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NASA: Issues for Authorization, Appropriations, and Oversight in the 114th Congress

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Summary

Spaceflight fascinates and inspires many Americans, but in a time of constrained federal budgets, it must compete with a multitude of other national priorities. As the 114th Congress conducts oversight and considers authorization and appropriations legislation for the National Aeronautics and Space Administration (NASA), an overarching question will be how NASA should move forward within budget constraints.

The National Aeronautics and Space Administration Authorization Act of 2010 (P.L. 111-267) set a new direction for NASA's human spaceflight programs. For access to low Earth orbit, including the International Space Station (ISS), it confirmed NASA's plans to develop a commercial space transportation capability for both cargo and astronauts. The first commercial cargo flight for ISS resupply was conducted in May 2012. Pending the planned availability of commercial crew transportation in 2017, NASA is paying Russia to carry U.S. astronauts to and from the ISS on Soyuz spacecraft. Issues for Congress include the cost, schedule, and safety of future commercial crew services, as well as the need for alternatives if commercial providers do not succeed.

For human exploration beyond Earth orbit, the 2010 NASA authorization act mandated development of the Orion Multipurpose Crew Vehicle and the Space Launch System (SLS) rocket to launch Orion into space. A test flight of Orion, on an existing rocket and without a crew, took place in December 2014. The first test flight of Orion on the SLS, again without a crew, is planned for FY2018. The first test flight with a crew is planned for FY2021-FY2022. Issues include NASA's ability to meet that schedule, the feasibility of accelerating the schedule, the payload mass capability of the SLS in the near and long term, and how Orion and the SLS should be used when operational. NASA plans to send humans to an asteroid by 2025 and to Mars in the 2030s, but some in Congress would prefer to focus on returning humans to the Moon. Orion and the SLS could also be used as a backup option for access to the ISS, but that option raises additional questions about cost and schedule.

U.S. use of the ISS is currently authorized through FY2020. NASA has announced that it plans to extend ISS operations through at least 2024. In addition to crew access concerns and issues related to service life extension, Congress is likely to examine the utilization of the ISS for research, both through traditional NASA mechanisms and via the independently managed ISS national laboratory process.

Many in Congress are concerned that the needs of the human spaceflight program may reduce the resources available for NASA's other activities, including science, aeronautics research, and education. Funding for Earth science satellites is particularly contentious, because of their use for climate change research. Proposed cuts in funding for planetary science have encountered opposition in both Congress and the scientific community. The explosion of a small asteroid over Chelyabinsk, Russia, in 2013 may have increased congressional interest in the science and potential threat of near-Earth asteroids and comets. The Administration's proposals to reorganize federal science, technology, engineering, and mathematics (STEM) education programs would affect numerous NASA education activities, especially those outside the Office of Education.

NASA's budget for FY2015 is $18.010 billion, an increase from $17.647 billion in FY2014. The 113th Congress considered NASA reauthorization legislation, but none was enacted.

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Introduction

Spaceflight fascinates and inspires many Americans, but in a time of constrained federal budgets, it must compete with a multitude of other national priorities. As the 114th Congress conducts oversight and considers authorization and appropriations legislation for the National Aeronautics and Space Administration (NASA), an overarching question will be how NASA should move forward within budget constraints. This report discusses a number of issues that arise within the framework of that question. Among them are the following:

- Can commercial services transport U.S. astronauts into Earth orbit, including to the International Space Station, cost-effectively and safely?
- For human spaceflight beyond Earth orbit, will the spacecraft now in development be ready on schedule, and how should they be used when operational?
- How will the needs of the human spaceflight program affect resources for NASA's science missions, aeronautics research, and education programs?
- What is the appropriate level of NASA support for Earth science, planetary science, and other scientific fields?
- In general, is NASA being asked to do more than it can afford?

Major NASA policy developments since the start of the current Administration include:

- in October 2009, the influential Augustine report on the future of U.S. human spaceflight;
- early in 2010, the Obama Administration's announcement of a plan to cancel the Bush Administration's Vision for Space Exploration and rely on commercial services for crew access to Earth orbit;
- later in 2010, Congress's passage of the NASA Authorization Act of 2010 (P.L. 111-267), mandating the development of new spacecraft for human exploration beyond Earth orbit;
- the final flight of the space shuttle in July 2011; and
- in FY2011, FY2012, and FY2013, annual reductions in NASA's budget as a result of government-wide fiscal constraints.

This report begins with some context: a brief survey of NASA's organization and programs, a summary of recent NASA authorization legislation, and an overview of NASA's budget. Subsequent sections address policy topics in each major NASA mission area.

NASA Organization and Programs

NASA was created by the National Aeronautics and Space Act of 1958 (P.L. 85-568) to conduct civilian space and aeronautics activities. Its FY2015 budget is $18.010 billion. NASA employs approximately 17,700 civil servants (full-time equivalents).[1] It is led by Administrator Charles F. Bolden, Jr.[2]

NASA has four mission directorates. The Human Exploration and Operations Mission Directorate is responsible for human spaceflight activities, including the International Space Station and development efforts for future crewed spacecraft. The Science Mission Directorate manages robotic science missions, such as the Hubble Space Telescope, the Mars rover Curiosity, and satellites for Earth science research. The Space Technology Mission Directorate develops new technologies, such as advanced propulsion and laser communications, for use in future space missions. The Aeronautics Research Mission Directorate conducts research and development on aircraft and aviation systems. In addition to the mission directorates, the Office of Education manages formal and informal education programs for school children, college and university students, and the general public.[3]

Most of the activities that make up these programs are managed and conducted by a system of field centers. The nine NASA field centers are Ames Research Center at Moffett Field, CA; Armstrong Flight Research Center in Edwards, CA;[4] Glenn Research Center in Cleveland, OH; Goddard Space Flight Center in Greenbelt, MD; Johnson Space Center in Houston, TX; Kennedy Space Center in Cape Canaveral, FL; Langley Research Center in Hampton, VA; Marshall Space Flight Center in Huntsville, AL; and Stennis Space Center near Slidell, MS. The Jet Propulsion Laboratory in Pasadena, CA, which is sometimes considered a tenth field center, is operated for NASA by the California Institute of Technology. Goddard Space Flight Center manages the Goddard Institute for Space Studies in New York, NY; the Independent Validation and Verification Facility in Fairmont, WV; and the Wallops Flight Facility in Wallops Island, VA. Marshall Space Flight Center manages the Michoud Assembly Facility in New Orleans, LA. The NASA Shared Services Center is on the grounds of Stennis Space Center.[5]

Authorization Context

For most of the three decades after NASA's establishment in 1958, Congress passed a NASA authorization act nearly every year. Starting in the 1990s, these acts became less frequent. In the past decade, Congress has enacted three NASA authorization acts: the National Aeronautics and Space Administration Authorization Acts of 2005 (P.L. 109-155), 2008 (P.L. 110-422), and 2010 (P.L. 111-267).[6]

[1] NASA congressional budget justification for FY2015, p. SD-5.

[2] For a brief biography, see http://www.nasa.gov/about/highlights/bolden_bio.html. Biographies of other senior NASA officials are available through links at http://www.nasa.gov/about/org_index.html.

[3] For links to the websites of these organizations and other NASA offices, see http://www.nasa.gov/about/org_index.html.

[4] Formerly the Dryden Flight Research Center. Renamed in January 2014 by P.L. 113-75 to honor Neil Armstrong, the first human to set foot on the Moon.

[5] For links to the websites of these centers and other facilities, see http://www.nasa.gov/about/org_index.html.

[6] A case study on the history of NASA authorization legislation is included in (name redacted), "Changes in the Purposes and Frequency of Authorizations of Appropriations," pp. 259-279, in U.S. Senate, Committee on Rules and Administration, *The Evolving Congress*, Committee Print S.Prt. 113-30.

The 2010 act set a new direction for NASA's human spaceflight programs. It confirmed the already planned termination of the space shuttle program, which had provided access to space for U.S. astronauts since 1981.[7] In place of the space shuttle, the act established two new programs for human spaceflight. First, for access to low Earth orbit, including the International Space Station (ISS), it confirmed NASA's plans to develop a commercial space transportation capability for both cargo and astronauts.[8] Second, for human exploration beyond Earth orbit, the act mandated the development of a crew capsule, to be known as the Multipurpose Crew Vehicle (MPCV), and a heavy-lift rocket to launch the capsule, to be known as the Space Launch System (SLS).[9] The act directed that the MPCV and SLS should serve as backup systems for cargo and crew access to the ISS, in the absence of a successful commercial capability.[10] It also supported "full and complete utilization" of the ISS through at least 2020 and gave direction to NASA regarding ISS utilization and management.[11]

In making these changes, the 2010 act assented to the Obama Administration's cancellation of the Constellation program. The purpose of Constellation had been to implement the Vision for Space Exploration, a policy announced by President Bush in January 2004 as a new direction for NASA following the February 2003 *Columbia* space shuttle disaster.[12] Under the Vision, NASA was to focus its efforts on returning humans to the Moon by 2020 and eventually sending humans to Mars and "worlds beyond." The main elements of the Vision were as follows:

- Return the space shuttle to flight status following the *Columbia* disaster, but then retire the space shuttle in 2010 (later changed to 2011). After the retirement of the space shuttle, use Russian Soyuz spacecraft for human access to space while developing a replacement vehicle.
- Complete construction of the ISS in accord with existing international commitments, but then terminate U.S. use of the ISS at the end of 2015.
- Under the Constellation program, develop new systems for human space exploration: the Ares I rocket to launch astronauts into low Earth orbit; 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; the Altair lunar lander; and various lunar surface systems.

Although Congress endorsed the broad goals of the Vision in the 2005 and 2008 NASA authorization acts, concerns grew about its cost and schedule. In 2009, NASA and the Office of Science and Technology Policy chartered a committee chaired by Norman R. Augustine to reexamine NASA's human spaceflight goals.[13] The report of the Augustine committee found that

[7] P.L. 111-267, Title VI.

[8] P.L. 111-267, Title IV.

[9] P.L. 111-267, Title III.

[10] P.L. 111-267, Section 302(c)(1)(D) and Section 303(b)(3).

[11] P.L. 111-267, Title V.

[12] "President Bush Announces New Vision for Space Exploration Program: Remarks by the President on U.S. Space Policy," White House press release, January 14, 2004, http://history.nasa.gov/Bush%20SEP.htm.

[13] The Office of Science and Technology Policy is part of the Executive Office of the President. See CRS Report RL34736, *The President's Office of Science and Technology Policy (OSTP): Issues for Congress*, by (name redacted) and (name redacted).

- developing Ares I, Orion, and the other Constellation systems was likely to take longer than NASA anticipated;
- without substantial increases in NASA funding, human exploration could not continue "in any meaningful way";
- not extending U.S. use of the ISS past 2015 would "significantly impair U.S. ability to develop and lead future international spaceflight partnerships"; and
- commercial services to launch crews into Earth orbit were "within reach."

The report also examined alternatives to the spacecraft being developed under Constellation and considered several alternatives to the Moon as the first destination for future human exploration beyond Earth orbit.[14]

In February 2010, the Obama Administration's budget for FY2011 proposed a number of changes for NASA, some of them based on the Augustine report. The proposals were controversial in Congress and led to an extensive debate about whether to retain Constellation and the Vision or, if not, what alternative approach to take. The 2010 NASA authorization act was the result of this debate, but some advocates of other approaches remained unsatisfied.

In addition to human spaceflight, the 2010 act addressed NASA's programs in science, aeronautics, space technology, and education, as well as cross-cutting institutional and management issues. It also authorized NASA appropriations for FY2011 through FY2013.[15]

Because the provisions authorizing appropriations did not extend past FY2013, and in order to address other policy concerns, the 113th Congress considered new authorization legislation. In July 2013, the House Committee on Science, Space, and Technology ordered reported the NASA Authorization Act of 2013 (H.R. 2687) by a vote of 22 to 17. The ranking Member of the Subcommittee on Space introduced an alternative bill with the same title (H.R. 2616). These bills were effectively superseded by a bipartisan compromise bill, the NASA Authorization Act of 2014 (H.R. 4412), which was passed by the House in June 2014. In the Senate, in July 2013, the Committee on Commerce, Science, and Transportation ordered reported another NASA Authorization Act of 2013 (S. 1317) by a vote of 13 to 12. An amended version of S. 1317 was reported on December 10, 2014, but did not receive floor action before the 113th Congress adjourned. None of these bills was ultimately enacted.

The 114th Congress is widely expected to make a renewed effort to pass NASA authorization legislation.

