-term effects of space travel on human biology.

Concerned that the station's function as a research laboratory was being eroded, Congress took several legislative actions. The NASA Authorization Act of 2005 required NASA to allocate at least 15% of the funds budgeted to ISS research to "life and microgravity science research that is not directly related to supporting the human exploration program."[100] It also required NASA to submit a research plan for utilization of the ISS.[101] Issued in June 2006, the plan described proposed R&D and utilization activities in each of six disciplinary areas.[102] It characterized the ISS as a long-duration test-bed for future lunar missions; a flight analog for future missions to Mars; a laboratory for research directly related to human space exploration, such as human health countermeasures, fire suppression, and life support; and an opportunity to gain experience in managing international partnerships for long-duration space missions. The plan stated that research not related to exploration would continue "at a reduced level." At about the same time, the National Academies issued a review of NASA's plans for the ISS.[103] This review noted "with concern" that the objectives of the ISS "no longer include the fundamental biological and physical research that had been a major focus of ISS planning since its inception." It concluded that "once lost, neither the necessary research infrastructure nor the necessary communities of scientific investigators can survive or be easily replaced."

ISS National Laboratory

The 2005 authorization act designated the U.S. portion of the ISS as a national laboratory, to be available for use by other federal agencies and the private sector.[104] As required by the act, NASA submitted a plan for this designation in May 2007.[105] It concluded that NASA use of the ISS must continue to have first priority, that use by non-NASA entities should be funded by those entities, and that "the availability of cost-effective transportation services will directly affect the ability of the ISS to operate as a national laboratory in the years to come." The impact that the national laboratory designation would have was initially unclear. In the NASA Authorization Act of 2008, Congress directed NASA to establish an advisory committee on the effective utilization of the ISS as a national laboratory.[106] As of mid-2009, NASA had established agreements for use of the ISS with at least five other federal agencies, three private firms, and one university, and had identified "firm interest" in using the ISS for education; human, plant, and animal biotechnologies;

(...continued)

Committee on Science, April 25, 2001.

[100] P.L. 109-155, Section 204.

[101] P.L. 109-155, Section 506.

[102] National Aeronautics and Space Administration, *Research and Utilization Plan for the International Space Station*, June 2006, http://www.exploration.nasa.gov/documents/reports/NASA_Research_and_Utilization_Plan_for_the_ISS.pdf.

[103] National Research Council, *Review of NASA Plans for the International Space Station*, 2006, http://www.nap.edu/catalog/11512.html.

[104] P.L. 109-155, Section 507.

[105] National Aeronautics and Space Administration, *NASA Report to Congress Regarding a Plan for the International Space Station National Laboratory*, May 2007, http://www.nasa.gov/pdf/181149main_ISS_National_Lab_Final_Report_rev2.pdf.

[106] P.L. 110-422, Section 602.

aerospace technologies; and defense sciences research.[107] NASA officials believe that about half of planned U.S. utilization resources on the ISS could be available for non-NASA use.[108]

The NASA Authorization Act of 2010 directed NASA to contract with a nonprofit organization to manage the activities of the ISS national laboratory.[109] Under this provision, 50% of the U.S. research capacity allocation on the ISS will be reserved for experiments managed through the national laboratory process, and NASA utilization in excess of 50% will have to be requested through a proposal to the managing organization. NASA expects to select the managing organization no sooner than May 2011.[110]

ISS Service Life Extension

The U.S. ISS components were designed for a 15-year lifetime from the date of deployment. They were launched at various times during the assembly process, but the nominal reference point is considered to be the launch of the U.S. laboratory module Destiny in February 2001. Despite the 15-year specification, past experience "clearly indicates that systems are capable of performing safely and effectively for well beyond their original design lifetime" if properly maintained, refurbished, and validated. The first milestones for a decision on service life extension past February 2016 will occur in 2014.[111]

In order to receive a greater return on the cost and effort that have been invested in ISS construction, the NASA Authorization Act of 2010 extended operation and utilization of the ISS through at least FY2020. It also directed NASA to carry out a comprehensive review to identify spare and replacement parts that this extension will necessitate. A report on the review is to be provided to Congress in January 2011, and the Government Accountability Office is to provide its assessment of the report within 90 days after that.[112]

In addition to cost, extending the life of the ISS will require overcoming several technical challenges. At present, failed parts are returned to Earth in the space shuttle for refurbishment. After the conclusion of the shuttle program, this repair strategy will likely no longer be possible, as most of the cargo vehicles being considered for the post-shuttle period are not capable of returning cargo back to Earth.[113] Instead, new parts will need to be manufactured and sent up, but even this may be impossible in a few cases, as some ISS parts are too large for any of the planned

[107] National Aeronautics and Space Administration, Congressional Budget Justification for FY2010, http://www.nasa.gov/pdf/345225main_FY_2010_UPDATED_final_5-11-09_with_cover.pdf, p. SPA-15.

[108] Ibid.

[109] P.L. 111-267, Section 504.

[110] National Aeronautics and Space Administration, "Competitive Acquisition of Cooperative Agreement for ISS National Laboratory Management Entity: Supplemental Information," http://www.nasa.gov/pdf/507694main_CAN_Supplemental_Information.pdf. See also "Draft Cooperative Agreement Notice No. NNH11SOMD002C," http://nspires.nasaprs.com/external/viewrepositorydocument/cmdocumentid=251501/Draft ISS National Lab Not-for-Profit CAN 12_3_2010 Draft Release.pdf; and "Reference Model for the International Space Station U.S. National Laboratory," http://www.nasa.gov/pdf/487816main_10_09_22 ISS National Lab ProOrbis Reference Model.pdf.

[111] National Aeronautics and Space Administration, *NASA Report to Congress Regarding a Plan for the International Space Station National Laboratory*, p. 5.

[112] P.L. 111-267, Section 503(b)-(c).

[113] After delivering their payloads, they are designed to burn up in the atmosphere or crash into the ocean.

post-shuttle cargo alternatives. Last but not least, as ISS components reach the end of their 15-year design life, they will need to be recertified, which is a potentially complex and costly process.

