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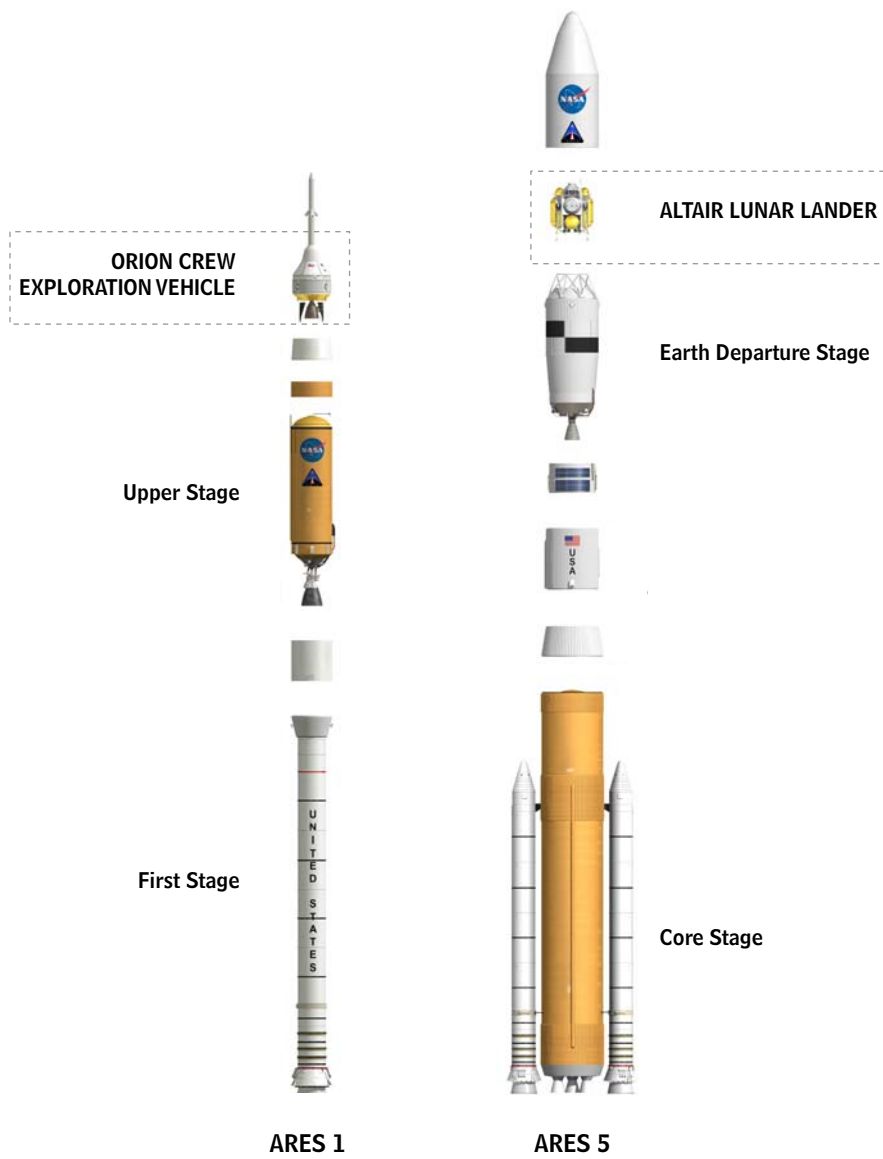
REPORT

The Budgetary Implications of NASA's Current Plans for Space Exploration

April 2009



CONGRESSIONAL BUDGET OFFICE
SECOND AND D STREETS, S.W.
WASHINGTON, D.C. 20515



Source: National Aeronautics and Space Administration (February 2008).



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Notes

Numbers in the text and tables may not add up to totals because of rounding.

Unless otherwise noted, dollar amounts in this report are 2009 dollars of budget authority.