Budget and Appropriations Context

Funding for NASA is provided in the annual Commerce-Justice-Science appropriations act. For FY2015, this was Division B of the Consolidated and Further Continuing Appropriations Act, 2015 (P.L. 113-235), enacted in December 2014, which provided $18.010 billion for NASA. For

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

[15] P.L. 111-267, Title I.

further information about FY2015 appropriations legislation, see CRS Report R43509, *Commerce, Justice, Science, and Related Agencies: FY2015 Appropriations*.

Congressional budget justifications provide detailed information about the Administration's annual budget proposals for NASA and how the requested funding would be used.[16] The Administration's FY2015 budget, released in March 2014, requested a total of $17.461 billion for NASA, plus an additional $886 million as part of the proposed Opportunity, Growth, and Security Initiative (OGSI), which was not considered part of the base budget request.

Table 1 summarizes recent NASA funding. More detailed figures for particular programs are provided later in this report. For additional information, including historical data by program, see CRS Report R43419, *NASA Appropriations and Authorizations: A Fact Sheet.*

Table 1. NASA Funding, FY2013-FY2015

(budget authority in millions of dollars)

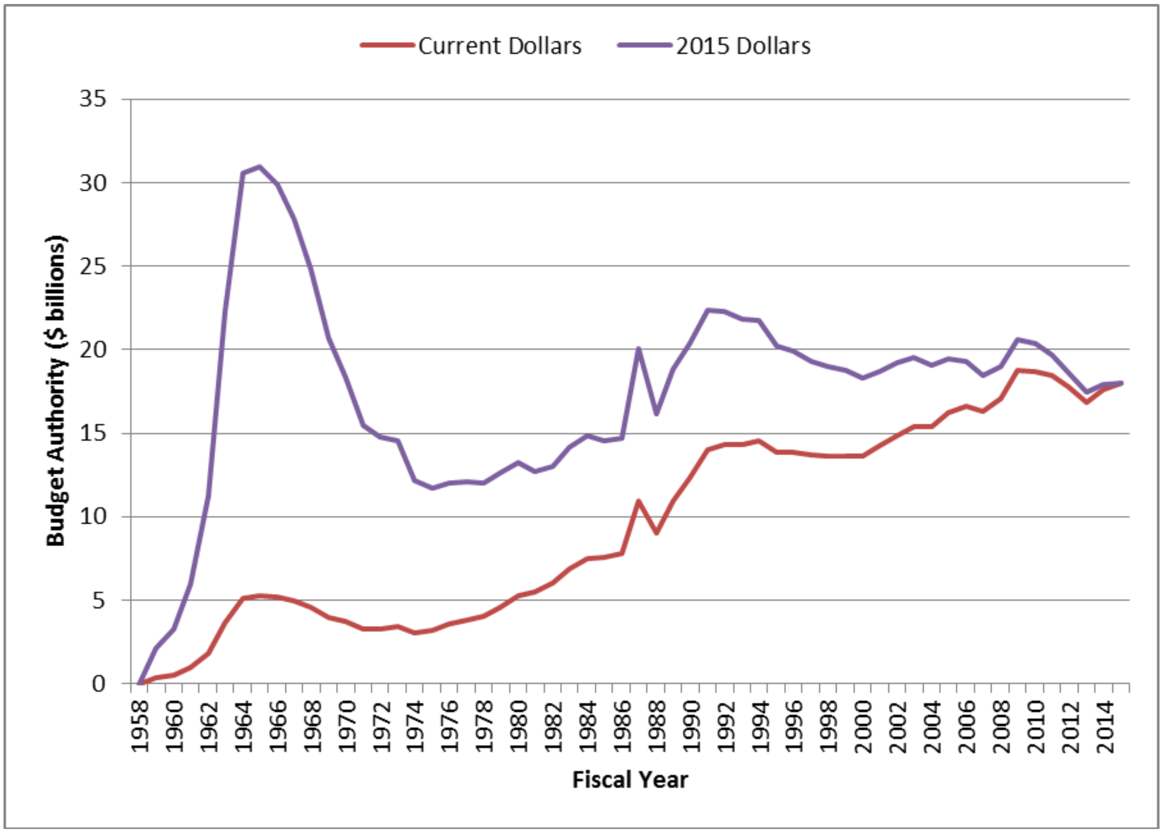
	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Science	$4,781.6	$5,151.2	$5,244.7
Aeronautics	529.5	566.0	651.0
Space Technology	614.5	576.0	596.0
Exploration	3,705.5	4,113.2	4,356.7
Space Operations	3,724.9	3,778.0	3,827.8
Education	116.3	116.6	119.0
Cross-Agency Support	2,711.0	2,793.0	2,758.9
Construction and Environmental Compliance and Remediation	660.9	515.0	419.1
Inspector General	35.3	37.5	37.0
Total NASA	**16,879.5**	**17,646.5**	**18,010.2**

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan, and personal communication between CRS and NASA, February 2014. Note that the congressional budget justification omits $14 million in supplemental FY2013 funding provided by P.L. 113-2 for Construction and Environmental Compliance and Remediation. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

In arguing for additional NASA funding, advocates often compare current funding levels with historical trends. **Figure 1** shows NASA funding in current dollars and inflation-adjusted FY2015 dollars from the agency's establishment in 1958 to the present. The large peak in the 1960s is the Apollo program. The narrow peak in FY1987 is the construction of a replacement space shuttle after the *Challenger* disaster in January 1986. In inflation-adjusted terms, NASA funding was fairly steady for most of the past 20 years, but dropped in FY2013 to a level below any other year since FY1988.

[16] NASA congressional budget justifications are available online at http://www.nasa.gov/news/budget/index.html.

Figure 1. NASA Funding, FY1958-FY2015



Sources: FY1958-FY2008 from *Aeronautics and Space Report of the President*, 2008 edition, http://history.nasa.gov/presrep2008.pdf. FY2009-FY2013 from NASA congressional budget justifications, FY2011-FY2015. FY2014 from P.L. 113-76. FY2015 from P.L. 113-235. Current dollars deflated to FY2015 dollars using GDP (chained) price index from President's budget for FY2015, Historical Table 10.1, http://www.whitehouse.gov/omb/budget/Historicals.

Notes: Transition quarter between FY1976 and FY1977 omitted.

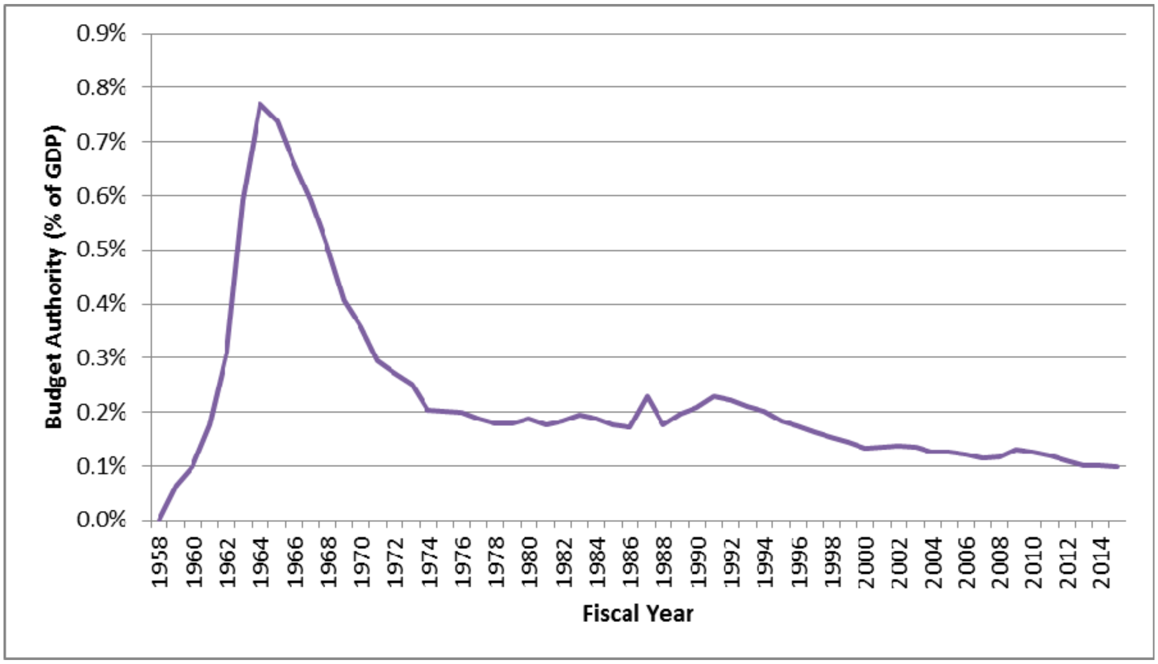
Another historical trend often cited by NASA advocates is the ratio of NASA funding to U.S. gross domestic product (GDP). This is shown in **Figure 2**. The Apollo and post-*Challenger* peaks are again evident. In these terms, the past 20 years have been a steady decline, except for a brief plateau in the early 2000s, an uptick in FY2009, and a smaller uptick in FY2014.[17] As a share of GDP, the FY2013, FY2014, and FY2015 appropriations are lower than any other year since FY1960.

While advocates of more funding for NASA generally consider these trends persuasive, others may not. One counterargument is that federal funding should be allocated based on the merit and importance of current programs, without regard to the funding those programs have received in the past. Another is that federal programs in general *should* represent a lower share of GDP, in order to address the federal deficit and debt or to reduce the tax burden on the economy.

[17] Most of the increase in FY2009 resulted from supplemental funding appropriated in the American Recovery and Reinvestment Act of 2009 (P.L. 111-5), commonly known as the stimulus bill. The increase in FY2014 followed reductions due to sequestration in FY2013.

Figure 2. NASA Funding as a Percentage of GDP, FY1958-FY2015

(budget authority)



Sources: NASA funding FY1958-FY2008 from *Aeronautics and Space Report of the President*, 2008 edition, http://history.nasa.gov/presrep2008.pdf. FY2009-FY2013 from NASA congressional budget justifications, FY2011-FY2015. FY2014 from P.L. 113-76. FY2015 from P.L. 113-235. GDP data from President's budget for FY2015, Historical Table 10.1, http://www.whitehouse.gov/omb/budget/Historicals.

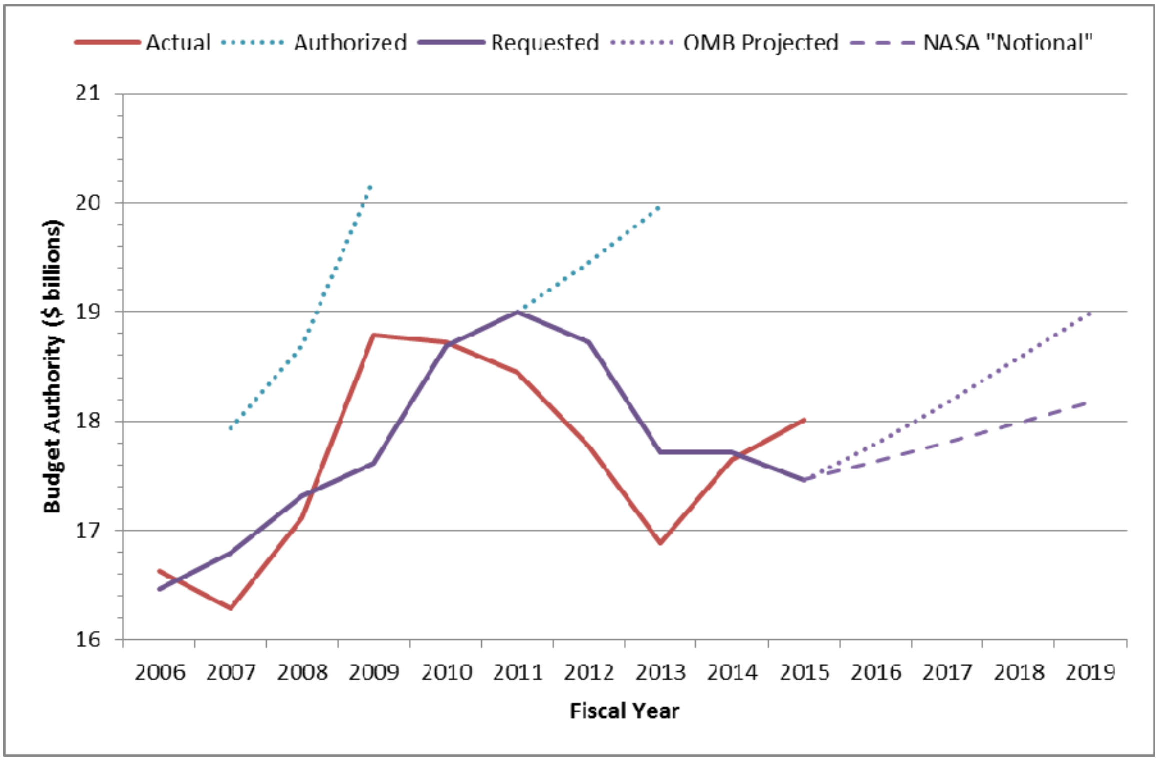
Notes: Transition quarter between FY1976 and FY1977 omitted.