Post-Shuttle Access to the ISS

The U.S. space shuttle has been the major vehicle taking crews and cargo to and from the ISS. Russian Soyuz spacecraft also carry both crews and cargo. Russian Progress spacecraft carry cargo only, as they are not designed to survive reentry into the Earth's atmosphere. A Soyuz is always attached to the station as a "lifeboat" in case of an emergency. The "lifeboat" Soyuz must be replaced every six months.

Paying Russia for flights on the Soyuz is the only short-term option for U.S. human access to the ISS after the end of the space shuttle program. In 2009, in order to permit such payments, Congress extended a waiver of the Iran, North Korea, and Syria Nonproliferation Act (P.L. 106-178 as amended) until July 1, 2016.[114]

One element of NASA's plans for ensuring cargo access to the ISS during the gap is the Commercial Orbital Transportation Services (COTS) program to develop commercial capabilities for cargo spaceflight. Under the COTS program, SpaceX Corporation is developing a vehicle known as Dragon, and Orbital Sciences Corporation is developing a vehicle known as Cygnus. Both are cargo-only vehicles (at least in their initial versions) and will have about one-eighth the capacity of the space shuttle.[115] Only Dragon will be capable of returning cargo to Earth as well as launching it into space. The first test flight of Dragon took place successfully in December 2010. Cygnus has not yet flown into space. In the NASA Authorization Act of 2008, Congress directed NASA to develop a contingency plan for post-shuttle cargo resupply of the ISS in case commercial cargo services are unavailable.[116] This plan was transmitted to Congress in March 2010.[117]

Noncommercial alternatives for cargo, in addition to the Russian Progress, include the European Automated Transfer Vehicle (ATV) and the Japanese H-II Transfer Vehicle (HTV). The first ATV was launched in March 2008 and carried out docking demonstrations with the ISS the following month. The first HTV was launched in September 2009 and also docked successfully with the ISS. Contracting with Russia for use of the Progress would probably require passing an additional waiver of the Iran, North Korea, and Syria Nonproliferation Act. Like Dragon and Cygnus, the ATV, HTV, and Progress all have significantly smaller cargo capacity than the space shuttle.[118] None of the noncommercial alternatives is capable of returning cargo to Earth.

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[114] Consolidated Security, Disaster Assistance, and Continuing Appropriations Act of 2009 (P.L. 110-329), Section 125. For more information, see CRS Report RL34477, *Extending NASA's Exemption from the Iran, North Korea, and Syria Nonproliferation Act*, by (name redacted) and Mary Beth Nikitin.

[115] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, Fig. 4.2.2-1, p. 53.

[116] P.L. 110-422, Section 603.

[117] NASA, *Logistics Contingency Plan for the International Space Station*, March 2010.

[118] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, Fig. 4.2.2-1, p. 53. The Progress has about 10% the cargo capacity of the shuttle. The HTV and ATV have about 20%.

In addition to commercial cargo services, the NASA Authorization Act of 2010 authorized the establishment and funding of a program to advance the development of commercial services that could carry crews. Commercial crew transportation services are discussed further in the next section.

Future Access to Space

Whatever spacecraft are ultimately used for access to the ISS following the end of the space shuttle program, in the long term new vehicles will be needed to carry humans and cargo into space, both to low Earth orbit and beyond. Under the Constellation program, these vehicles would be the crew capsule Orion, the Ares I rocket to launch Orion into low Earth orbit, and the heavy-lift Ares V rocket to launch cargo. Under the new direction established by the NASA Authorization Act of 2010, they would be a multipurpose crew vehicle based on Orion; a new, crew-capable, heavy-lift rocket referred to in the act as the space launch system; and commercial services to carry astronauts to and from low Earth orbit. (The multipurpose crew vehicle and space launch system would together provide a backup option in the event that those commercial services are not available when needed.) A variety of alternatives to these plans have been proposed, particularly with respect to heavy-lift rockets.

Orion and Ares

Development of Orion and Ares I is well under way by NASA and its contractors. Development of Ares V has not begun, but Ares I and Ares V would share some components. If the Constellation program were continued, the first crewed flight of Orion and Ares would be scheduled for 2015. The Augustine committee concluded that a 2017 date is more realistic and that a delay until 2019 is possible.

Orion is similar to an enlarged Apollo capsule. It is designed to carry six astronauts and to operate in space for up to six months. An upgraded version would be required for travel to the Moon or beyond. The Augustine committee concluded that Orion "will be acceptable for a wide variety of tasks in the human exploration of space" but expressed concern about its operational cost once developed. The committee suggested that a smaller, lighter, four-person version could reduce operations costs for support of the ISS by allowing landing on land rather than in the ocean and by enabling simplifications in the launch-abort system.[119]

The Ares I rocket is designed to be a high-reliability launcher that, when combined with Orion, will yield a crew transport system with an estimated 10-fold improvement in safety relative to the space shuttle. The development of Ares I has encountered some technical difficulties, but the Augustine committee characterized these as "not remarkable" and "resolvable."[120]

Ares V is designed to be capable of launching 160 metric tons of cargo into low Earth orbit.[121] By comparison, the space shuttle has a cargo capacity for ISS resupply missions of about 16 metric

[119] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 58.

[120] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p.60.

[121] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great* (continued...)

tons, and the ISS, which was launched in pieces over a decade, weighs a total of 350 metric tons.[122] For human missions beyond low Earth orbit, Ares V would launch equipment into orbit for rendezvous with an Orion launched by an Ares I. At present, Ares V is only a conceptual design. The Augustine committee described it as "an extremely capable rocket" but estimated that it was unlikely to be available until the late 2020s.

Multipurpose Crew Vehicle and Space Launch System

For human space flight beyond low Earth orbit, the NASA Authorization Act of 2010 directed NASA to develop a multipurpose crew vehicle, based on Orion, and a new crew-capable, heavy-lift rocket known as the space launch system.

The multipurpose crew vehicle would "continue to advance the development" of the features, designs, and systems of Orion. Its capabilities would include serving as the primary crew vehicle for missions beyond low Earth orbit; conducting in-space operations, such as rendezvous, docking, and extra-vehicular activities; and delivering crews and cargo to the ISS, if commercial and other alternative services are unavailable. The act established December 31, 2016, as the target date for achieving full operational capability.[123]

The capabilities of the space launch system would include lifting the multipurpose crew vehicle; initially, without an upper stage, lifting payloads weighing between 70 and 100 metric tons into low Earth orbit; with an integrated upper stage, lifting payloads weighing at least 130 metric tons; and delivering crews and cargo to the ISS, if commercial and other alternative services are unavailable. December 31, 2016, is the target date for achieving full operational capability of the initial version, without an upper stage.