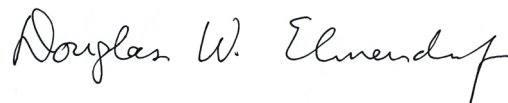


Preface

In response to a directive in the National Aeronautics and Space Administration Authorization Act of 2008, the Congressional Budget Office (CBO) has updated its 2004 report analyzing the budgetary implications of the National Aeronautics and Space Administration's (NASA's) vision for the nation's space exploration program. On the basis of NASA's current estimates of costs, this report considers the effects that cost growth could have on the Constellation program, which will produce the agency's new generation of spacecraft designed for human spaceflight, and updates comparisons of the costs for that program with those for the Apollo program and past proposals for human exploration of the moon.

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Douglas W. Elmendorf
Director

April 2009

Contents

Summary 1

NASA's Current Plans 3

Expected Cost Growth in NASA's Programs and Alternative Scenarios 6

Comparison of the Constellation and Apollo Programs 14

Appendix: Details of NASA's Plans, by Directorate and Function 19

Tables

1.	Budgets and Schedules for NASA's Plans and Alternative Scenarios	2
2.	Projected Average Annual Funding for NASA's Plans	5
3.	Projected Average Annual Funding for NASA Under Alternative Scenarios	15
A-1.	Projected Average Annual Funding for the Exploration Systems and the Space Operations Mission Directorates	22
A-2.	Projected Average Annual Funding for the Science and the Aeronautics Research Mission Directorates	25
A-3.	Projected Average Annual Funding for NASA's Cross-Agency Support	26

Figures

1.	Projected Funding for NASA's Plans	4
2.	Projected Schedules for NASA's Plans	6
3.	Effects on NASA's Plans Under Scenario 1: Keep Funding Fixed and Allow Schedules to Slip	8

Figures (Continued)

4.	Projected Funding Under Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station	10
5.	Effects of Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station	11
6.	Effects of Scenario 3: Achieve the Constellation Program's Schedule and Allow the Science Schedule to Slip	12
7.	Projected Funding Under Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics	13
8.	Effects of Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics	14
9.	Comparison of the Constellation, Apollo, and Other Programs	16
A-1.	Planned Budgets for the Exploration Systems and the Space Operations Mission Directorates	21
A-2.	Planned Budgets for the Science and the Aeronautics Research Mission Directorates	24
A-3.	Planned Budgets for Cross-Agency Support	27

Box

1.	Growth in the Costs of NASA's Past Programs	7
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The Budgetary Implications of NASA's Current Plans for Space Exploration

Summary

In 2004, President Bush announced his “Vision for U.S. Space Exploration,” which called for the National Aeronautics and Space Administration (NASA) to develop new vehicles for spaceflight that would allow humans to return to the moon by 2020. In response, NASA restructured its plans to achieve that objective, and in September 2004, the Congressional Budget Office (CBO) published a budgetary analysis of NASA’s new plans.¹ This report updates that analysis, incorporating elements of NASA’s plans that had not been established in 2004.

To meet the goal set by the President, NASA reduced its planned budgets supporting science and research in aeronautics by more than 40 percent and made plans to complete construction of the International Space Station and retire the space shuttle by 2010. Using about \$100 billion of potential funding through 2020 made available by those changes, NASA began developing new vehicles for human spaceflight in what the agency calls its Constellation program. Two of those vehicles—the Ares 1 crew launch vehicle and the Orion crew exploration vehicle—are to achieve “initial operating capability” by March 2015. At that point, the vehicles should be capable of carrying a crew of astronauts to the International Space Station. NASA is also developing additional vehicles and systems—including the Ares 5 cargo launch vehicle and the Altair lunar lander—that are needed to return humans to the moon.²

According to NASA, its current plans will require an average of \$19.1 billion of funding annually from 2010 through 2025, with the Constellation program accounting for about half of the total by 2017. Under its current plans, the agency also intends to conduct 79 new robotic science missions through 2025, requiring funding of \$4.7 billion annually, and to perform aeronautics research, at a cost of about \$460 million annually.