Analysts also often compare actual appropriations for NASA with the amounts authorized in NASA authorization acts, the amounts requested by current and former Administrations, the amounts projected for future years by the Office of Management and Budget (OMB), and the "notional" amounts given for future years in NASA's congressional budget justifications.[18] As shown in **Figure 3**, actual appropriations rarely match the amounts authorized and may not even trend in the same direction. The authorized increase from FY2007 to FY2009 corresponded to an actual increase, but the authorized increase from FY2011 to FY2013 corresponded to an actual decrease.

[18] An administrative provision in the Consolidated Appropriations Act, 2008 (P.L. 110-161) requires NASA to include estimated budgets for the next five years in its annual congressional budget justifications (51 U.S.C. 30103(c)). Since the FY2012 budget request, NASA has labeled these amounts as "notional." NASA's notional estimates in the FY2015 justification projected 1% growth each year. In contrast, OMB projected larger increases that varied from year to year. According to NASA, the OMB projections were "mechanically calculated" to meet statutory budget caps, but for NASA's congressional budget justifications, "NASA and the Administration agreed that it was much more prudent" to plan to lower out-year amounts and make adjustments in future budget cycles (NASA Office of Legislative and Intergovernmental Affairs, email to CRS, May 20, 2014).

Figure 3. Actual, Authorized, Requested, and Projected NASA Funding, FY2006-FY2019

(budget authority in billions of dollars)



Sources: Actual FY2006-FY2008 from *Aeronautics and Space Report of the President*, 2008 edition, http://history.nasa.gov/presrep2008.pdf. Actual FY2009-FY2013 from NASA congressional budget justifications, FY2011-FY2015. Actual FY2014 from P.L. 113-76. Actual FY2015 from P.L. 113-235. Authorized from P.L. 109-155, P.L. 110-422, and P.L. 111-267. No authorization for FY2006, FY2010, or FY2014-FY2019. Requested from NASA congressional budget justifications, FY2006-FY2015. OMB projected from President's budget for FY2015, Historical Table 5.2, http://www.whitehouse.gov/omb/budget/Historicals. NASA "notional" from NASA congressional budget justification, FY2015.

A frequent concern is that NASA is being asked to do more than it can afford. This concern is not new. For example, when the Bush Administration announced the Vision for Space Exploration in 2004, it proposed little new funding to implement it. A widely discussed "sand chart" showed modest funding increases in FY2005 and FY2006, but otherwise projected a NASA budget out to FY2020 that increased only at about the rate of inflation. Because of the Vision's strong emphasis on human spaceflight, supporters of other NASA programs, especially science and aeronautics, feared that the Vision's funding needs would put the rest of the agency under great budget pressure. In early 2006, a former NASA Associate Administrator for Space Science testified:

> Two years ago, the President released his *Vision for Space Exploration* and provided a budget that would support it. In the intervening two years, the Administration has reduced this budget to the point where the plan is insupportable. Last year, aeronautics and technology suffered. This year, the Agency's science program is to be cannibalized, even

> though the NASA Administrator had promised not to transfer "one thin dime" from scientific exploration into human space flight.[19]

By 2009, the Augustine report concluded that executing NASA's plans would require an additional $3 billion per year, even with some schedule delays.[20]

The Augustine report's conclusions were a major impetus behind the passage of the 2010 NASA authorization act, but despite the changes in direction made by that act, concerns remain. Actual appropriations fell short of the authorized amounts without any major tasks being taken off NASA's agenda. In September 2012, the chairman of the NASA Advisory Council testified:

> As I look at NASA's response to the Authorization Act of 2010, I cannot escape the conclusion that the agency is being asked to do too much with too little. The act provides the agency with a clear set of goals and priorities. The Administration has provided another set of goals and priorities. These two sets of guidance are not dramatically dissimilar, but taken together they call for more than the agency can do with the budget it has.[21]

In May 2014, the NASA Inspector General testified that:

> We agree ... that, in effect, too many programs are chasing too few dollars at NASA. Accordingly, we continue to view declining budgets and fiscal uncertainties as the most significant external challenges to NASA's ability to successfully move forward on its many projects and programs.[22]

Human Spaceflight

Shortly after NASA was established in 1958, its Mercury program launched U.S. astronauts into suborbital space (1961) and then Earth orbit (1962). Between 1969 and 1972, the Apollo program landed 12 U.S. astronauts on the Moon. After the final Apollo mission, the United States did not launch humans into space again until the first flight of the space shuttle in 1981. Following the *Columbia* space shuttle disaster in 2003, NASA limited use of the space shuttle to the flights necessary for construction of the International Space Station (ISS).[23] The last space shuttle flight was completed in July 2011. At present, NASA relies on Russian Soyuz spacecraft for astronaut access to the ISS, and NASA's human spaceflight activities are focused on ISS operations and research, the development of a U.S. commercial capability to launch crews into Earth orbit, and the development of future spacecraft for human exploration beyond Earth orbit.

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[19] Wesley T. Huntress, Jr., Director, Geophysical Laboratory, Carnegie Institution of Washington, testimony before the House Committee on Science, March 2, 2006.

[20] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, pp. 15-17.

[21] Steven W. Squyres, Goldwin Smith Professor of Astronomy, Cornell University, testimony before the Senate Committee on Commerce, Science, and Transportation, September 12, 2012.

[22] Testimony of Paul K. Martin, Inspector General, National Aeronautics and Space Administration, before the Senate Committee on Appropriations, Subcommittee on Commerce, Justice and Science, and Related Agencies, May 1, 2014, http://oig.nasa.gov/congressional/NASAIGMARTIN_05_01_14.pdf.

[23] The sole exception was a mission in 2009 to service the Hubble Space Telescope.

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.[24]

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).[25] The United States also has an ISS participation agreement with Brazil, independent of the 1998 framework.

Issues of congressional interest include the full utilization of the ISS for research, the nature of that research, the management of the ISS as a national laboratory for use by other federal agencies and the private sector, the extension of ISS operations past 2020, and access to the ISS for crews and cargo.

Use of the ISS for Research

During more than two decades of ISS design and construction, cost growth and schedule delays resulted in the repeated downsizing of the project's scope and capabilities.[26] These changes raised concern in Congress that the space station's function as a research laboratory was being eroded. One issue of interest to Congress is whether the research capacity of the ISS is being fully utilized. Another is how research associated directly with human spaceflight should be prioritized on the ISS, compared with research in other fields of science.

In 2009, the Government Accountability Office identified several factors that might limit research use of the ISS: limited cargo capacity to carry research payloads to the ISS, a lack of funding to develop and launch experiments, limited crew time to conduct research, and the uncertain future of the ISS past 2015.[27] Since that time, commercial ISS cargo flights have begun, and U.S. utilization of the ISS has been extended (see "Crew and Cargo Access to the ISS" and "ISS Service Life Extension" below). Funding and crew time, however, likely remain as challenges for increased research utilization. Since 2011, NASA has exceeded its goal of spending an average of

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

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

[26] For a historical perspective on the evolution of the space station's purposes and capabilities, see (name redacted), Congressional Research Service, testimony before the Senate Committee on Commerce, Science, and Transportation, Subcommittee on Science and Space, April 20, 2005.

[27] Government Accountability Office, *International Space Station: Significant Challenges May Limit Onboard Research*, GAO-10-9, November 2009.

35 hours per week on scientific investigations.[28] As of mid-FY2014, research facility occupancy was 60%.[29] Although the ISS is designed to support a crew of up to seven astronauts, it currently operates with a maximum of six, so that the crew can be evacuated in an emergency using two Soyuz spacecraft (which carry a maximum of three each). If a seventh crew member could be added, that could potentially add about 33 hours of crew research time per week—nearly double the current amount.[30]

The NASA Authorization Act of 2005 required NASA to allocate at least 15% of the funds budgeted for ISS research to "life and microgravity science research that is not directly related to supporting the human exploration program."[31] It also required NASA to submit a research plan for utilization of the ISS.[32] Issued in June 2006, the plan described proposed R&D and utilization activities in each of six disciplinary areas.[33] 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 human space exploration would continue "at a reduced level."

At about the same time, the National Research Council issued a review of NASA's plans for the ISS.[34] 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."

In 2011, the National Research Council issued its first decadal survey (see "NRC Decadal Surveys" below) of NASA's life and physical sciences programs.[35] The report found that "The ISS is the only existing and available platform of its kind, and it is essential that its presence and dedication to research for the life and physical sciences be fully utilized in the decade ahead." It identified research priorities, both for research that enables space exploration and for research enabled by access to space, and it made recommendations regarding management, oversight, and funding. The report "strongly" recommended "that NASA intensify the utilization of the ISS as a world-class research laboratory engaged in both basic and applied research.... The goal should be to maximize the utilization of existing facilities and to engage world-class scientists and engineers to carry out research."

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[28] National Aeronautics and Space Administration, Office of Inspector General, *NASA's Efforts to Maximize Research on the International Space Station*, IG-13-019, July 8, 2013.

[29] NASA Office of Legislative and Intergovernmental Affairs, email to CRS, May 9, 2014. Facility occupancy is calculated as a combination of the occupancy of internal research facility sites, the occupancy of external research facilities, and the use of available duty cycles of operational facilities.

[30] NASA Inspector General, *NASA's Efforts to Maximize Research on the International Space Station*.

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

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

[33] 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.

[34] National Research Council, *Review of NASA Plans for the International Space Station*, 2006.

[35] National Research Council, *Recapturing a Future for Space Exploration: Life and Physical Sciences Research for a New Era*, 2011. This report was mandated by the explanatory statement for the Consolidated Appropriations Act, 2008 (P.L. 110-161).

According to the NASA Administrator:

> Within the limits of NASA's budget constraints, we will closely consider the recommendations of the Decadal Survey in decisions on investments in new research facilities and capabilities for the ISS, in a research program that balances the pursuit of significant new scientific discoveries and the construction of a foundation of knowledge that supports future human exploration missions.[36]

In subsequent briefings to the National Research Council, NASA officials stated that

- a NASA steering committee will develop a framework for implementing the decadal survey's recommendations;
- all current ISS space biology and physical sciences experiments fit within the decadal survey's high-priority recommendations, but numerous recommended research areas are not currently being addressed;
- results from NASA's evaluation of the decadal survey recommendations will be adapted in future NASA solicitations for research proposals; and
- a decadal survey evaluation committee will reconvene annually to evaluate progress.[37]

ISS National Laboratory

In an effort to increase use of the ISS by other federal agencies and the private sector, the 2005 NASA authorization act designated the U.S. portion of the ISS as a national laboratory.[38] As required by the act, NASA submitted a plan for this designation in May 2007.[39] 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 of the national laboratory designation 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.[40] NASA chartered this committee, the International Space Station National Laboratory Advisory Committee (INLAC), in 2009.[41] NASA has not yet appointed members to the INLAC, however, because of the subsequent transition of ISS national laboratory management to an independent, nonprofit organization.[42]

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[36] Charles F. Bolden Jr., Administrator, National Aeronautics and Space Administration, response to questions for the record, hearing before the Senate Committee on Commerce, Science, and Transportation, March 7, 2012.

[37] Office of the Chief Scientist, National Aeronautics and Space Administration, "NASA's Approach in Developing a Response to the Decadal Survey" (briefing charts), July 26, 2012; and D. Marshall Porterfield, Director, Life and Physical Sciences Division, Human Exploration and Operations Mission Directorate, National Aeronautics and Space Administration, briefing to the National Research Council, July 26, 2012.

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

[39] 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.

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

[41] For the current INLAC charter, renewed in October 2011, see http://oiir.hq.nasa.gov/ISS_National_Lab.pdf.

[42] NASA Office of Legislative and Intergovernmental Affairs, emails to CRS, July 10, 2013, and May 15, 2014.

In 2010, the Senate Committee on Commerce, Science, and Transportation concluded that because of "prior shifts in NASA mission and research priorities ... an independent body should be established to ... manage the ISS national laboratory."[43] The 2010 authorization act directed NASA to contract with a nonprofit organization to carry out this function.[44] Under the act, 50% of the U.S. research capacity allocation on the ISS is to be reserved for experiments managed through the national laboratory process, and NASA utilization in excess of 50% is to be requested through a proposal to the managing organization.