In January 2011, NASA submitted a preliminary report to Congress on its plan for implementing the authorization act's requirements for the multipurpose crew vehicle human and space launch systems.[124] The report stated that NASA has not yet been able to identify spacecraft designs that meet the act's capability and schedule requirements within the authorized funding levels.

Heavy-Lift Alternatives

The Augustine committee identified three categories of heavy-lift launchers that could be alternatives to Ares V: a scaled-down version of Ares V called Ares V Lite; a rocket derived from the design of the space shuttle; and a rocket derived from the Evolved Expendable Launch Vehicle. Unlike Ares V, each of these could be rated to carry humans (in an Orion capsule) as well as cargo.[125]

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Nation, p. 59.

[122] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 53 and 64.

[123] P.L. 111-267, Section 303.

[124] NASA, *Preliminary Report Regarding NASA's Space Launch System and Multi-Purpose Crew Vehicle*, January 2011, http://www.nasa.gov/pdf/510449main_SLS_MPCV_90-day_Report.pdf. This report was required by P.L. 111-267, Section 309.

[125] NASA requires crewed space systems to be certified as human-rated. See *Human-Rating Requirements for Space*
(continued...)

The Ares V Lite would be a slightly lower-performance version of the Ares V, capable of launching about 140 metric tons rather than 160. For human missions beyond Earth orbit, two launches of Ares V Lite, rather than one of Ares I and one of Ares V, would considerably increase the payload that could be carried to the destination. Some human missions beyond Earth orbit could be accomplished with a single Ares V Lite launch.[126]

Shuttle-derived vehicles would use the same main engines, solid rocket boosters, and external tanks as the space shuttle. They could be either in-line or side-mount. In other words, the payload could be mounted either on top or on the side. One example of the in-line option is the Jupiter design advocated by DIRECT, a group ostensibly led by NASA engineers working anonymously on their own time.[127] The Augustine committee did not compare the in-line and side-mount variants in detail, but it considered the side-mount option to be inherently less safe when carrying a crew. A shuttle-derived launcher would likely be able to lift 90 to 110 metric tons into orbit.

The Evolved Expendable Launch Vehicle program was a U.S. Air Force program that resulted in the development of the Delta IV and Atlas V rockets. Current EELV systems are not rated to carry humans. In testimony to the Augustine committee, the Aerospace Corporation stated that a human-rated variant of the Delta IV Heavy would be capable of carrying Orion to the ISS.[128] A super-heavy EELV variant could carry a cargo payload of about 75 metric tons. The Augustine committee concluded that using an EELV variant to launch Orion would only make sense if a super-heavy EELV variant were to be selected for heavy-lift cargo launch.

In addition to differences in capability, the Augustine committee found that these alternatives differ in their life-cycle costs, operational complexity, and "way of doing business." The committee concluded that Ares V Lite would be the most capable; that a shuttle derivative would take maximum advantage of existing infrastructure, facilities, and production capabilities; and that an EELV derivative could potentially have the lowest operating costs, but would require a significant restructuring of NASA. The committee noted that each alternative has strong advocates and that "the claimed cost, schedule, and performance parameters include varying degrees of aggressiveness."[129] It did not explicitly recommend any of the alternatives over the others.

The NASA Authorization Act of 2010 directed NASA to "extend or modify existing ... contracts" when developing the new space launch system. Moreover, Senate report language anticipated that

> in order to meet the specified vehicle capabilities and requirements, the most cost-effective and "evolvable" design concept is likely to follow what is known as an "in-line" vehicle design, with a large center tank structure with attached multiple liquid propulsion engines

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Systems, NASA Procedural Requirement 8705.2B, http://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_8705_002B_. Engineering requirements such as redundancy and fault tolerance are greater for human-rated systems than for uncrewed systems.

[126] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 66-67.

[127] See http://www.directlauncher.com/.

[128] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 69.

[129] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 72.

> and, at a minimum, two solid rocket motors composed of at least four segments being attached to the tank structure to form the core, initial stage of the propulsion vehicle.[130]

This language is seen by most analysts as calling for a design similar to the Augustine committee's Ares V Lite option, or possibly another in-line shuttle-derived design. Some observers have questioned whether it is appropriate for Congress to give such specific guidance about engineering design choices.[131] NASA officials have indicated their intent to "work with stakeholders in Congress to determine an appropriate transportation architecture"[132] and have stated that "we have done some very objective heavy-lift studies [and] will try to influence the conversation to make sure we don't preclude possible answers that might be the optimum overall."[133]

Commercial Crew Transportation Services

The NASA Authorization Act of 2010 authorized the establishment and funding of a program to advance the development of commercial services that can carry astronauts. The Commercial Crew Development (CCDev) program extends and authorizes an initiative begun with funds from the American Recovery and Reinvestment Act of 2009 (ARRA, P.L. 111-5). A number of companies, including SpaceX, Orbital, Boeing, Virgin Galactic, and the Sierra Nevada Corporation, have expressed interest in providing commercial crew launch services.[134] Before CCDev, the COTS program considered the use of commercial services for ISS crew transfer and crew rescue (a capability known as COTS D).

Regarding the option of relying on commercial services in lieu of Ares I for all crew access to low Earth orbit, the Augustine committee concluded the following:[135]

- Considering that all U.S. crew launch systems to date have been built by industry, "there is little doubt" that the U.S. aerospace industry is capable of building and operating a four-passenger "crew taxi" to low Earth orbit.
- Because of the importance of crew safety, commercial crew transport services would need to include "a strong, independent mission assurance role for NASA."
- If the service were developed so as to meet commercial needs as well as NASA's, there would be private-sector customers to share operating costs with NASA. In

[130] S.Rept. 111-278, p. 9. Note that the Senate version of the bill was passed by the House without changes.