1. See Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration* (September 2004).

2. See Congressional Budget Office, *Alternatives for Future U.S. Space-Launch Capabilities* (October 2006).

Table 1.**Budgets and Schedules for NASA's Plans and Alternative Scenarios**

	Average Annual Funding, 2010 to 2025 (Billions of 2009 dollars)	Ares 1's and Orion's IOC	Humans' Return to the Moon	No. of Science Missions Through 2025	Space Shuttle's Retirement	End of Support for ISS
NASA's Plans	19.1	March 2015	2020	79	September 2010	December 2015
Scenario 1: Keep Funding Fixed and Allow Schedules to Slip	19.1	Late 2016	2023	64	September 2010	December 2015
Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station	23.8	March 2015	2020	79	March 2015	December 2020
Scenario 3: Achieve the Constellation Program's Schedule and Allow the Science Schedule to Slip	21.1	March 2015	2020	64	September 2010	December 2015
Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics	19.1	March 2015	2020	44	September 2010	December 2015

Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Notes: IOC = initial operating capability; ISS = International Space Station.

All scenarios incorporate cost growth for the affected programs that averages 50 percent, which is the amount that occurred for 72 of NASA's past programs.

CBO's analysis considers four alternatives to NASA's current plans, accounting for the possibility of cost growth like what has happened in the past:

- If NASA's funding was maintained at \$19.1 billion annually and the agency realized cost growth in its programs consistent with the average for 72 of its past programs, its planned schedules for spaceflight programs would be delayed. In particular, the initial operating capability for Ares 1 and Orion would be pushed to late 2016, the return of humans to the moon would slip to 2023, and 15 of 79 science missions would be delayed beyond 2025. The space shuttle would be retired in 2010 and support for the International Space Station would end after 2015.
- If NASA's funding was increased to about \$23.8 billion annually, the agency would be able to meet its planned schedules notwithstanding cost growth consistent with the average for its past programs. Furthermore, that increase in its budgets would allow NASA to extend the operation of the space shuttle to 2015 and to support the operation of the International Space Station to 2020.
- Between those two alternatives, if NASA's funding was increased to about \$21.1 billion annually, the agency would be able to meet its planned schedules for the Constellation program even if cost growth was consistent with the average for past programs. But that amount of funding would not permit NASA to fly the space shuttle beyond 2010 or to support the space station beyond 2015. Moreover, under this budgetary scenario, 15 of the planned science missions would be delayed past 2025.
- Finally, if NASA's funding was maintained at \$19.1 billion annually and the agency reduced funding for science and research in aeronautics to cover cost growth in the Constellation program, it could conduct 44 science missions (35 fewer than planned) by 2025, and the cut to aeronautics research would be more than one-third.

Table 1 encapsulates NASA's plans and summarizes those scenarios.

NASA's Current Plans

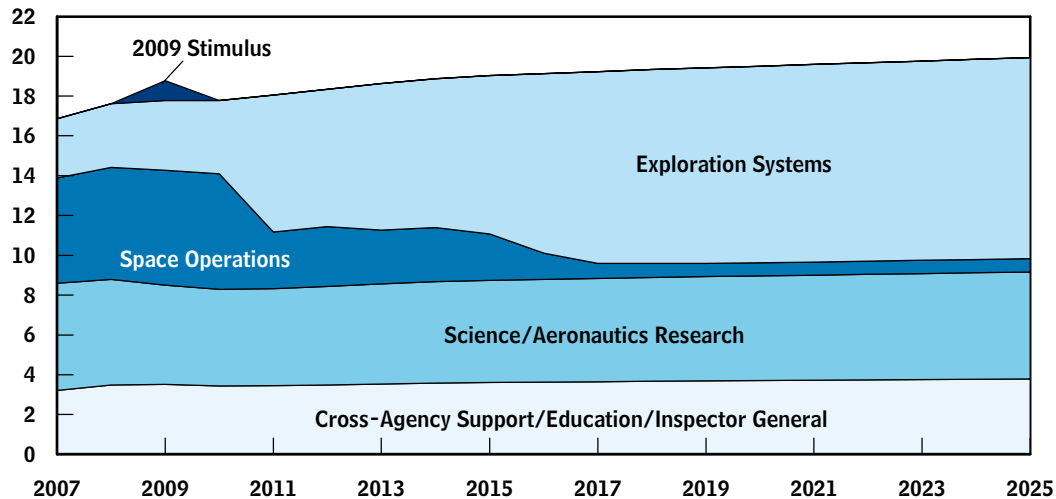
According to NASA, its plans for conducting human and robotic spaceflight and supporting science and research in aeronautics from 2010 to 2025 will require funding averaging \$19.1 billion annually.³ About 80 percent of the funding for NASA's activities is distributed across the agency's four mission directorates: Exploration Systems, Space Operations, Science, and Aeronautics Research. The remaining 20 percent is in