In September 2011, NASA announced the selection of the Center for the Advancement of Science in Space (CASIS) as the managing organization for the ISS national laboratory.[45] CASIS issued its first solicitation for research proposals in June 2012. In November 2012, it announced the award of its first grants, which went to two universities and a small company for research on protein crystallization.[46] In July 2013, the NASA Inspector General concluded that "CASIS's success is critical to maximizing the research capabilities of the ISS" and recommended that "in order to better assess the performance of CASIS, [NASA should] work with CASIS to develop precise annual performance metrics that measure CASIS's success at fostering private research on the ISS."[47] CASIS identified a list of performance metrics in its annual program plan for FY2014, submitted in October 2013.[48] CASIS officials have reportedly found that government rights to intellectual property developed on the ISS may deter some potential commercial research.[49] Authorization bills proposed in the 113th Congress included provisions intended to address this concern.[50]

ISS Service Life Extension

To increase the return on the resources invested in ISS construction, the NASA Authorization Act of 2010 extended U.S. operation and utilization of the ISS by five years, to at least FY2020.[51] The U.S. ISS components were designed for a 15-year lifetime from the date of deployment.[52] Despite the 15-year specification, NASA has stated that 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.[53]

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43 S.Rept. 111-278.

44 P.L. 111-267, Section 504.

45 "NASA Names CASIS to Manage Space Station National Lab Research," NASA press release 11-294, September 9, 2011. For more information about CASIS, see http://www.iss-casis.org/.

46 Center for the Advancement of Science in Space, "CASIS Announces First Grants for Protein Crystallization," press release November 1, 2012.

47 NASA Inspector General, "NASA's Efforts to Maximize Research on the International Space Station."

48 NASA Office of Legislative and Intergovernmental Affairs, email to CRS, June 9, 2014.

49 National Aeronautics and Space Administration, Office of Inspector General, *Extending the Operational Life of the International Space Station Until 2024*, IG-14-031, September 18, 2014.

50 See, for example, H.R. 4412, Section 212, and S. 1317, Section 223.

51 P.L. 111-267, Section 503(a).

52 Components were launched at various times during the ISS assembly process. The nominal reference point is generally considered to be the launch of the U.S. laboratory module Destiny in February 2001.

53 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, p. 5.

The 2010 authorization act directed NASA to carry out a comprehensive review to identify spare and replacement parts that utilization through FY2020 will necessitate.[54] The review identified no issues outside "the normal range of human spaceflight risk" and concluded that "the structural and non-replaceable hardware of the ISS ... [is] compatible with the extension of the ISS to 2020 either as is or with modification."[55] Assessments of this review by the Government Accountability Office found that NASA's analysis was supported by sufficient and reliable data and used reasonable methodologies, but that estimates of the need for spare and replacement parts are sensitive to assumptions about hardware reliability.[56]

In January 2014, the Administration announced that it intends to extend the service life of the ISS further, to at least 2024.[57] In the same month, the annual report of NASA's Aerospace Safety Advisory Committee stated that:

> As NASA assesses ISS life extension, it should also review the objectives for continued ISS use and clearly articulate them to ensure that the costs and safety risks are balanced. Given that human space flight is inherently risky, that risk always needs to be weighed against the value to be gained by the endeavor.[58]

A report by the NASA Inspector General examined the challenges NASA would face in extending ISS operations to 2024. It identified no major technical obstacles but concluded that NASA must address risks such as insufficient power generation, replacement parts for key hardware, and limited capacity to transport large replacement components. The Inspector General also found that NASA's cost projections for future ISS operations appear overly optimistic.[59]

In May 2014, Russian Deputy Prime Minister Dmitry Rogozin announced that Russia does not intend to extend its participation in the ISS past 2020.[60] The significance of this statement is not yet clear, however, as subsequent reports indicated that the Russian space agency Roscosmos was still considering an extension of its ISS participation.[61]

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

[55] National Aeronautics and Space Administration, *Maintenance of the United States Segment and Assurance of Continued Operations of the International Space Station Through 2020*, January 10, 2011.

[56] Government Accountability Office, *International Space Station: Ongoing Assessments for Life Extension Appear to Be Supported*, GAO-11-519R, April 11, 2011; and Government Accountability Office, *International Space Station: Approaches for Ensuring Utilization through 2020 Are Reasonable but Should Be Revisited as NASA Gains More Knowledge of On-Orbit Performance*, GAO-12-162, December 2011.

[57] John P. Holdren and Charles Bolden, "Obama Administration Extends International Space Station until at Least 2024," January 8, 2014, http://www.whitehouse.gov/blog/2014/01/08/obama-administration-extends-international-space-station-until-least-2024.

[58] National Aeronautics and Space Administration, Aerospace Safety Advisory Panel, *Aerospace Safety Advisory Panel Annual Report for 2013*, January 15, 2014, http://oiir.hq.nasa.gov/asap/documents/2013_ASAP_Annual_Report.pdf, p. 1.

[59] National Aeronautics and Space Administration, Office of Inspector General, *Extending the Operational Life of the International Space Station Until 2024*, IG-14-031, September 18, 2014.

[60] Amy Svitak and Amy Butler, "Russia's Space Program Retaliates Against U.S. Sanctions," *Aviation Week*, May 13, 2014, http://aviationweek.com/space/russia-s-space-program-retaliates-against-us-sanctions.

[61] See, for example, "Making a Difference: Dmitry Rogozin, Russian Deputy Prime Minister," *Space News*, September 8, 2014, http://spacenews.com/41794making-a-difference-dmitry-rogozin-russian-deputy-prime-minister/.

Crew and Cargo Access to the ISS

Before 2011, the space shuttle was the primary vehicle for carrying crews and cargo to and from the ISS. Russian Soyuz spacecraft also carried both crews and cargo. Russian Progress spacecraft carried cargo only, as they are not designed to survive reentry into the Earth's atmosphere. With the final space shuttle flight in July 2011, this picture changed significantly.

For crew access to the ISS, Soyuz spacecraft are currently the only available option.[62] In 2009, in order to permit payments to Russia for Soyuz flights, Congress extended a waiver of the Iran, North Korea, and Syria Nonproliferation Act (P.L. 106-178 as amended) until July 1, 2016.[63] In addition, as was the case before the end of the space shuttle program, 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.

For cargo delivery to the ISS, NASA has contracted with two U.S. companies under the Commercial Resupply Services program. The first operational commercial cargo mission for ISS resupply was carried out in October 2012 by Space Exploration Technologies Corporation (SpaceX) using its Dragon spacecraft and Falcon 9 rocket. The other provider, Orbital Sciences Corporation, conducted its first operational cargo resupply mission in January and February 2014, using its Cygnus spacecraft and Antares rocket. These commercial capabilities were developed and demonstrated under NASA's Commercial Orbital Transportation Services (COTS) program. Noncommercial alternatives for cargo delivery, in addition to the Russian Progress, include the European Automated Transfer Vehicle (ATV) and the Japanese H-II Transfer Vehicle (HTV). All these alternatives have a significantly smaller cargo capacity than the space shuttle. Only the Dragon is capable of returning cargo to Earth.

Commercial Crew

In addition to commercial cargo services, NASA is working with U.S. companies to develop commercial services for transporting crews to and from low Earth orbit. Beginning in 2009, the Commercial Crew Development (CCDev) program worked in partnership with eight companies to develop crew transportation concepts and enabling capabilities. In August 2012, NASA announced awards under the Commercial Crew Integrated Capability (CCiCap) program to three companies—the Boeing Company, SpaceX, and Sierra Nevada Corporation—to develop integrated systems to carry crews into low Earth orbit. The Boeing and SpaceX agreements are expected to result in a critical design review of an integrated system. The Sierra Nevada agreement, with only about half as much funding, is expected to "advance ... toward critical design."[64] In September 2014, NASA awarded contracts to Boeing and SpaceX under the Commercial Crew Transportation Capability (CCtCap) program, which will initiate the final development, testing, and verification necessary to allow crewed demonstration flights and will also include initial service missions to the ISS.[65] NASA anticipates that these commercial crew

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[62] Commercial crew transportation services, currently under development with NASA support as the planned replacement for Soyuz flights, are discussed further in the next section, "Commercial Crew."

[63] 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 (name redacted).

[64] NASA FY2014 congressional budget justification, p. EXP-33.

[65] National Aeronautics and Space Administration, "NASA Chooses American Companies to Transport U.S.
(continued...)

activities will result in the availability of commercial services by 2017. Some of the potential providers hope to achieve an earlier date.

In addition to oversight of how NASA and its commercial partners are progressing in the development a commercial crew capability, issues for Congress include the potential commercial market for the resulting services, NASA's use of Space Act Agreements rather than conventional contracts with the companies involved, and processes for ensuring crew safety.

Competition and Commercial Demand

One argument for moving to a commercial model for crew transportation is the belief that it could reduce costs. In a commercial market, operating costs could be shared between NASA and other customers. In addition, competition among multiple providers could drive commercial companies to be more efficient. Some critics, however, question the assumptions behind the commercial approach. In particular, the likely extent of non-NASA demand for crew transportation is uncertain, and some observers doubt whether NASA demand will be sufficient to support multiple providers.

In 2011, as directed by the 2010 authorization act, NASA conducted an assessment of the commercial market for crew and cargo spacecraft.[66] The assessment considered four market segments: the space programs of other countries, private space tourism, applied research and technology development, and other uses, such as satellite servicing, media, entertainment, and education. NASA identified a likely market for crew transportation only in the first two of these segments. Over a 10-year period, the assessment anticipated a total non-NASA market for crew transportation of between 44 and 359 individuals. The low-end estimate was driven mostly by foreign space programs. The high-end estimate was driven more by private tourism. For comparison, the assessment projected that NASA's requirements for ISS crew rotation will include two flights per year with up to four astronauts per flight. This flight rate would mean a NASA market for a total of up to 40 individuals if the service became available in 2016 (one year earlier than now anticipated) and continued through 2020, the currently authorized end date for U.S. utilization of the ISS. If the same flight rate continued for the entire 10-year period of the analysis, it would mean a total NASA market of up to 80 individuals. The assessment emphasized that "market demand is extremely difficult to assess."

The perspectives of the providers differ. Boeing, although optimistic about the potential for non-NASA customers, is basing its plans primarily on the NASA market:

> There definitely is potential for a commercial market. It is in my view, not well defined, the depth of it is difficult to estimate, and so developing a business case that depends on it is a difficult thing. So we have chosen to develop a system that will be affordable if the only transportation that we do is government transportation to ISS.... In parallel, though, we are also working hard to develop a commercial market independent of that.[67]

(...continued)

Astronauts to International Space Station," press release 14-256, September 16, 2014.

[66] National Aeronautics and Space Administration, *Commercial Market Assessment for Crew and Cargo Systems*, April 27, 2011. This report was mandated by P.L. 111-267, Section 403.

[67] John Elbon, Vice President and General Manager for Space Exploration, The Boeing Company, testimony before the House Committee on Science, Space, and Technology, October 26, 2011.

SpaceX is more confident about the commercial potential: "In ten years there will be more commercial ... manned flights to space than there will be government. I am quite confident of that."[68]

If in fact the primary market is two NASA flights per year to the ISS, some observers question whether that flight rate can support more than one provider. If there were only a single provider, that would cast doubt on the idea of reducing costs through competition. The Augustine report stated that "it is crucial to the success of the program that multiple providers be carried through to operational service."[69] NASA's Aerospace Safety Advisory Panel has expressed concern that "the ability to sustain a competitive environment may fall victim to further funding shortfalls."[70]

Use of Space Act Agreements

The CCDev and CCiCap awards were Space Act Agreements (SAAs), rather than contracts under the Federal Acquisition Regulation (FAR).[71] The use of SAAs can increase flexibility for both NASA and the company when establishing milestones, schedules, and payments. SAAs are often funded partly (and in some cases, entirely) by the company, rather than by NASA. In addition, SAAs avoid accounting requirements and other FAR rules that companies may see as expensive and cumbersome. On the other hand, the use of SAAs limits NASA's ability to set requirements. Under an SAA, NASA "cannot dictate specific system concepts or elements or mandate compliance with its requirements. Rather, commercial partners are free to determine the system requirements and concepts they believe will best serve their target markets."[72]

SAAs cannot be used for procurement, and many observers believe that they would be inappropriate for activities relating to safety certification, because NASA should be able to set its own safety requirements. In December 2012, NASA issued FAR-based contracts to the three CCiCap companies to conduct early-stage activities related to safety certification.[73] NASA also used FAR-based contracts for the September 2014 CCtCap awards and intends to do so for subsequent procurements of crew transportation services.[74]

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[68] Elon Musk, Chief Executive Officer and Chief Technology Officer, Space Exploration Technologies Corporation, testimony before the House Committee on Science, Space, and Technology, October 26, 2011.