[131] For example, Henry Spencer, "Politics Should Not Dictate Design of NASA Rockets," *New* Scientist, 24 November; Jeff Foust, "Congress as Rocket Designers," *Space Politics*, August 15, 2010, http://www.spacepolitics.com/2010/08/15/congress-as-rocket-designers/; and Bill Adkins, quoted in Amy Klamper, "U.S. Senate-Prescribed Heavy-Lifter Looks Like Ares 5," *Space News*, August 13, 2010, http://www.spacenews.com/civil/081310senate-prescribed-heavy-lifter-looks-like-ares.html.

[132] Lori Garver, Deputy Administrator, NASA, quoted in Amy Klamper, "Garver, Bolden Urge Passage of NASA Authorization," *Space News*, September 29, 2010, http://www.spacenews.com/civil/100929-garver-bolden-nasa-authorization.html.

[133] Doug Cooke, Associate Administrator For Exploration Systems, NASA, quoted in Amy Klamper, "U.S. Senate-Prescribed Heavy-Lifter Looks Like Ares 5."

[134] For more information, see http://www.nasa.gov/offices/c3po/partners/ccdev_info.html.

[135] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 70-72.

that case, the cost of the program to NASA would be about $5 billion, and a service could be in place by 2016.

- If the private sector effort were to fail in mid-program, the task of crew transport would revert to NASA. NASA should continue development of Orion and move quickly toward the development of a human-ratable heavy-lift rocket as a fallback option to mitigate this risk.

The Augustine committee found that the commercial space industry is "burgeoning," and concluded that creating an assured initial market would eventually have the potential—"not without risk"—to significantly reduce costs to the government.

Issue for Congress: Safety

Space travel is inherently dangerous. Nevertheless, NASA's policy is that "safety is and will always be our number one priority in everything we do."[136] The Augustine committee described safety as a *sine qua non.*[137] Analysts and policy makers generally agree with this emphasis, but some have concerns about whether it is matched by NASA's implementation of its safety policies and procedures.

The Columbia Accident Investigation Board found in 2003 that "throughout its history, NASA has consistently struggled to achieve viable safety programs and adjust them to the constraints and vagaries of changing budgets.... NASA's safety system has fallen short of the mark."[138] It concluded that "a broken safety culture," including a "reliance on past success as a substitute for sound engineering practices," was an organizational cause of the *Columbia* disaster.[139] It found that one contributing factor was "intense schedule pressure," which had also been identified as an organizational cause of the space shuttle *Challenger* disaster in 1986.[140] It recommended that NASA establish a technical engineering authority, reporting directly to the NASA Administrator rather than to the space shuttle program, that independently verifies launch readiness and has sole authority to grant waivers for technical standards.[141] In response to these findings, NASA has made many changes, including the establishment of an independent NASA Engineering and Safety Center under the auspices of the headquarters Office of Safety and Mission Assurance.

Nevertheless, some analysts see signs that potential problems remain. The deadline of 2010 to complete construction of the space station and stop flying the space shuttle created schedule pressure for both programs until NASA converted it from a hard deadline to a flexible goal (now extended to early 2011). In 2006, NASA decided to a proceed with a shuttle mission, even though the Chief Engineer and the head of the Office of Safety and Mission Assurance recommended against the launch because of an issue with the shuttle ice-frost ramps that they characterized as

[136] Jeffrey Hanley, Manager, NASA Constellation Program, testimony before the House Committee on Science and Technology, Subcommittee on Space and Aeronautics, December 2, 2009.

[137] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 9.

[138] Columbia Accident Investigation Board, vol. 1, p. 192.

[139] Columbia Accident Investigation Board, vol. 1, pp. 184 and 9.

[140] Columbia Accident Investigation Board, vol. 1, p. 97.

[141] Columbia Accident Investigation Board, vol. 1, p. 193.

"probable/catastrophic."[142] Some observers saw signs of "reliance on past success" in NASA's justification for this decision: the NASA Administrator disagreed with the "probable" characterization because "we have 113 flights with this vehicle ... and while we've had two loss of vehicle incidents, they've not been due to ice-frost ramps."[143] (The two officials who recommended against launch stated that they were comfortable with the decision to overrule them because "the risk was to the vehicle and not the crew.")[144] A member of NASA's Aerospace Safety Advisory Panel testified in late 2009 that describing safety as a *sine qua non* "oversimplifies a complex and challenging problem" and that NASA "has given serious consideration only recently" to the establishment of safety requirements for commercial crew transport services.[145]

NASA argues that it continues to implement initiatives to improve safety. These include greater emphasis on training and qualification of safety professionals; an emphasis on "safety culture," including more open communication and clear appeal paths to the Administrator for safety-related dissenting opinions; more modeling and validation of software requirements; and improved tools for knowledge and requirements management.[146]

The advent of commercial spacecraft that carry crews into space will require new processes for ensuring crew safety. The NASA Authorization Act of 2010 directed NASA to develop and make public "detailed human rating processes and requirements" for crewed commercial spacecraft that are "at least equivalent to" the existing requirements for human rating of NASA spacecraft.[147] NASA issued this document in December 2010.[148] It asserts that "a crew transport capability that meets the safety requirements in this document will be approximately an order of magnitude safer than the space shuttle."[149]

Destinations for Human Exploration

Until 2010, the Vision for Space Exploration established the Moon as NASA's next goal for human exploration beyond low Earth orbit, followed eventually by Mars. In considering possible modifications to the Vision, space policy experts and other interested observers suggested various alternative goals. For example, some proposed that Mars should be the immediate objective,

[142] "July 1 Shuttle Launch OK'd with Some Reservations," *Aerospace Daily*, June 20, 2006.

[143] Ibid.

[144] "Shuttle Launch Holdouts Explain No-Go Recommendations," *Aerospace Daily*, June 22, 2006.

[145] John Marshall, NASA Aerospace Safety Advisory Panel, testimony before the House Committee on Science and Technology, Subcommittee on Space and Aeronautics, December 2, 2009, http://democrats.science.house.gov/Media/file/Commdocs/hearings/2009/Space/2dec/Marshall_Testimony.pdf.