3. Information on NASA's plans for 2009 to 2013 comes from *Budget of the United States Government, Fiscal Year 2009* and for the period beyond 2013, from data provided by the agency. NASA assumes an inflation rate of 2.4 percent each year beyond 2013, compared with CBO's assumption of 1.9 percent. At that lower rate, NASA would realize a slight increase in its budget in real (inflation-adjusted) terms.

Figure 1.

Projected Funding for NASA's Plans

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: NASA received stimulus funding in February 2009 under the American Recovery and Reinvestment Act.

accounts funding cross-agency support, education, and its inspector general (see Figure 1 and Table 2).

NASA plans to more than double the annual budget for the Exploration Systems mission directorate between 2010 and 2025, from \$3.7 billion to over \$10 billion. More than 90 percent of the directorate's budget will be devoted to the Constellation program—to develop and then operate new human exploration vehicles, including the Ares 1 crew launch vehicle, Orion crew exploration vehicle, Ares 5 cargo launch vehicle, and Altair lunar lander.⁴ NASA's current plans provide for the initial operating capability of Ares 1 and Orion by March 2015, at which point those vehicles will be able to conduct missions to the International Space Station. The agency also plans to complete development of the Ares 5 cargo launch vehicle and Altair lunar lander in time to return humans to the moon in 2020.

In conjunction with increases in funding for the Constellation program, NASA plans substantial decreases in the annual budgets for the Space Operations mission directorate. Between 2010 and 2025, the agency plans to decrease annual funding for the directorate from \$5.8 billion to \$0.7 billion. Through that directorate, NASA pays for

4. At some point, NASA plans to shift funding for operation of the Constellation program's vehicles to the Space Operations mission directorate, but the agency has not yet stated when that change will occur.

Table 2.**Projected Average Annual Funding for NASA's Plans**

(Billions of 2009 dollars)

Directorate or Function	2010- 2013	2014- 2017	2018- 2021	2022- 2025	2010- 2025
Exploration Systems	6.2	8.5	9.8	10.0	8.7
Space Operations	3.6	1.8	0.7	0.7	1.7
Science	4.5	4.7	4.8	4.9	4.7
Aeronautics Research	0.4	0.5	0.5	0.5	0.5
Cross-Agency Support, Education, and IG	3.5	3.6	3.7	3.8	3.6
Total	18.2	19.1	19.5	19.8	19.1

Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Notes: IG = inspector general.

the operation of the space shuttle and the International Space Station along with associated support activities. According to the agency's plans, the space shuttle will be retired in September 2010, once construction of the space station is complete, freeing up funds that will be shifted to the Constellation program.⁵ In addition, according to plans, funding for the space station's operations will cease after December 2015, freeing up additional funds to shift to the Constellation program.⁶