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

[70] *Aerospace Safety Advisory Panel Annual Report for 2013*, p. 1.

[71] Space Act Agreements are a form of "other transaction" authorized by the National Aeronautics and Space Act of 1958 (51 U.S.C. 20113(e)). For more information, see CRS Report RL34760, *Other Transaction (OT) Authority*, by (name redacted). NASA originally planned to use a FAR-based contract (the Commercial Crew Integrated Design Contract) for the work covered by the CCiCap SAAs. It changed this plan in December 2011. See "NASA Takes Next Step in Developing Commercial Crew Program: Competitive Agreements Will Keep U.S. Commercial Space Program on Track," NASA press release 11-419, December 15, 2011.

[72] Paul Martin, Inspector General, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, October 26, 2011.

[73] "NASA Awards Contracts in Next Step Toward Safely Launching American Astronauts from U.S. Soil," NASA press release 12-429, December 10, 2012.

[74] NASA FY2015 congressional budget justification, p. EXP-43.

Safety of Commercial Human Spaceflight

The advent of commercial spacecraft that carry crews into space will require new processes for ensuring crew safety. In general, the Federal Aviation Administration (FAA) Office of Commercial Space Transportation is responsible for regulating U.S. commercial space launch and reentry.[75] At present, however, the authority of the FAA to regulate commercial spacecraft for the safety of their human crews is limited.[76] The Augustine committee concluded that commercial crew transport services would need to include "a strong, independent mission assurance role for NASA."[77]

Addressing the safety regulation roles of the FAA and NASA, the chairman of the FAA's Commercial Space Transportation Advisory Committee (COMSTAC) testified in March 2012 that

> Both agencies are working to ensure compatibility between NASA requirements and FAA regulations.... A single, consistent regulatory and licensing regime for both government and non-government customers is critical to the long-term success of commercial human spaceflight providers and to enable the development of new customers and markets for private human spaceflight capabilities. The COMSTAC strongly supports FAA licensing of commercial human spaceflight activities, including those commercial activities conducted for [NASA].... Any customer, including NASA, can impose additional safety requirements and approval processes by contract.[78]

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.[79] Issued in December 2010, this document 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."[80] A NASA official testified in September 2012 that

> NASA is committed to ensuring that the requirements, standards, and processes for [Crew Transportation System] certification for all commercial missions are held to the same or equivalent safety standards as Government human spaceflight missions. NASA certification will cover all aspects of a crew transportation system, including: development, test, evaluation, and verification; program management and control; flight readiness certification;

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[75] See http://www.faa.gov/about/office_org/headquarters_offices/ast/about/.

[76] Until October 1, 2015, the FAA "may issue regulations governing the design or operation of a launch vehicle to protect the health and safety of crew and space flight participants" only when "restricting or prohibiting design features or operating practices that ... have resulted in a serious or fatal injury ... to crew or space flight participants during a licensed or permitted commercial human space flight" or that have "contributed to an unplanned event or series of events ... that posed a high risk" of doing so (51 U.S.C. 50905(c)). This moratorium was extended by Section 827 of the FAA Modernization and Reform Act of 2012 (P.L. 112-95).

[77] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 70.

[78] Wilbur C. Trafton, Chairman, Commercial Space Transportation Advisory Committee, testimony before the House Committee on Science, Space, and Technology, March 20, 2012.

[79] 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.

[80] 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, p. 4.

launch, landing, recovery, and mission operations; sustaining engineering, and maintenance/upgrades.[81]

In January 2014, while acknowledging "considerable progress" in the Commercial Crew program, NASA's Aerospace Safety Advisory Panel (ASAP) identified three continuing safety concerns:

- insufficient funding, which "can ... result in lower performance validation and higher failure risk through improper or insufficient testing";
- the CCtCap acquisition strategy, which ASAP believes increases safety risks; and
- ambiguous goals and priorities, which make it difficult to determine the acceptable level of risk because "the value of the anticipated outcome ... remains muddy."[82]

Multipurpose Crew Vehicle and Space Launch System

For human spaceflight beyond Earth orbit, the NASA Authorization Act of 2010 directed NASA to develop a Multipurpose Crew Vehicle (MPCV) and a rocket known as the Space Launch System (SLS) to carry the MPCV into orbit.[83] The act directed that the MPCV should "continue to advance the development" of the Constellation program's Orion capsule. Indeed, the MPCV is now generally referred to as Orion. The act also directed that, in addition to their primary mission beyond Earth orbit, the MPCV and SLS should be capable of delivering crews and cargo to the ISS, if commercial and other alternative services are not available.

Issues for Congress include the schedule for Orion and SLS development and the likely schedule of flights once operational, the payload capability of the SLS, the potential use of Orion and the SLS for crew access to the ISS if commercial crew transportation services fail to materialize, and the destination for human exploration using Orion and the SLS once they are available.

Orion/SLS Schedule and Cost

The 2010 NASA authorization act established December 31, 2016, as the target date for achieving full operational capability for the MPCV and an initial version of the SLS. In January 2011, however, NASA reported that it was unable to identify spacecraft designs that met the act's capability and schedule mandates within the authorized funding levels.[84] NASA currently plans an uncrewed test flight of Orion and SLS (known as EM-1) in FY2018 and a flight with a crew on board (known as EM-2) in FY2021-FY2022. An uncrewed test flight of Orion without the SLS (on a commercial Delta IV rocket) was conducted in December 2014.

[81] William H. Gerstenmaier, Associate Administrator for Human Exploration and Operations, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, September 14, 2012.

[82] *Aerospace Safety Advisory Panel Annual Report for 2013*, pp. 13-15.

[83] P.L. 111-267, Sections 302 and 303.

[84] 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.

Congressional advocates of the SLS have sought to accelerate this schedule. According to NASA, the date of the EM-1 test flight would be difficult to bring forward, even with additional funding, because it depends on technical requirements such as engineering design and manufacturing schedules and the need for adequate testing.[85] Accelerating the schedule for the EM-2 flight may be more feasible. For example, a contractor representative testified in 2012 that

> The initial [EM-1] flight ... is constrained by the schedule needed to develop, integrate ... and test the SLS core stage. Increased funding would not accelerate the [EM-1] flight, but would provide additional schedule confidence. The [EM-2] flight on the other hand is constrained by the currently proposed budgets. If additional funds were applied to the SLS core stage, the [EM-2] flight could be accelerated.[86]

Since that time, however, the launch schedule has moved back, not forward. Before the release of NASA's FY2015 budget in March 2014, the announced launch date for EM-1 was 2017, and the announced launch date for EM-2 was 2021.

Another schedule concern is the expected launch rate once Orion and the SLS become operational. Following the EM-2 crewed test flight, NASA expects operational missions to occur approximately once every two years. According to the chairman of the NASA Advisory Council:

> The low flight rate projected for SLS and Orion is a serious problem. No human-rated launch system in NASA's history has flown so infrequently. With such a low launch rate it will not just be difficult to maintain program momentum; it will be difficult to keep flight teams sharp and mission-ready.[87]

In December 2014, a NASA official testified that NASA "would like to fly at roughly a flight rate of about once per year" and is analyzing that flight rate to see whether it can be achieved within the available budget and whether it would "provide enough frequency of flight that it answers those safety concerns."[88]

During 2014, NASA established formal cost and schedule baselines for the SLS ($9.7 billion) and associated ground systems ($2.8 billion) through FY2018. A similar baseline for Orion is expected in May 2015; the preliminary estimate is between $8.5 billion and $10.3 billion. According to the Government Accountability Office, however, the long-term affordability of the human exploration program remains uncertain, despite these cost estimates, because the estimates "do not provide any information about the longer-term, life-cycle costs of developing, manufacturing, and operating the launch vehicles." For example, the baseline estimate for the SLS does not include program costs after EM-1 or costs associated with SLS versions after Block 1 (see next section).[89]

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[85] See, for example, Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, March 7, 2012.

[86] Jim Chilton, Exploration Vice President, The Boeing Company, response to questions for the record, hearing before the House Committee on Science, Space, and Technology, September 12, 2012.

[87] Steven W. Squyres, Goldwin Smith Professor of Astronomy, Cornell University, testimony before the House Committee on Science, Space, and Technology, June 19, 2013.

[88] William H. Gerstenmaier, Associate Administrator for Human Exploration and Operations, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, December 10, 2014.

[89] Government Accountability Office, *NASA: Human Space Exploration Programs Face Challenges*, GAO-15-248T, December 10, 2014.

According to NASA policy, project planning and budgeting should be based on a 70% joint cost and schedule confidence level, unless a lower level of at least 50% is formally approved, justified, and documented.[90] The formal cost and schedule baselines established for the SLS and associated ground systems use the 70% level, but the program is pursuing more aggressive internal schedule goals with confidence levels as low as 30%.[91] Administrator Bolden testified in May 2014 that:

> I'm comfortable with having SLS come in at less than a 70 percent joint confidence level because of the maturity of the ... system ... a joint confidence level of 70 percent—which would be great, if we had it—is not required to make me feel confident that we're going to be able to deliver.... I will have the same assurance at a lower joint confidence level for SLS that I have for other projects that are much less mature at a joint confidence level of 70 percent.[92]

The Consolidated and Further Continuing Appropriations Act, 2015 (P.L. 113-235) directed that future NASA budget submissions shall include funding and schedule projections for Orion and the SLS that are consistent with a 70% joint confidence level.

SLS Payload Mass

The 2010 act specifies that the initial version of the SLS is to be capable of lifting payloads weighing between 70 and 100 metric tons into low Earth orbit, and a subsequent version is to be capable of lifting payloads weighing at least 130 metric tons. Some early reactions to this mandate were skeptical. In the floor debate on the act, one Member referred to the SLS as "a rocket designed by Senators and not by engineers ... a rocket that doesn't meet [NASA's] needs."[93] The NASA Administrator argued that the 130 metric ton capability was unnecessary in the near term, and that building a rocket of that size now would be premature, because by the time a 130 metric ton capability is needed, technology will have advanced:

> Not only is it not wise, it's not necessary for us to build a 130-metric-ton, heavy-lift vehicle right off the bat. By the time we need to go ... to Mars or to an asteroid, [for which] you need a 130-metric-ton vehicle ... its weight may be significantly less than what a 130-metric-ton vehicle is today because we're using composite tanks.[94]

Others view the 130 metric ton version as essential. For example, one Member recently stated that:

> As important as building the rocket is building the right rocket, the 130 metric ton version, not the half-capable 70 metric ton first step.... [95]

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[90] NASA Procedural Requirement 7120.5E, http://nodis3.gsfc.nasa.gov/displayDir.cfm?Internal_ID=N_PR_7120_005E_, Section 2.4.4. A joint confidence level of 70% means that there is a 70% estimated probability of achieving the stated cost and schedule.

[91] Government Accountability Office, *NASA: Human Space Exploration Programs Face Challenges*.

[92] Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration, oral testimony at a hearing of the Senate Committee on Appropriations, Subcommittee on Commerce, Justice, Science, and Related Agencies, May 1, 2014.

[93] Rep. Gabrielle Giffords, *Congressional Record*, September 29, 2010, p. H7358.

[94] Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration, remarks at the Center for Strategic and International Studies, *NASA and Accelerating American Innovation*, March 10, 2011.

[95] Rep. Mo Brooks, remarks at hearing of the House Committee on Science, Space, and Technology, June 19, 2013.

NASA has identified three generations of the SLS: Block 1, with a lift capability of 70 metric tons; Block 1A, 105 metric tons; and Block 2, 130 metrics tons. These three versions will "fulfill specific, important roles within the exploration architecture":

- Block 1 "will prove out the new Core Stage and integrated stack for the initial exploration missions and can support scientific payloads with requirements beyond commercial lift capabilities."
- Block 1A "provides significant 'mission capture' for the next set of human missions beyond" low Earth orbit.
- Block 2 "would be used for full capability asteroid missions and ultimately missions to Mars."[96]

Orion/SLS as Backup Option for ISS Access

Although the Orion and the SLS are primarily intended for exploration beyond Earth orbit, the 2010 NASA authorization act directs that they should be capable of serving as a backup system for delivering crew and cargo to the ISS in the event that commercial and partner-supplied spacecraft are not available.[97] The Augustine report concluded that if NASA's efforts to develop a commercial crew capability fail, "the most cost-effective fallback option ... is to continue to develop the Orion, and move as quickly as possible to the development of a human-ratable heavy lift vehicle" (such as the SLS).[98]

One concern about this approach is that the planned lift capability of the SLS far exceeds what is required for ISS access. The Ares I, which would have launched Orion into Earth orbit under the Constellation program, would have had a payload mass of about 25 metric tons. The overcapacity of the SLS (70 metric tons, even in Block 1) would likely make it an expensive option for ISS missions.