[146] Bryan O'Connor, Chief, NASA Office of Safety and Mission Assurance, testimony before the House Committee on Science and Technology, Subcommittee on Space and Aeronautics, December 2, 2009, http://democrats.science.house.gov/Media/file/Commdocs/hearings/2009/Space/2dec/OConnor_Testimony.pdf.

[147] P.L. 111-267, Section 403(b)(1). The existing requirements are specified in NASA Procedural Requirement 8705.2B, *Human-Rating Requirements for Space Systems*, http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8705&s=2B.

[148] NASA, *Commercial Crew Transportation System Certification Requirements for NASA Low Earth Orbit Missions*, ESMD-CCTSCR-12.10, http://www.nasa.gov/pdf/504982main_CCTSCR_Dec-08_Basic_Web.pdf.

[149] Ibid., p. 4.

rather than returning to the Moon first.[150] Others suggested human missions to asteroids or other solar system destinations.

The Augustine committee concluded that current technology is insufficiently developed to make a Mars mission safe. It found that Mars is "unquestionably the most interesting destination in the inner solar system" and the "ultimate destination for human exploration" but "not the best first destination."[151] A spacecraft that lands on either the Moon or Mars must overcome the lunar or Martian "gravity well" before returning to Earth.[152] The fuel required to accomplish this makes either destination challenging. As potential alternatives, the Augustine committee considered fly-by missions to either the Moon or Mars, missions that would orbit either the Moon or Mars, missions that would land on the moons of Mars, and missions to near-Earth objects such as asteroids or comets. They also considered missions to various Lagrange points. Lagrange points are special locations in space, defined relative to the orbit of the Moon around the Earth or the Earth around the Sun. They are planned locations for future unmanned science spacecraft, and some scientists believe they will be important in determining routes for future interplanetary travel. Possible activities at each of these destinations are shown in **Figure 1**.

The Administration's plan, first articulated in the President's speech in April 2010,[153] is for NASA's first destination beyond low Earth orbit to be an asteroid, followed by an orbit of Mars and subsequently a Mars landing. This plan appears to be consistent with the NASA Authorization Act of 2010, which states that "a long-term objective for human exploration of space should be the eventual international exploration of Mars."[154] The act also, however, mandates a review by National Academies of the goals, capabilities, and direction of human space flight.[155]

Alternatives to Human Exploration

Given the costs and risks of human space exploration, Congress could decide to curtail or postpone future human exploration missions and shift the emphasis of the nation's space program to other endeavors. The cost of human exploration is substantial, and according to the Augustine committee, it is not a continuum: there is an "entry cost" below which a successful program cannot be conducted at all.[156] Congress could decide that this minimum cost is not affordable. Similarly, no matter how energetically NASA addresses safety concerns, human spaceflight is an inherently risky endeavor. Congress could decide that the potential benefits are insufficient to justify the safety risks.

[150] See, for example, the advocacy of the Mars Society, http://www.marssociety.org/.

[151] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 21.

[152] At least one observer has suggested the launching humans to Mars without plans to return them to Earth. See Lawrence M. Krauss, "A One-Way Ticket to Mars," *New York Times*, September 1, 2009. It seems unlikely that this option would be politically viable.

[153] "Remarks by the President on Space Exploration in the 21st Century," White House press release, April 15, 2010, http://www.whitehouse.gov/the-press-office/remarks-president-space-exploration-21st-century.

[154] P.L. 111-267, Section 301(a)(5).

[155] P.L. 111-267, Section 204.

[156] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 23.

Figure 1. Potential Activities at Alternative Human Exploration Destinations (in Addition to the Moon and Mars) as Evaluated by the Augustine Committee

Destination	Public Engagement	Science	Human Research	Exploration Preparation
Lunar Flyby/Orbit	Return to Moon, "any time we want"	Demo of human robotic operation	10 days beyond radiation belts	Beyond LEO shakedown
Earth Moon L1	"On-ramp to the inter-planetary highway"	Ability to service Earth Sun L2 spacecraft at Earth Moon L1	21 days beyond the belts	Operations at potential fuel depot
Earth Sun L2	First human in "deep space" or "Earth escape"	Ability to service Earth Sun L2 spacecraft at Earth Sun L2	32 days beyond the belts	Potential servicing, test airlock
Earth Sun L1	First human "in the solar wind"	Potential for Earth/Sun science	90 days beyond the belts	Potential servicing, test in-space habitation
NEO's	"Helping protect the planet"	Geophysics, Astrobiology, Sample return	150-220 day, similar to Mars transit	Encounters with small bodies, sample handling, resource utilization
Mars Flyby	First human "to Mars"	Human robotic operations, sample return?	440 days, similar to Mars out and return	Robotic operations, test of planetary cycler concepts
Mars Orbit	Humans "working at Mars and touching bits of Mars"	Mars surface sample return	780 days, full trip to Mars	Joint robotic/human exploration and surface operations, sample testing,
Mars Moons	Humans "landing on another moon"	Mars moons' sample return	780 days, full rehearsal Mars exploration	Joint robotic/human surface and small body exploration

Source: Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 41.

Notes: L1 and L2 refer to particular Lagrange points (see text). A NEO is a near-Earth object such as an asteroid or a comet.

Several options are available as alternatives to human space exploration. Congress could seek to accomplish some of the same goals through other means, such as through robotic exploration. It could focus on technology development, in the hope of developing new technology that makes human spaceflight safer and more affordable in the future. It could focus on NASA's other activities, such as Earth science and aeronautics. Given sufficient funding, of course, all these options are also available in conjunction with human exploration rather than as alternatives to it. For example, the Augustine committee acknowledged that robotic exploration is important as a precursor to human exploration.

Robotic Exploration

Advocates of robotic missions assert that robotic exploration can accomplish outstanding science and inspire the public just as effectively as human exploration. The Mars rovers are a familiar example of a successful robotic science mission that has captured considerable public attention. Advocates also claim that robotic missions can accomplish their goals at less cost and with greater safety than human missions. They do not need to incorporate systems for human life support or human radiation protection, they do not usually need to return to Earth, and they pose no risk of death or injury to astronauts. Some analysts assert further that exploring with humans

"rules out destinations beyond Mars."[157] Given that current plans include no destinations beyond Mars and treat Mars itself only as a long-term goal, this last limitation may not be important in the near term, even if it is correct.