For the Science directorate and the Aeronautics Research directorate, NASA intends essentially constant annual budgets from 2010 to 2025, at \$4.7 billion and \$460 million, respectively. The Science directorate develops hardware for and carries out robotic missions in four primary areas: earth science, planetary science, astrophysics, and heliophysics. Through 2025, NASA intends to conduct 79 such missions investigating the Earth, the solar system, the universe, and the sun, along with performing other science-related research activities in areas such as weather and climate change. The Aeronautics Research directorate performs its work in four categories: aviation safety, airspace systems, fundamental aeronautics, and aeronautics testing. (Figure 2 summarizes NASA's plans.)⁷

5. NASA could decide to forgo any planned missions for the space shuttle that are not completed by September 30, 2010, in order to avoid using funds intended for the Constellation program and causing delays for it. See Congressional Budget Office, "An Analysis of NASA's Plans for Continuing Human Spaceflight After Retiring the Space Shuttle," letter to the Honorable Dave Weldon, M.D. (November 3, 2008).

6. NASA's current plans do not preclude operation of the space station in 2016 and beyond should additional funding be made available.

7. The current version of NASA's plans can be found at www.nasa.gov/offices/pae/references/index.html.

Figure 2.

Projected Schedules for NASA's Plans

Directorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Exploration Systems								▼					▼					
							Ares 1's and Orion's IOC					Humans' Return to the Moon						
Space Operations			▼					▼										
		Space Shuttle's Retirement					End of Support for ISS											
Science Number of Planned Missions	12	7	3	5	5	7	6	5	6	3	6	3	6	2	5	4	3	3

Source: Congressional Budget Office based on data provided by the National Aeronautics and Space Administration (NASA).

Note: IOC = initial operating capability; ISS = International Space Station.

NASA also intends essentially constant annual budgets from 2010 to 2025 for cross-agency support activities (\$3.5 billion), education (\$120 million), and its inspector general (\$39 million). The accounts for cross-agency support provide funding for the agency's management and operations and its nine field research and spaceflight centers throughout the United States, as well as maintenance of NASA's infrastructure.

In February 2009, NASA received an additional \$1 billion in funding under the American Recovery and Reinvestment Act. The legislation directed the agency to use the funding for exploration (\$400 million), science (\$400 million), aeronautics research (\$150 million), and cross-agency support (\$50 million).⁸

Expected Cost Growth in NASA's Programs and Alternative Scenarios

On the basis of the cost growth that has occurred in the past, CBO's analysis indicates that the costs of NASA's development programs could grow by 50 percent, on average. That analysis examined the performance of 72 of the agency's past programs—65 percent of which experienced less than 50 percent cost growth and 35 percent of which experienced more (see Box 1).⁹ NASA's budgetary plans include reserves in the agency's development programs that would allow cost growth of about 25 percent to be accommodated.¹⁰ Because of the likelihood that NASA will not meet its planned schedules if funded at its current level, CBO considered four alternative scenarios. Under those scenarios, CBO estimated what would happen to the schedules given the

8. The appendix to this report provides more details of NASA's plans, by directorate and function.

9. See Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration*.

10. NASA's current planning process requires sufficient funding so that programs can be conducted with a 65 percent level of confidence, and agency officials suggest that that approach should prevent cost growth like what has occurred in past programs.

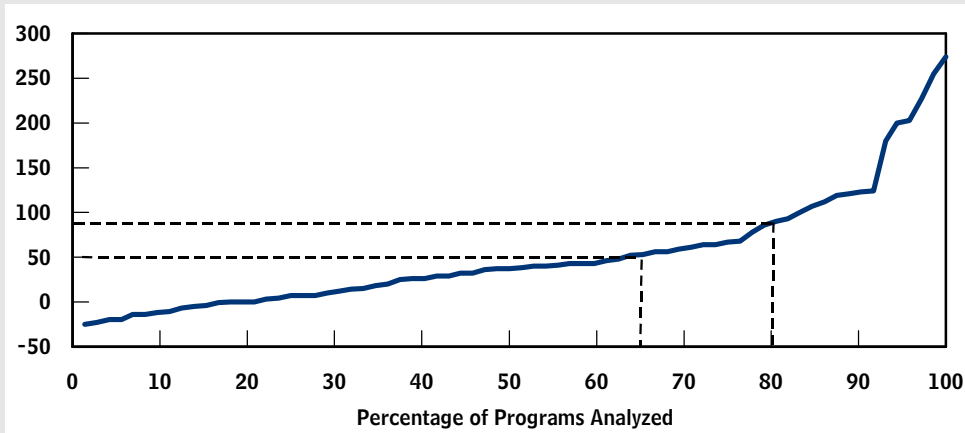
Box 1.