Another concern is that the currently authorized end date for U.S. utilization of the ISS is in 2020. This is before the planned date of even the first test flight of Orion and the SLS with a crew on board. Orion and the SLS could therefore be available as a backup for ISS access only if the service life of the ISS is extended (as the Administration has proposed; see "ISS Service Life Extension" above) or if the availability of Orion and SLS can be brought forward.

If NASA's efforts to develop a commercial crew capability fail, however, the only other alternative for crew access to the ISS would be to continue paying Russia for Soyuz flights. Many policy makers consider this an inherently unattractive option. The 2013 National Space Transportation Policy states that "The Administrator of the National Aeronautics and Space Administration ... shall ... rely upon U.S.-manufactured space transportation vehicles as the foundation for access to space."[99] Continued payments to Russia would also require a further

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[96] Daniel L. Dumbacher, Deputy Associate Administrator for Exploration Systems Development, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, September 12, 2012.

[97] P.L. 111-267, Sections 302(c)(1)(D) and 303(b)(3).

[98] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 71.

[99] Executive Office of the President, "National Space Transportation Policy," November 21, 2013, p. 3.

extension of a waiver of the Iran, North Korea, and Syria Nonproliferation Act (see "Crew and Cargo Access to the ISS" above).

Destinations for Human Exploration Beyond Earth Orbit

From 2004 to 2010, the Vision for Space Exploration established the Moon, followed eventually by Mars, as NASA's goal for human exploration beyond Earth orbit. 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, rather than returning to the Moon first.[100] Others suggested human missions to asteroids or other solar system locations that would be less technologically challenging than an immediate mission to Mars, while still being worthwhile scientifically and as steps toward subsequent destinations. According to the Augustine committee:

> Mars stands prominently above all other opportunities for exploration. Mars is unquestionably the most scientifically interesting destination in the inner solar system, with a planetary history much like Earth's. It possesses resources that can be used for life support and propellants ... But Mars is not an easy place to visit.[101]

The Augustine committee concluded that while Mars is the ultimate destination for human exploration, it is "not a viable first destination" because of the likely cost and the "considerable" safety risk with current technology.[102]

The Obama Administration's plan, first articulated in April 2010,[103] is for an asteroid to be NASA's first destination beyond Earth orbit, followed by an orbit of Mars and subsequently a Mars landing. NASA states that it plans to send humans to an asteroid by 2025 and to Mars in the 2030s.[104] 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."[105]

The 2010 act also mandated a review by the National Academies of the goals, capabilities, and direction of human space flight.[106] The 2014 report of that review found that

> for the foreseeable future, the only feasible destinations for human exploration are the Moon, asteroids, Mars, and the moons of Mars. Among this small set of plausible goals for human space exploration, the most distant and difficult is a landing by human beings on the surface of Mars—requiring overcoming unprecedented technical risk, fiscal risk, and programmatic

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

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

[102] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 37.

[103] "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.

[104] See, for example, Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, April 24, 2013.

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

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

> challenges. Thus the horizon goal for human space exploration is Mars. All long-range space programs, by all potential partners, for human space exploration converge on this goal.[107]

The report assessed a variety of mission sequences, each with Mars as a final destination following earlier expeditions elsewhere. The report did not recommend any one of these pathways over the others.

An earlier National Academies study found

> little evidence that a current stated goal for NASA's human spaceflight program—namely, to visit an asteroid by 2025—has been widely accepted as a compelling destination by NASA's own workforce, by the nation as a whole, or by the international community. On the international front there appears to be continued enthusiasm for a mission to the Moon but not for an asteroid mission, although there is both U.S. and international interest in robotic missions to asteroids.[108]

In the FY2014 budget, NASA proposed a mission, now known as the Asteroid Redirect Mission (ARM), that would capture a small asteroid robotically, redirect it into orbit around the Moon, and explore it with astronauts as an early destination for Orion and the SLS, perhaps as soon as the first crewed flight in FY2021-FY2022. A variant option would capture a large boulder from the surface of an asteroid, rather than an entire asteroid. NASA argues that the proposed ARM would provide a useful early destination for Orion and the SLS while at the same time meeting other goals for the science of asteroids and the demonstration of advanced technology. For example, a robotic spacecraft using new solar electric propulsion technology (which NASA is developing anyway, for other purposes) would be used to redirect the target asteroid's orbit. A study of a possible asteroid retrieval mission by the Keck Institute for Space Studies concluded in 2012 that "placing a 500-[tonne] asteroid in high lunar orbit would provide a unique, meaningful, and affordable destination for astronaut crews in the next decade" and estimated that the full life-cycle cost might be about $2.6 billion.[109] According to NASA officials, the proposed NASA mission differs in several respects from the mission examined by the Keck Institute, and the cost, while not yet determined, "will be something less than their estimate."[110] A Mission Concept Review, including an independent cost estimate, is scheduled for February 2015.[111] The ARM has met with opposition in Congress. For example, the joint explanatory statement on appropriations for FY2014 called it "still an emerging concept" and stated that "NASA has not provided Congress with satisfactory justification materials" and that additional groundwork "is needed ... prior to NASA and Congress making a long-term commitment to this mission concept."[112]

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[107] National Research Council, *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*, 2014, p. S-3.

[108] National Research, Council, *NASA's Strategic Direction and the Need for a National Consensus*, 2012.

[109] Keck Institute for Space Studies, *Asteroid Retrieval Feasibility Study*, April 2, 2012, p. 6. Additional information on this study is available at http://www.kiss.caltech.edu/study/asteroid/.

[110] Charles F. Bolden, Jr., Administrator, National Aeronautics and Space Administration, testimony before the House Committee on Science, Space, and Technology, April 24, 2013.

[111] (name redacted), "NASA Delays Decision on Asteroid Redirect Mission Options," SpacePolicyOnline.com, December 17, 2014.

[112] Joint explanatory statement on the Consolidated Appropriations Act, 2014 (P.L. 113-76), *Congressional Record*, January 15, 2014, Book II, p. H515.

Another option that has been proposed for the first crewed flight of Orion and SLS is a fly-by of Mars. In February 2014, the House Committee on Science, Space, and Technology held a hearing on a version of this concept that would include a fly-by of Venus en route to Mars.[113]

At present, NASA's focus is on Orion and the SLS, with little work under way to develop complementary landers and surface systems. In August 2013, the NASA Inspector General noted that

> unless NASA begins a program to develop landers and surface systems, NASA astronauts will be limited to orbital missions using the MPCV [i.e., Orion]. Under the current budget environment, it appears unlikely that NASA will obtain significant funding to begin development of this additional exploration hardware, thereby delaying such development into the 2020s. Given the time and money necessary to develop landers and associated systems, it is unlikely that NASA would be able to conduct any surface exploration missions until the late 2020s at the earliest.[114]

FY2015 Budget and Appropriations

Human spaceflight activities at NASA are funded by two appropriations accounts. The Exploration account funds the development of future capabilities, including the Orion Multipurpose Crew Vehicle, the Space Launch System, and the Commercial Crew program. The Space Operations account funds operational programs: the International Space Station, including the cost of Soyuz flights to carry U.S. astronauts to and from the ISS and commercial cargo flights for ISS resupply; the Space and Flight Support program, which supports activities such as launch services and space-ground communications; and (before FY2014) the space shuttle, including program closeout costs. **Table 2** shows the allocation of human spaceflight funding among these activities in FY2013, FY2014, and FY2015.

Table 2. NASA Human Spaceflight Funding, FY2013-FY2015

(budget authority in millions of dollars)

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Exploration	**$3,705.5**	**$4,113.2**	**$4,356.7**
Exploration Systems Development	2,883.8	3,115.2	3,245.3
- *Orion Multi-Purpose Crew Vehicle*	*1,113.8*	*1,197.0*	*1,194.0*
- *Space Launch System*	*1,414.9*	*1,600.0*	*1,700.0*
- *Exploration Ground Systems*	*355.1*	*318.2*	*351.3*
Commercial Spaceflight	525.0	696.0	805.0
Exploration Research and Development	296.7	302.0	306.4
Space Operations	**3,724.9**	**3,778.0**	**3,827.8**
Space Shuttle	38.8	0.0[a]	—[b]

[113] House Committee on Science, Space, and Technology, *Mars Flyby 2021: The First Deep Space Mission for the Orion and Space Launch System?*, hearing, February 27, 2014.

[114] National Aeronautics and Space Administration, Office of Inspector General, *Status of NASA's Development of the Multi-Purpose Crew Vehicle*, IG-13-022, August 15, 2013.

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
International Space Station	2,775.9	2,964.1[a]	—[b]
Space and Flight Support	910.2	812.3[a]	—[b]

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

a. From March 2014 operating plan. Not specified in P.L. 113-76 or the explanatory statement. The operating plan also transferred $1.6 million from Space Operations to other accounts.

b. Not specified in P.L. 113-235 or the explanatory statement.

In the Exploration account, the President's FY2015 request for Orion, the SLS, and related ground systems was a decrease of 10.6%, while the request for Commercial Spaceflight, which funds the commercial crew program, was an increase of 21.8%.[115] As in past years, many in Congress saw this proposal as evidence of a difference in human spaceflight priorities between Congress and the Administration, and this perceived difference was controversial. Congress ultimately appropriated increases for both programs, as shown in the table.

The FY2015 report of the Senate Committee on Appropriations (S.Rept. 113-181) would have required certified cost and pricing data for NASA's commercial crew contracts. Advocates of this language described it as promoting transparency. Others, noting that it was drawn from federal cost-plus contracting,[116] argued that it was not suitable for the fixed-price commercial approach that NASA is using for the commercial crew program. The final FY2015 explanatory statement did not include the Senate language.

Science

NASA's Science Mission Directorate conducts research through its Earth Science, Planetary Science, Astrophysics, and Heliophysics Divisions. In addition, the Joint Agency Satellite Division conducts systems engineering, hardware development, and acquisition of operational satellites on behalf of other agencies. This section discusses selected issues of interest to Congress: the use of decadal surveys for Science program planning at NASA; the Earth Science program and its relationship with Earth-observing satellite activities at other agencies; Mars exploration and near-Earth object research in the Planetary Science program; the James Webb Space Telescope in the Astrophysics program; and FY2015 budget and appropriations issues for NASA Science.

NRC Decadal Surveys

The Science Mission Directorate makes extensive use of the National Research Council (NRC) for program planning and prioritization. The NRC has been publishing decadal surveys for more

[115] The Commercial Spaceflight budget item no longer includes funding for commercial cargo activities, as they have moved from development to operations.

[116] See the requirements in Federal Acquisition Regulation 15.403-4.

than 50 years.[117] These reports typically provide recommendations and priorities for research in a particular field of science or engineering over the decade following publication. The process of preparing such studies usually includes multiple opportunities for input from the scientific community. The resulting reports are therefore generally taken to represent that community's consensus view, and Congress frequently cites decadal surveys in support of particular NASA programs or missions. According to NASA's congressional budget justification for FY2015:

> NASA uses the recommendations of the National Academies' decadal surveys for guidance in planning the future of its science programs. For over 30 years, decadal surveys have proven indispensable in establishing a broad consensus within the national science community on the state of the science, the highest priority science questions we can address, and actions we can take to address those priority science topics. NASA uses these recommendations to prioritize future flight missions, including space observatories and probes, as well as technology development and proposals for theoretical and suborbital supporting research. In that process, NASA must also adapt science-based decadal survey recommendations to actual budgets, existing technological capabilities, national policy, partnership opportunities, and other programmatic factors.[118]

Earth Science

NASA describes the goal of the Earth Science program as to "study planet Earth from space to advance scientific understanding and meet societal needs."[119] In the 2014 NASA strategic plan, Objective 2.2 is to "advance knowledge of Earth as a system to meet the challenges of environmental change, and to improve life on our planet."[120] The statutory goal of the Earth Science program is:

> to pursue a program of Earth observations, research, and applications activities to better understand the Earth, how it supports life, and how human activities affect its ability to do so in the future.[121]

The Earth Science program has expanded in recent years. The NRC recommended in its 2007 decadal survey that the United States "should renew its investment in Earth observing systems and restore its leadership in Earth science and applications."[122] In response, Congress and the Administration increased the share of NASA's Science funding devoted to Earth Science from 26% in FY2008 to 34% in FY2015 (down slightly from 35% in FY2014). The NASA Authorization Act of 2010 directed NASA to "undertake to implement, as appropriate, missions identified in the National Research Council's Earth Science Decadal Survey."[123] Because much of the program supports research relating to climate change, however, some in Congress object to

[117] The first was National Academy of Sciences, *Ground-Based Astronomy: A Ten-Year Program,* published in 1964.