Advocates of human missions note that science is not NASA's only purpose and claim that human exploration is more effective than robotic exploration at such intangible goals as inspiring the public, enhancing national prestige, and satisfying the human urge to explore and discover. They assert that even considering science alone, human missions can be more flexible in the event of an unforeseen scientific opportunity or an unexpected change in plans. As support for this assertion, they often cite the human missions to repair and upgrade the Hubble telescope. On the other hand, the Hubble repairs and upgrades required extensive planning and the development of new equipment. They were not a real-time response to an unexpected event. Moreover, robotic missions can also sometimes be modified to respond to opportunities and mishaps, through software updates and other changes worked out by scientists and engineers back on Earth.

A few analysts portray robotic exploration as an alternative to human exploration. For the most part, however, the two alternatives are considered complementary, rather than exclusive. The Augustine committee, for example, found that without both human and robotic missions, "any space program would be hollow."[158] In addition, many analysts consider that in the absence of human missions, support for NASA as a whole would dwindle, and fewer resources would be available for robotic missions as well.

Emphasize Technology Development

If congressional policy makers were to conclude that cost and safety concerns make a human exploration program unaffordable or undesirable in the near term, they might seek to scale back NASA's human spaceflight program and focus on technology development, in the hope that improved technology will make the costs and risks of space travel more attractive in the future.

The strategy of developing improved technology and acquiring greater expertise could take many forms. It could complement a continuing, aggressive program of human exploration. For example, it is similar, in some ways, to the Augustine committee's suggestion (in its "flexible path" option) of visiting a series of less challenging destinations before attempting a Moon landing. It could also accompany a program of human missions in low Earth orbit without immediate plans for more distant destinations. It could even be part of a program that abandoned human spaceflight in the near term. Developing new technology effectively would likely be difficult, however, without a means of testing it in realistic missions. A program without any human spaceflight at all would risk losing existing expertise through inactivity.

The Augustine committee, the National Academies, and the Administration's FY2011 budget proposals all recommended a greater emphasis on technology development as a complement to an ongoing program of human spaceflight. The Augustine committee described NASA's space technology program as "an important effort that has significantly atrophied over the years."[159] It

[157] See, for example, Robert L. Park, *What's New*, September 11, 2009, http://bobpark.physics.umd.edu/WN09/wn091109.html.

[158] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 114.

[159] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great* (continued...)

recommended that technology development be closely coordinated with ongoing programs, but conducted independently of them. The National Academies also recommended that NASA revitalize its technology development program. Like the Augustine committee, the Academies concluded that this program should be conducted independently. They recommended that NASA establish a DARPA-like technology development organization that reports directly to the Administrator.[160]

The NASA Authorization Act of 2010 accepted the Administration's request to establish a new space technology program, although the funding it authorized for this effort was less than the Administration had proposed. It directed NASA to provide an implementation plan for the program by February 2011, and it directed the Administration to develop a national policy to guide space technology development programs across the federal government through 2020.[161]

Other Space Policy Issues

In addition to the programmatic and prioritization issues that are the main focus of this report, NASA faces some cross-cutting challenges, such as acquisition and financial management, and issues involving its relationships with other agencies and the commercial space launch industry.

NASA Acquisition and Financial Management

Since 1990, the GAO has identified acquisition management at NASA as a high-risk area for the federal government.[162] Although a 2009 update noted that "NASA has made a concerted effort to improve its acquisition management," it also stated that "since fiscal year 2006, 10 out of 12 ... major development projects in implementation exceeded their baseline thresholds."[163] NASA issued an improvement plan in response to GAO's finding.[164] The NASA Authorization Act of 2010 directed NASA to submit annual reports on its implementation of the improvement plan.[165]

In the NASA Authorization Act of 2005, Congress established requirements for baselines and cost controls.[166] The requirements include additional reviews of any program that appears likely to exceed its baseline cost estimate by 15% or its baseline schedule by six months and a prohibition on continuing any program that exceeds its cost baseline by 30% unless Congress specifically

(...continued)

Nation, p. 112.

[160] National Research Council, *America's Future in Space*, pp. 61-62. DARPA is the Defense Advanced Research Projects Agency, http://www.darpa.mil/, a frequent model for technology development agencies within other departments.

[161] P.L. 111-267, Sections 101(4)(B), 102(4)(B), 103(4)(B), 904, 905, and 906.

[162] Government Accountability Office, *High-Risk Series: An Update*, GAO-09-271, January 2009. As of this 2009 update, GAO listed 31 high-risk areas.

[163] Ibid., p. 77.

[164] National Aeronautics and Space Administration, *NASA Plan for Improvement in the GAO High-Risk Area of Contract Management*, October 31, 2007, updated January 31, 2008, http://www.nasa.gov/pdf/270426main_NASA_High-RiskCAP-Jan2008Final.pdf.

[165] P.L. 111-267, Section 1203.

[166] P.L. 110-422, Section 103.

authorizes the program to continue. These requirements are similar to the Nunn-McCurdy cost-containment requirements for the Department of Defense.

In November 2008, the NASA Inspector General identified financial management as one of NASA's most serious challenges.[167] The Inspector General's report found continuing weaknesses in NASA's financial management processes and systems, including its internal controls over property accounting. It noted that these deficiencies had resulted in disclaimed audits of NASA's financial statements since FY2003, largely because of data integrity issues and a lack of effective internal control procedures. According to the report, NASA had made progress in addressing these deficiencies, but the FY2009 audit was again disclaimed.[168] The FY2010 audit, however, was qualified, rather than disclaimed; the NASA inspector general called this "a notable improvement."[169]

U.S. Space Policy Governance

A variety of governmental and nongovernmental organizations help to coordinate and guide U.S. space policy. These include the Office of Science and Technology Policy (OSTP) and the National Science and Technology Council (NSTC), both in the Executive Office of the President, as well as outside advisory groups, such as the NASA Advisory Council,[170] committees of the National Academies,[171] and independent committees such as the Augustine committee.