Growth in the Costs of NASA's Past Programs

The Congressional Budget Office (CBO) based its projections of cost growth for the National Aeronautics and Space Administration's (NASA's) development programs on an analysis of the agency's past programs. In the 2004 study that this paper updates, CBO analyzed 72 of NASA's programs.¹ Using the earliest available estimate generated by NASA for a program's cost and the program's final actual cost, CBO computed the percentage cost growth (adjusted for inflation) that each program realized. The range for the 72 programs spanned a low of a 25 percent cost reduction to a high of more than 250 percent cost growth (see the figure). The average cost growth for the 72 programs all together was about 50 percent—with 65 percent of them below that amount and 35 percent above—and 20 percent of the projects experienced cost growth of 90 percent or more.

Cost Growth for 72 of NASA's Programs

(Percentage of cost growth)



Source: Congressional Budget Office.

1. See Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration* (September 2004).

current funding and what amounts of additional funding would be required to accomplish all of the plans on schedule and to accomplish some of them.

Scenario 1: Keep Funding Fixed and Allow Schedules to Slip

If funding remained fixed, cost growth in NASA's spaceflight programs would cause planned schedules to be delayed. Cost growth averaging 50 percent would be about twice the planned reserves, and delays would occur if the agency did not seek and

Figure 3.

Effects on NASA’s Plans Under Scenario 1: Keep Funding Fixed and Allow Schedules to Slip

Directorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Exploration Systems								▲	▲				▲			▲		
								Ares 1's and Orion's IOC					Humans' Return to the Moon					
Space Operations		▼	▼					▼	▼									
		Space Shuttle's Retirement						End of Support for ISS										
Science																		
Number of Planned Missions	12	7	3	5	5	7	6	5	6	3	6	3	6	2	5	4	3	3
Number of Missions Under Scenario 1	12	5	3	4	4	4	5	5	4	3	5	3	4	2	4	4	3	2
Cumulative Reduction		-2	-2	-3	-4	-7	-8	-8	-10	-10	-11	-11	-13	-13	-14	-14	-14	-15

Source: Congressional Budget Office based on data provided by the National Aeronautics and Space Administration (NASA).

Notes: IOC = initial operating capability; ISS = International Space Station.

The scenario incorporates cost growth that averages 50 percent, which is the amount that occurred for 72 of NASA’s past programs.

receive additional funding from the Congress. By CBO’s projections, with such cost growth and fixed annual budgets for the Constellation program, the initial operating capability for Ares 1 and Orion would be delayed from March 2015 to late 2016, and the first mission to return humans to the moon would be delayed from 2020 to 2023 (see Figure 3). CBO derived those estimates by factoring in historical cost growth and then gauging when annual budgets would provide sufficient funding. If the programs experienced greater cost growth, their milestones would be delayed even more. Some of NASA’s ongoing programs, such as the Mars Science Laboratory, have already experienced cost growth greater than 50 percent.¹¹

If funding remained fixed and historical cost growth occurred for NASA’s science missions, 15 fewer such missions could occur through 2025 than what NASA has planned. CBO derived that estimate by applying 50 percent cost growth to the

11. Although the Mars Science Laboratory was initially classified as a “medium” mission (that is, with a range of costs from \$300 million to \$750 million) costing more than \$650 million, NASA’s first formal baseline estimate for the project, provided in August 2006 as part of the preliminary design process, was \$1.63 billion. The project is now estimated to cost more than \$2 billion, and its launch has been delayed from 2009 to 2011, requiring an additional \$200 million of funding annually in 2010 and 2011. Formal baseline estimates for the Constellation program’s Ares 1 and Orion have not yet been completed.