[118] NASA FY2015 congressional budget justification, p. SCI-5.

[119] http://science.nasa.gov/about-us/organization-and-leadership/division-bios/.

[120] National Aeronautics and Space Administration, *2014 Strategic Plan*, http://www.nasa.gov/sites/default/files/files/2014_NASA_Strategic_Plan.pdf, p. 30.

[121] 51 U.S.C. 60501.

[122] National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, 2007. See also National Research Council, *Earth Science and Applications from Space: A Midterm Assessment of NASA's Implementation of the Decadal Survey*, 2012.

[123] P.L. 111-267, Section 704.

proposals to increase support for Earth Science, especially when other NASA activities may face decreases.

Congressional policy makers have also taken a long-standing interest in the relationship between NASA's Earth Science program and the satellite programs of the National Oceanic and Atmospheric Administration (NOAA), which operates Earth-observing satellites for weather forecasting and other purposes, and the U.S. Geological Survey (USGS), which operates the Landsat land-imaging satellites.[124] The NASA Authorization Act of 2010 directed the Office of Science and Technology Policy 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 USGS to establish a formal mechanism to transition NASA research and assets to NOAA and USGS operations.[125] Given the extent to which these requirements overlap with earlier provisions in the 2005 and 2008 NASA authorization acts,[126] achieving Congress's goals for the NASA-NOAA relationship appears to be challenging.

The Joint Agency Satellite Division acquires operational Earth-observing satellites for NOAA on a cost-reimbursement basis, using funds appropriated to NOAA. In the 112th Congress, the Senate Committee on Appropriations recommended funding these activities in NASA's budget instead.[127] This proposal was not renewed in the 113th Congress.

Mars Exploration

NASA's goals for the Mars Exploration program, an activity of the Planetary Science Division, are to determine whether life ever arose on Mars, to characterize the climate of Mars, to characterize the geology of Mars, and to prepare for human exploration.[128] In 2011, an NRC decadal survey identified three high-priority science goals: to determine whether life ever arose on Mars, to understand the processes and history of the Martian climate, and to determine the evolution of the Martian surface and interior.[129] These goals appear to be consistent with the first three goals articulated by NASA. The decadal survey did not address the fourth NASA goal, relating to human exploration.

In recent years, NASA has proposed near-term reductions in funding for Mars Exploration. The Mars Science Laboratory mission was launched in November 2011 and landed on Mars in August 2012, delivering the rover Curiosity, whose discoveries include the first evidence of flowing streambeds on Mars.[130] The Mars Atmosphere and Volatile Evolution (MAVEN) mission, intended to answer scientific questions about liquid water on Mars, atmospheric loss, climate history, and habitability, was launched in November 2013 and arrived at Mars in September

[124] NOAA is in the Department of Commerce. USGS is in the Department of the Interior.

[125] P.L. 111-267, Sections 702 and 703. The strategic plan was issued as Executive Office of the President, National Science and Technology Council, *National Strategy for Civil Earth Observations*, April 2013, http://www.whitehouse.gov/sites/default/files/microsites/ostp/nstc_2013_earthobsstrategy.pdf.

[126] P.L. 109-155, Section 306; and P.L. 110-422, Sections 202, 204, and 507.

[127] Commerce, Justice, Science, and Related Agencies Appropriations Act, 2013 (S. 2323, S.Rept. 112-158).

[128] NASA congressional budget justification for FY2015, p. PS-36.

[129] National Research Council, *Vision and Voyages for Planetary Science in the Decade 2013-2022*, 2011, http://www.nap.edu/catalog.php?record_id=13117.

[130] For further information, see http://mars.jpl.nasa.gov/msl/.

2014.[131] In general, costs for mission formulation, development, and implementation are higher than costs for operations after launch. Nevertheless, despite funding increases for new Mars missions that NASA projects in future years, advocates may fear that near-term cuts could have long-term impacts.

Near-Earth Objects

Another Planetary Science activity, research on near-Earth objects (NEOs), received increased congressional and public attention following the explosion of a small asteroid over Chelyabinsk, Russia, in February 2013.[132] NEOs are asteroids and comets that come close to Earth's orbit.[133] In addition to their scientific interest, many policy makers are concerned about the threat they could pose to human life and property, were they to collide with Earth. The House Committee on Science, Space, and Technology held hearings in March and April 2013 on government and private-sector efforts to track and mitigate the threat of NEOs. The Senate Committee on Commerce, Science, and Transportation held a hearing in March 2013 on space threats, including NEOs.

In 1998, NASA committed to cataloging 90% of the NEOs larger than 1 kilometer in diameter within 10 years.[134] As of December 2014, 868 asteroids of this size had been discovered.[135] NASA estimates that this represents about 95% of the total.[136] While a NEO of this size that struck the Earth "would cause a global catastrophe," none of those yet discovered pose any threat of Earth impact within the next 100 years.[137]

The NASA Authorization Act of 2005 directed NASA to expand its NEO survey to all objects larger than 140 meters in diameter and to catalog 90% of such objects within 15 years.[138] An NRC report in 2010 made recommendations for achieving this goal and for NEO hazard mitigation.[139] In September 2014, the NASA Inspector General reported that NASA had cataloged only about 10% of NEOs larger than 140 meters and was unlikely to meet the 90% goal by 2020.[140] The Inspector General found that the NEO program is hindered by a lack of structure and limited resources, would benefit from improved internal oversight of grants and task orders, and could take more advantage of formal partnerships with other federal agencies and international peers.

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131 For further information, see http://science.nasa.gov/missions/maven/.

132 For more information on the NASA Near-Earth Object program, see http://neo.jpl.nasa.gov/.

133 The NASA Authorization Act of 2005 defines a near-Earth object as an asteroid or comet whose nearest approach to the Sun is less than 1.3 times the distance of the Earth from the Sun (P.L. 109-155, Section 321).

134 Carl Pilcher, Science Director, Solar System Exploration, National Aeronautics and Space Administration, testimony before the House Committee on Science, May 21, 1998.

135 National Aeronautics and Space Administration, Near Earth Object program, "Near-Earth Asteroid Discovery Statistics," http://neo.jpl.nasa.gov/stats/.

136 James Green, Director, Planetary Science Division, National Aeronautics and Space Administration, testimony before the Senate Committee on Commerce, Science and Transportation, March 20, 2013.

137 Ibid.

138 P.L. 109-155, Section 321, known as the George E. Brown, Jr. Near-Earth Object Survey Act.

139 National Research Council, *Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies*, 2010.

140 National Aeronautics and Space Administration, Office of Inspector General, *NASA's Efforts to Identify Near-Earth Objects and Mitigate Hazards*, IG-14-030, September 15, 2014.

By comparison, the Chelyabinsk asteroid was 17 to 20 meters in diameter.[141] The object that caused the 1908 Tunguska explosion, believed to be the largest impact event in recorded history, was probably between 50 and 100 meters in diameter.[142] The target of NASA's proposed Asteroid Redirect Mission (see "Destinations for Human Exploration Beyond Earth Orbit" above) is expected to be 7 to 10 meters in diameter.[143]

James Webb Space Telescope

The James Webb Space Telescope (JWST), a project of the Astrophysics Division, is a planned successor to the Hubble Space Telescope. Unlike Hubble, which orbits the Earth at an altitude of 353 miles, JWST is designed to operate in deep space, about 1 million miles from Earth. Its primary mirror is larger than Hubble's, and its instruments are being optimized for infrared rather than visible light. This is expected to allow it to observe objects farther away and further back in time, as well as relatively cool objects such as protostars and protoplanetary disks. NASA plans to launch JWST in October 2018.

Cost increases and schedule delays made JWST controversial in previous Congresses. Following an independent review in 2010, NASA developed a revised plan for the JWST program in 2011. In 2012, Congress capped the formulation and development cost of JWST at $8 billion and mandated annual reports on the program by the Government Accountability Office.[144] In its third such report in December 2014, GAO found that work on JWST was on schedule and on budget, but that technical challenges had diminished the project's schedule reserve and increased risk. The report recommended that NASA update its cost risk analysis regularly.[145] Continued congressional oversight of the JWST program is likely.

FY2015 Budget and Appropriations

NASA's Science appropriations account includes funding for each of the four Science Mission Directorate research divisions. Funding for the James Webb Space Telescope is budgeted separately from funding for the rest of the Astrophysics Division. For FY2015, Congress also provided separate funding for the Science Mission Directorate's education and public outreach activities (see also "Education" below). See **Table 3**.

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[141] National Aeronautics and Space Administration, "Russia Meteor Not Linked to Asteroid Flyby," updated March 21, 2013, http://www.nasa.gov/mission_pages/asteroids/news/asteroid20130215.html.

[142] J. E. Lyne and Michael Tauber, "Origin of the Tunguska Event," *Nature*, vol. 375, pp. 638-639, June 22, 1995.

[143] Personal communication between NASA and CRS, June 6, 2013.

[144] Consolidated and Further Continuing Appropriations Act, 2012 (P.L. 112-55) and H.Rept. 112-284.

[145] Government Accountability Office, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining*, GAO-15-100, December 2014. The previous annual reports were Government Accountability Office, *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration*, GAO-13-4, December 2012, and Government Accountability Office, *James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress*, GAO-14-72, January 2014.

Table 3. NASA Science Funding, FY2013-FY2015

(budget authority in millions of dollars)

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Science	**$4,781.6**	**$5,151.2**	**$5,244.7**
Earth Science	1,659.2	1,826.0	1,772.5
Planetary Science	1,271.5	1,345.0	1,437.8
Astrophysics	617.0	668.0	684.8
James Webb Space Telescope	627.6	658.2	645.4
Heliophysics	606.3	654.0	662.2
Education	0.0	0.0	42.0

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

In Planetary Science, the President's FY2015 budget request included $15 million for continued study of a potential future mission to Jupiter's moon Europa. Congress provided $69.7 million in FY2013 and $80 million in FY2014 for formulation of a Europa mission, which was a high priority of the 2011 NRC decadal survey of planetary science.[146] The NRC expressed reservations, however, at the mission's estimated a cost of $4.7 billion. In April 2014, NASA issued a request for information seeking Europa mission concepts costing less than $1 billion.[147] The FY2015 report of the House Appropriations Committee (H.Rept. 113-448) concluded that "the Committee has not seen any credible evidence" that a $1 billion cost is feasible and directed NASA "not to use further project resources in pursuit of such an unlikely outcome." Congress ultimately appropriated $100 million in FY2015 for planning a Europa mission in line with the planetary science decadal survey. It also directed NASA to evaluate use of the Space Launch System as the launch vehicle for such a mission.[148]

In Astrophysics, the President's FY2015 request included $12.3 million for the Stratospheric Observatory for Infrared Astronomy (SOFIA) and stated that NASA would place the SOFIA aircraft in storage unless international partners could support the U.S. share of its operating costs. SOFIA reached full operating capability in February 2014, and previous budgets envisioned 20 years of operations at a cost of about $85 million per year. According to NASA, however, "because SOFIA development has taken much longer than originally envisioned ... the observatory will no longer provide the kind of scientific impact and synergies with other missions as once planned." Congress ultimately appropriated $70 million for SOFIA in FY2015 to maintain core operations. It directed NASA to "continue to seek partners to restore SOFIA to its full operational level" and stated that "any science mission terminations should be made only after a senior review that evaluates the relative scientific benefit and return on investment."[149]

[146] National Research Council, *Vision and Voyages for Planetary Science in the Decade 2013-2022* (National Academies Press, 2011). Available online at http://www.nap.edu/catalog.php?record_id=13117.

[147] National Aeronautics and Space Administration, "Europa Mission Concepts Costing Less than $1 Billion," solicitation NNH14ZDA008L, April 28, 2014. Available at https://nspires.nasaprs.com/external/solicitations/.

[148] *Congressional Record*, December 11, 2014, Book II, p. H9349.

[149] Ibid.