The National Academies have recommended that the President

> task senior executive-branch officials to align agency and department strategies; identify gaps or shortfalls in policy coverage, policy implementation, and resource allocation; and identify new opportunities for space-based endeavors that will help to address the goals of both the U.S. civil and national security space programs.[172]

The Obama Administration has stated that it intends to reestablish the National Aeronautics and Space Council (NASC), "which will report to the President and oversee and coordinate civilian, military, commercial and national security space activities."[173] The NASC was established along with NASA itself by the National Aeronautics and Space Act of 1958 (P.L. 85-568). It was most active during the Kennedy Administration, when it recommended, among other policies, the Apollo program to send humans to the Moon. Some analysts attribute its influence during this

[167] National Aeronautics and Space Administration, Office of the Inspector General, *NASA's Most Serious Management and Performance Challenges*, November 10, 2008, http://oig.nasa.gov/NASA2008ManagementChallenges.pdf.

[168] See House Committee on Science and Technology, Subcommittee on Investigations and Oversight and Subcommittee on Space and Aeronautics, *Independent Audit of the National Aeronautics and Space Administration*, hearing December 3, 2009.

[169] National Aeronautics and Space Administration, Office of the Inspector General, *Audit of the National Aeronautics and Space Administration's Fiscal Year 2010 Financial Statements*, IG-11-006, November 15, 2010. A disclaimed audit means that the auditor is unable to obtain sufficient information to express an opinion. A qualified audit means that in the opinion of the auditor, the financial statements fairly represent the financial position, with specified exceptions. The exceptions noted in the FY2010 audit related to valuations in prior years.

[170] *NASA Advisory Council (NAC)*, http://www.nasa.gov/offices/nac/home/index.html.

[171] Such as the Space Studies Board, http://sites.nationalacademies.org/SSB/index.htm, the Aeronautics and Space Engineering Board, http://sites.nationalacademies.org/deps/ASEB/, and their committees and subcommittees.

[172] National Research Council, *America's Future in Space*, p. 8.

[173] Office of Science and Technology Policy, *Issues: Technology*, http://www.ostp.gov/cs/issues/technology.

period to the fact that it was chaired by Vice President Johnson. The NASC was abolished in 1973, reestablished in 1989 as the National Space Council, then abolished again in 1993, with its functions absorbed into the NSTC.

Some aspects of space policy are documented in a formal presidential statement of national space policy. In 2006, the Bush Administration issued such a statement,[174] replacing a previous one that had been in place for 10 years.[175] The 2006 policy established principles and goals for U.S. civilian and national security space programs and set guidelines for a few specific issues such as the use of nuclear power in space and the hazard of debris in orbit. It defined the space-related roles, responsibilities, and relationships of NASA and other federal agencies, such as the Department of Defense and the Department of Commerce. The Obama Administration issued an updated national space policy in June 2010.[176] The new policy reiterated the policy changes proposed in the Administration's FY2011 budget and placed new emphasis on international cooperation and development of the commercial space industry.

U.S. National Security Space Programs

National security space programs, conducted by the Department of Defense (DOD) and the intelligence community, are less visible than NASA, but their budgets are comparable to NASA's. A key issue for them is how to avoid the cost growth and schedule delays that have characterized several recent projects. A shared industrial base and other areas of common concern sometimes result in NASA issues affecting national security programs and vice versa. For example, some policy makers expressed concern about the impact of cancelling of Ares I on the industrial base for solid rocket motors used by DOD.[177] The NASA Authorization Act of 2010 directed NASA to assess, in consultation with DOD and the Department of Commerce, the effects of the end of the space shuttle program, and the transition to the space launch system authorized by the act, on the U.S. industrial base for solid and liquid rocket motors.[178] Further discussion of national security space programs is beyond the scope of this report.

NASA's Relationship with NOAA

Congressional policy makers have taken a long-standing interest in NASA's relationship with the National Oceanic and Atmospheric Administration (NOAA), which operates Earth observing satellites for weather forecasting and other purposes. The NASA Authorization Act of 2005 mandated the establishment of a joint NASA-NOAA working group; required NASA and NOAA to submit a joint annual report on coordination each February; directed NASA and NOAA to evaluate NASA science missions for their operational capabilities and prepare transition plans for those with operational potential; and directed NASA not to transfer any Earth science mission or

[174] National Security Presidential Directive (NSPD) 49, *U.S. National Space Policy*, August 31, 2006, http://www.fas.org/irp/offdocs/nspd/space.html.

[175] Presidential Decision Directive NSC-49/NSTC-8, *National Space Policy*, September 14, 1996, http://www.fas.org/spp/military/docops/national/nstc-8.htm.

[176] President of the United States, *National Space Policy of the United* States, June 28, 2010, http://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf.

[177] For example, see William Matthews, "Sen. Says Solid Rocket Motor Costs Will Double, Navy Disagrees," *Defense News*, March 17, 2010.

[178] P.L. 111-267, Section 306.

Earth observing system to NOAA until a transition plan has been approved and funds have been included in the NOAA budget request.[179] In the NASA Authorization Act of 2008, Congress directed OSTP to develop a process for transitions of experimental Earth science and space weather NASA missions to operational status under NOAA, including the coordination of agency budget requests;[180] mandated a National Academies study of the governance structure for U.S. Earth observation programs at NASA, NOAA, and other agencies, to be transmitted to Congress by April 2010;[181] and mandated a National Academies assessment of impediments to interagency cooperation on space and Earth science missions.[182] The report was on impediments to cooperation was issued in November 2010.[183] The NASA Authorization Act of 2010 directed OSTP to develop a strategic plan, updated at least every three years, to ensure greater cooperation among U.S. civilian Earth observation programs; and directed NASA to coordinate with NOAA and the U.S. Geological Survey (USGS) to establish a formal mechanism to transition NASA research and assets to NOAA and USGS operations.[184] The extent to which the provisions in the 2005, 2008, and 2010 acts overlap suggests that the requirements of the earlier acts have not yet been successful in achieving Congress's goals for the NASA-NOAA relationship.

The U.S. Commercial Space Industry

Industry has long had an important role in both space launch and the development and operation of commercial satellites. Although the commercial satellite launch business has dropped off in recent years, many analysts expect the industry to expand as space tourism develops and NASA begins to rely more on the commercial sector for space transportation.