72 percent of the Science mission directorate's budget that is used to develop hardware for science missions.¹²

CBO did not project cost growth in the Space Operations and Aeronautics Research directorates because the development of new spacecraft and other hardware is not a major part of the activities funded through those directorates. Finally, for this scenario, CBO assumed that NASA would forgo any missions on the space shuttle's launch manifest that did not occur by the September 30, 2010.

Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station

In analyzing NASA's plans, CBO estimated the additional funding that would be required under a scenario that addresses cost growth in development programs conducted within the agency's Exploration Systems and Science mission directorates and that funds changes to NASA's plans that various industry experts have discussed. The changes that CBO considered include extending the operation of the space shuttle to 2015 to eliminate the gap between its retirement and the availability of Ares 1 and Orion; extending support for the International Space Station by five years, allowing its continued use for experimentation, to December 2020; and fully funding investments in infrastructure, allowing NASA to perform the full amount of maintenance that the agency states is needed for its facilities. To cover all of the additional activities considered, NASA would require, by CBO's estimates, annual budgets averaging about \$23.8 billion, or about 25 percent more than under its current plans (see Figure 4).

In particular, cost growth for the spacecraft developed under the Constellation program within the Exploration Systems mission directorate would require additional funding of about \$1.0 billion in 2010 and amounts rising to about \$2.7 billion by 2020, CBO estimates. Those estimates assume that the development programs in the Constellation program would experience average cost growth of 50 percent and that it would be partially addressed by the 25 percent reserve funds that NASA says are included in planned budgets. Similarly, cost growth for spacecraft development programs conducted by the Science mission directorate would require additional funding of about \$700 million annually between 2010 and 2025, CBO projects.¹³

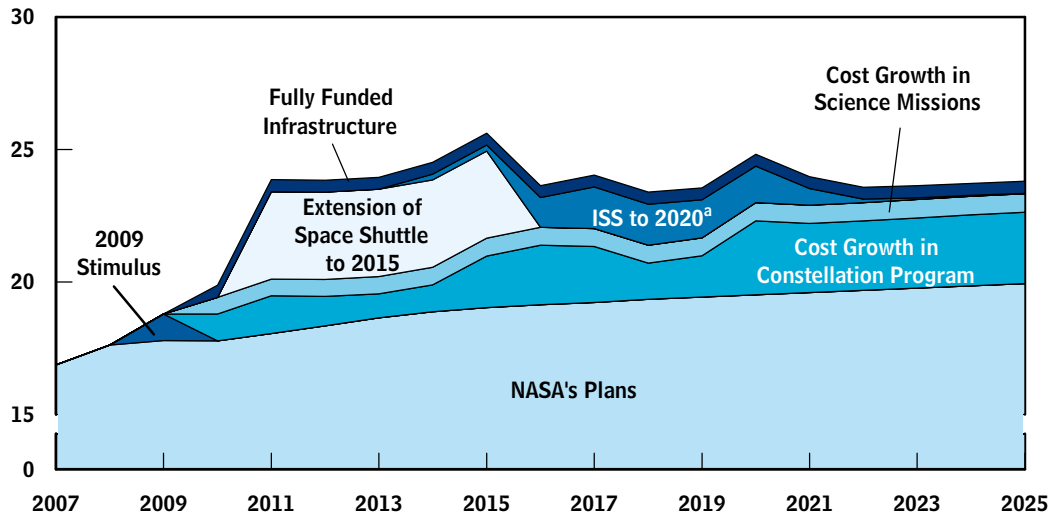
12. NASA officials indicate that an alternative to conducting fewer missions to accommodate cost growth would be to fly the same number of missions but reduce their capabilities and associated costs. Such reduced capabilities might be a smaller number of sensors or a stationary probe instead of a rover. Decisions to bring about such cost reductions would be most effective if made before a program was initiated instead of after costs had already been incurred to develop capabilities that would eventually be eliminated.