Space Technology

In 2009, both the Augustine committee and the NRC recommended a greater emphasis on technology development as a complement to NASA's human spaceflight activities. The Augustine committee described NASA's space technology program as "an important effort that has significantly atrophied over the years."[150] It recommended that technology development be closely coordinated with ongoing programs, but conducted independently of them. The NRC recommended that NASA revitalize its advanced technology development program by establishing an independent, DARPA-like organization that would support research serving both NASA and the private sector.[151] The NASA Authorization Act of 2010 gave formal approval to the establishment of a new space technology program.[152] Initially, the program was conducted through the Office of the Chief Technologist. In February 2013, NASA established it as a separate Space Technology Mission Directorate (STMD).

Strategic Planning

In 2010, NASA identified 14 space technology areas and prepared draft roadmaps identifying "the top technical challenges [in each area], the spaceflight missions they could impact or enable, and—as a byproduct—the important terrestrial fields they could advance."[153] The NRC evaluated and prioritized the results of this effort.[154] The technology priorities identified by the NRC have been incorporated into revised roadmaps and are the basis of the current STMD research and development portfolio.[155]

When establishing the space technology program, the 2010 authorization act directed NASA to prepare an implementation plan.[156] The resulting plan stated that NASA would use the space technology roadmaps and three thematic grand challenges—expanding human presence in space, managing in-space resources, and enabling transformational space exploration and scientific discovery—to guide and prioritize the space technology portfolio and its future investments.[157] The plan also identified three categories of technology to be developed: early-stage innovation, game-changing technology, and crosscutting capability demonstrations.

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[150] Review of U.S. Human Spaceflight Plans Committee, *Seeking a Human Spaceflight Program Worthy of a Great Nation*, p. 112.

[151] 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. 61-62. DARPA is the Defense Advanced Research Projects Agency, http://www.darpa.mil/, a frequent model for technology development agencies within other departments.

[152] P.L. 111-267, Section 904.

[153] National Aeronautics and Space Administration, "Space Technology Roadmaps: The Future Brought To You By NASA," http://www.nasa.gov/offices/oct/home/roadmaps/.

[154] National Research Council, *NASA Space Technology Roadmaps and Priorities: Restoring NASA's Technological Edge and Paving the Way for a New Era in Space*, 2012.

[155] NASA congressional budget justification for FY2015, p. TECH-3.

[156] P.L. 111-267, Section 905.

[157] National Aeronautics and Space Administration, *Implementation Plan for NASA's Space Technology Program*, February 10, 2011.

An expanded strategic plan for space technology, released in December 2012, identified four strategic goals:[158]

- extend and sustain human presence and activities in space;
- explore the structure, origin, and evolution of the solar system, and search for life past and present through in-situ measurements;
- expand understanding of the Earth and the universe through remote measurements; and
- energize the domestic space enterprise and extend the benefits of space for the nation.

To achieve these goals, the strategic plan identified three categories of technology investments. It concluded that c*ore* investments—in near-term technologies needed for mission-specific objectives—should make up 70% of the STMD portfolio. *Adjacent* investments—in high-priority but longer-term technologies that are not strategically indispensable—should be 20% of the portfolio. *Complementary* investments—in a broad range of technologies with long-term potential—should be 10% of the portfolio. It identified eight areas for core technology investments: launch and in-space propulsion; high data-rate communications; lightweight space structures and materials; robotics and autonomous systems; environmental control and life-support systems; space radiation mitigation; scientific instruments and sensors; and entry, descent, and landing.

The 2010 NASA authorization act also directed the Administration to develop a national policy to guide space technology development programs across the federal government through 2020.[159] In a January 2013 report, NASA provided a non-exhaustive list of interagency collaboration groups related to space technology and stated that

> NASA engages with Federal agencies to encourage and promote the development of technologies of mutual benefit, and works together with these partners to identify and avoid any unnecessary duplication of effort and resources. ... This collaboration also takes place with the sharing of scientific data and instrument development.[160]

FY2015 Budget and Appropriations

The President's FY2015 request for Space Technology was $706 million, an increase of 22.5%. Congress ultimately provided a more modest increase, as shown in **Table 4**. This pattern—a large requested increase, scaled back by Congress—has been typical for the Space Technology program since it was first proposed in the FY2011 budget.

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[158] National Aeronautics and Space Administration, *NASA Strategic Space Technology Investment Plan*, December 2012, http://www.nasa.gov/pdf/726166main_SSTIP_02_06_13_FINAL_hires=TAGGED.pdf.

[159] P.L. 111-267, Section 906.

[160] National Aeronautics and Space Administration, *NASA Space Technology: Building the Path to the Future*, January 29, 2013. According to NASA, this report and the *NASA Strategic Space Technology Investment Plan* (footnote 158) address the requirements of P.L. 111-267, Section 906 (NASA Office of Legislative and Intergovernmental Affairs, email to CRS, July 1, 2013).

Table 4. NASA Space Technology Funding, FY2013-FY2015

(budget authority in millions of dollars)

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Space Technology	$614.5	$576.0	$596.0

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

Aeronautics

In addition to its space activities, NASA conducts 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 U.S. 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. Opponents counter that the aviation industry itself should pay for its research and development needs. Against the background of this debate, NASA aeronautics programs have focused increasingly on long-term fundamental research and on research and development topics with clear public purposes, such as reducing noise and emissions, improving safety, and improving air traffic control.

Strategic Vision

In August 2013, NASA announced a new strategic vision for its aeronautics research.[161] The new vision identified three major drivers of changes in aviation over the next 20-40 years: global growth in the demand for air mobility; global climate issues, sustainability, and a transition to low-carbon fuels and alternative propulsion systems; and convergence with technologies driving other industries, such as smart materials, additive manufacturing, and embedded sensors. On this basis, the vision identified six research thrust areas: safe, efficient growth in global operations; innovation in commercial supersonic aircraft; ultra-efficient commercial vehicles; a transition to low-carbon propulsion; real-time, system-wide safety assurance; and assured autonomy for aviation transformation.

NASA plans to reorganize its aeronautics research program during FY2015 to align with the new strategic vision. Following this realignment, most existing projects are expected to continue, but research not directly related to the six thrust areas is to be phased out over the next several years.[162]

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[161] See National Aeronautics and Space Administration, "NASA Introduces New Blueprint for Transforming Global Aviation," August 14, 2013, http://www.nasa.gov/aero/strategic_vision/.

[162] NASA Office of Legislative and Intergovernmental Affairs, email to CRS, March 26, 2014.

FY2015 Budget and Appropriations

Table 5 summarizes funding for NASA aeronautics research in FY2013 through FY2015.

Table 5. NASA Aeronautics Funding, FY2013-FY2015

(budget authority in millions of dollars)

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Aeronautics	$529.5	$566.0	$651.0

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

In their reports for FY2015, the House and Senate Committees on Appropriations both supported the planned reorganization of NASA's aeronautics research program.

Education

In addition to NASA's Office of Education, the mission directorates historically conducted substantial education activities. Notably, the Science Mission Directorate had a policy for many years that each spacecraft mission should "allocate at least 1% of the mission budget for education and public outreach activities."[163] In some years, funding for education activities in the mission directorates was comparable to the funding of the Office of Education.

Reorganization Proposals

In the FY2014 budget, the Administration proposed a government-wide reorganization of activities in science, technology, engineering, and mathematics (STEM) education. As part of this proposal, numerous NASA education activities were to be terminated, including all those conducted by the Science Mission Directorate. While multiple federal agencies were to be affected by the reorganization plan, nearly half of the activities proposed for termination (37 out of 78) were at NASA.[164] A reduced level of NASA funding for STEM education was to be consolidated in the Office of Education, and more funding was to be directed to STEM education activities at the National Science Foundation, the Department of Education, and the Smithsonian Institution. NASA planned to "make its rich content knowledge and other assets available" to these other agencies, and in addition, "the best NASA education and public engagement programs from throughout the agency" were to receive funding from the NASA Office of Education "through an internal competitive process."[165]

[163] http://science.nasa.gov/researchers/education-public-outreach/strategy/.

[164] CRS analysis of Office of Science and Technology Policy, "78 Consolidated STEM Programs (Funding Redirected Outside of the Agency)," May 14, 2013.

[165] Leland D. Melvin, Associate Administrator for Education, National Aeronautics and Space Administration, and Co-Chair of the Federal Coordination in STEM Education Task Force, testimony before the House Committee on Science, Space, and Technology, June 4, 2013.

Congressional reaction to the proposed government-wide reorganization was mixed, and its impact on NASA was of particular concern.[166] The explanatory statement for the Consolidated Appropriations Act, 2014 (P.L. 113-76) stated in general that "the agreement does not adopt the reorganization; all STEM activities are funded in their existing programmatic structures unless explicitly noted otherwise."[167] Regarding NASA specifically, the statement directed that "consistent with longstanding NASA practice, the agreement maintains [education and public outreach] funding within the Science Mission Directorate," but it allowed NASA to "reorganize and consolidate" activities in the Office of Education.[168]

In the FY2015 budget, the Administration proposed what it described as a "fresh" reorganization of the federal STEM education portfolio. Unlike the FY2014 proposal, which sought to transfer funding between agencies, the FY2015 proposal focused on consolidating funding within agencies. The previous Science Mission Directorate policy, under which 1% of Science mission funding was allocated to education and public outreach, was terminated, although some education activities continued to be funded through Science.

For more information on the Administration's STEM education reorganization proposals, see CRS Report IN10011, *The Administration's Proposed STEM Education Reorganization: Where Are We Now?*

FY2015 Budget and Appropriations

Funding for the Office of Education is provided by NASA's Education account (see **Table 6**). Among the programs supported by this account are the National Space Grant College and Fellowship Program, the Experimental Program to Stimulate Competitive Research (EPSCoR), and the Minority University Research Education Program (MUREP), all of which typically receive close congressional attention.

In addition to the Education account, Congress created a new budget line item for Education in the Science appropriation for FY2015. See "FY2015 Budget and Appropriations" above under "Science."

Table 6. NASA Education Funding, FY2013-FY2015

(budget authority in millions of dollars)

	FY2013 Actual	FY2014 Enacted	FY2015 Enacted
Education	**$116.3**	**$116.6**	**$119.0**
Space Grant	37.2	40.0	40.0
EPSCoR	16.7	18.0	18.0
MUREP	27.9	30.0	32.0
Other	34.4	28.6	29.0

[166] See, for example, Member remarks at "STEM Education: The Administration's Proposed Reorganization," hearing of the House Committee on Science, Space, and Technology, June 4, 2013.

[167] *Congressional Record*, January 15, 2014, Book II, p. H515.

[168] Ibid., pp. H516-H517.

Sources: FY2013 from NASA's FY2015 congressional budget justification, representing the agency's August 2013 operating plan. FY2014 from P.L. 113-76 and explanatory statement, *Congressional Record*, January 15, 2014, Book II, at pp. H515-H517. FY2015 from P.L. 113-235 and explanatory statement, *Congressional Record*, December 11, 2014, Book II, at pp. H9348-H9349.

Conclusion

Although the 2010 authorization act set a new direction for NASA, especially in the area of human spaceflight, some advocates of other approaches remain unsatisfied, and many issues remain. Among these:

- Can commercial services transport U.S. astronauts into Earth orbit, including to the International Space Station, cost-effectively and safely? Will these services be available by 2017, as planned? Is the demand for such services sufficient to support more than one competing provider? Are current NASA requirements and FAA regulations sufficient to ensure the safety of commercial spacecraft that carry crews?
- For human spaceflight beyond Earth orbit, will the Orion and SLS spacecraft now in development be ready on schedule, and how should they be used when operational? Are their budgets sufficient to meet their schedules, and could budget increases accelerate their development? What lift capability should the SLS have? Are Orion and the SLS a realistic backup option for crew access to the International Space Station, if commercial services do not materialize? What destinations should be explored using these spacecraft, once they are operational? Is the proposed Asteroid Redirect Mission a good choice of destination for the first crewed flight?
- How will the needs of the human spaceflight program affect resources for NASA's science missions, aeronautics research, and education programs? In a time of declining budgets and fiscal uncertainty, how should NASA and Congress balance these competing priorities?
- What is the appropriate level of NASA support for Earth science, planetary science, and other scientific fields? Should the share of Earth science in NASA's overall science portfolio continue to expand? How would proposed reductions in funding for planetary science, including near-term reductions in funding for robotic Mars exploration, affect the field in the longer term? How should NASA and Congress respond to concerns about the threat of collisions with near-Earth objects such as asteroids?
- In general, is NASA being asked to do more than it can afford? Is the NASA Inspector General correct that "too many programs are chasing too few dollars"? If so, then which programs should be scaled back, and how should those decisions be made?

As the 114th Congress conducts oversight of NASA and considers authorization and appropriations legislation, it will likely seek to address many of these concerns.

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