The prospect of space tourism on commercial vehicles is becoming increasingly likely. With the exception of five suborbital demonstration flights in 2004, private space travel has until now been limited to the purchase of trips to the International Space Station on Russian Soyuz spacecraft. A number of commercial companies are now developing reusable spacecraft to carry private individuals on short-duration flights into the lower reaches of space. Concurrently, several companies and states are developing spaceports to accommodate anticipated increases in commercial space launches. The safety of commercial space launches, spaceports, and space tourism are regulated by the Federal Aviation Administration (FAA). According to the GAO, the FAA faces a number of challenges in commercial space regulation, including maintaining sufficient space expertise to conduct proper oversight, avoiding conflicts between its regulatory and promotional roles, and integrating spacecraft into the air traffic control system.[185]

Export control regulations administered by the Department of State under the International Traffic in Arms Regulations (ITAR) have often been a concern for this industry. The regulations limit the

[179] P.L. 109-155, Section 306.

[180] P.L. 110-422, Section 204.

[181] P.L. 110-422, Section 202. As of January 2011, it appears that this study is unlikely to take place. (Personal communication, National Academies staff, January 7, 2011.)

[182] P.L. 110-422, Section 507.

[183] National Research Council, *Assessment of Impediments to Interagency Collaboration on Space and Earth Science Missions* (prepublication version), 2010.

[184] P.L. 111-267, Sections 702 and 703.

[185] Government Accountability Office, *Commercial Space Transportation: Development of the Commercial Space Launch Industry Presents Safety Oversight Challenges for FAA and Raises Issues Affecting Federal Roles*, GAO-10-286T, December 2, 2009, http://www.gao.gov/new.items/d10286t.pdf.

export of satellites and related components because of the potential for their use in military systems. In order to expand opportunities for U.S. industry, some analysts and policy makers have advocated transferring the regulation of these technologies from ITAR to the Export Administration Regulations administered by the Department of Commerce.[186] In April 2010, following an interagency review, the Administration proposed a number of changes in the U.S. export control system, including the establishment of a single licensing agency.[187]

The development of commercial vehicles for cargo flights to the space station, and possibly to provide NASA with crew launch services into low Earth orbit, is discussed elsewhere in this report.

Legislation in the 111th Congress

The NASA Authorization Act of 2010 (P.L. 111-267) is discussed above in the section "Human Spaceflight: The 2010 Authorization Act" and elsewhere throughout this report.

Appropriations for NASA are provided in the Commerce, Justice, Science (CJS) appropriations bill. For more information on FY2011 appropriations legislation, see CRS Report R41161, *Commerce, Justice, Science, and Related Agencies: FY2011 Appropriations*. Like other agencies, NASA is currently operating at FY2010 funding levels under a continuing resolution, the Continuing Appropriations Act, 2010 (P.L. 111-242 as amended by P.L. 111-322).

For FY2010, the CJS bill was passed by the House and Senate as H.R. 2847. For final passage, it was included in the Consolidated Appropriations Act, 2010 (P.L. 111-117). For more information about FY2010 NASA appropriations, see CRS Report R40644, *Commerce, Justice, Science, and Related Agencies: FY2010 Appropriations*.

For FY2009 NASA appropriations legislation during the 111th Congress, including passage of the American Recovery and Reinvestment Act of 2009 (P.L. 111-5) and the Omnibus Appropriations Act, 2009 (P.L. 111-8), see CRS Report RL34540, *Commerce, Justice, Science and Related Agencies: FY2009 Appropriations*.

A number of other bills addressing specific topics related to NASA were introduced during the 111th Congress. Among these, P.L. 111-125 extended the current third-party liability indemnification for commercial launch services companies through 2012. P.L. 111-314 restated existing law relating to NASA and other space topics as a new, separate title of the U.S. Code.[188] Bills that did not become law included the following: H.R. 4804 and S. 3068, which would have extended the space shuttle and ISS programs, provided for the development of a National Space

[186] For more on this issue, see CRS Report RL31832, *The Export Administration Act: Evolution, Provisions, and Debate*, by (name redacted); and Department of Commerce and Federal Aviation Administration, *Introduction to U.S. Export Controls for the Commercial Space Industry*, October 2008, http://www.faa.gov/about/office_org/headquarters_offices/ast/media/Intro%20to%20US%20Export%20Controls.pdf.

[187] The White House, Office of the Press Secretary, "Fact Sheet on the President's Export Control Reform Initiative," April 20, 2010, http://www.whitehouse.gov/the-press-office/fact-sheet-presidents-export-control-reform-initiative.

[188] The new Title 51, National and Commercial Space Programs, is a rearrangement of provisions previously in Titles 15, 42, and 49. P.L. 111-314 did not create any new programs or repeal or modify any existing programs. See this explanation from the Office of the Law Revision Counsel of the House of Representatives: http://uscode.house.gov/cod/t51/.

Transportation system, and authorized appropriations for certain NASA programs; H.R. 1962, which would have extended the space shuttle program to 2015; H.R. 3853, which would have authorized grants to university consortia to establish centers in conjunction with NASA and industry; H.R. 5614, which would have required expenditure of appropriated FY2010 Constellation funds on the Constellation program, without terminating or descoping contracts; and S. 3180, which would have prohibited the use of the Anti-Deficiency Act (31 U.S.C. 1341) as the basis for terminating or eliminating a Constellation contract, program, project, or activity.

Summary of Major Issues for Congress

In conclusion, major space policy issues facing Congress include the following:

- Is there a national consensus for human exploration beyond Earth orbit, despite the inherent risks and the substantial cost?
- If so, what destination or destinations should NASA's human exploration program explore?
- If human exploration beyond Earth orbit is too costly or too dangerous, should NASA focus its efforts on human missions in Earth orbit, robotic exploration, technology development, other activities such as science and aeronautics, or some combination of these?
- When the space shuttle program ends during 2011, how should the transition of shuttle workforce and facilities be managed?
- Now that U.S. use of the International Space Station has been extended to at least 2020, how can the ISS be managed and utilized most effectively?
- What can be done to ensure that new spacecraft for human exploration, both government-owned and commercial, are developed effectively, despite budget constraints?
- How should NASA's multiple objectives be prioritized? What is the proper balance between human spaceflight, science, aeronautics, and education programs, and how can the balance be maintained if the cost of the larger, more prominent programs grows?

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