13. Although not considered in this scenario, the additional funding required from 2010 to 2025 (after reserves were exhausted) to accommodate 90 percent cost growth would be about \$4.6 billion annually for the Constellation program and \$1.8 billion annually for the spacecraft development programs conducted by the Science directorate, CBO projects. Among NASA's past missions that CBO analyzed, 80 percent had less than 90 percent cost growth, and 20 percent had more.

Figure 4.

Projected Funding Under Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: NASA received stimulus funding in February 2009 under the American Recovery and Reinvestment Act.

a. Under this scenario, NASA's support for the International Space Station (ISS) would extend until 2020.

CBO's projections for this scenario also include annual funding of about \$2.5 billion for activities not included in NASA's current plans. In particular, there has been discussion (in the press and by observers of the U.S. space program) of extending the space shuttle's operations to 2015 to eliminate the gap in the United States' ability to conduct human spaceflight between the shuttle's retirement and the initial operating capability of Ares 1 and Orion. CBO projects, on the basis of data provided by NASA, that the agency would require an additional \$3.3 billion annually from 2011 to 2015 to fly the space shuttle to the International Space Station three times each year. (Any missions currently on the space shuttle's launch manifest that were not conducted by September 30, 2010, probably would be the first of those missions.) Under this scenario, once the Ares 1 and Orion vehicles achieved their initial operating capability in 2015, the space shuttle would be retired without a gap in NASA's capability to conduct human spaceflight (see Figure 5).¹⁴

14. According to NASA officials, under this scenario conflicts for the workforce between activities for the space shuttle and for the Constellation program would need to be resolved, and the effect that the shuttle's continued operation could have for commercial cargo carriers would have to be mitigated.

Figure 5.

Effects of Scenario 2: Execute NASA’s Current Plans and Extend Operation of the Shuttle and Space Station

Directorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Exploration Systems								▲					▲					
								Ares 1’s and Orion’s IOC					Humans’ Return to the Moon					
Space Operations			▼					▼	▼				▼					
			Space Shuttle’s Retirement						End of Support for ISS									
Science Number of Planned Missions	12	7	3	5	5	7	6	5	6	3	6	3	6	2	5	4	3	3

Source: Congressional Budget Office based on data provided by the National Aeronautics and Space Administration (NASA).

Notes: IOC = initial operating capability; ISS = International Space Station.

The scenario incorporates cost growth that averages 50 percent, which is the amount that occurred for 72 of NASA’s past programs.

Continued operation of the space shuttle could affect the schedule on which the Constellation program could be executed even if additional funding was provided to NASA. In particular, continued use of both launchpads 39A and 39B at the Kennedy Space Center, at Cape Canaveral, Florida, could delay testing of the Ares 1 and Ares 5 launch vehicles because those launchpads need to be modified for that purpose. A test flight for Ares 1 has already been delayed because NASA has had to retain the use of both launchpads for the shuttle for a mission planned for May 2009 to service the Hubble space telescope; after that mission, modifications to launchpad 39B for use with Ares 1 can be completed.¹⁵ But modifications to launchpad 39A for use with Ares 5 can be completed only after the end of the shuttle’s operations. Therefore, extending those to 2015 using launchpad 39A could delay the development of Ares 5 and, in turn, the return of humans to the moon.

Some industry experts have also recommended that NASA continue to support the International Space Station until December 2020 instead of ending that support after December 2015.¹⁶ To accomplish that extension, NASA would require additional

15. The mission to service the Hubble requires launching the space shuttle into an orbit that precludes reaching the space station in the event of an emergency. Therefore, NASA will have another shuttle on standby for a rescue mission if necessary.

16. NASA currently plans to take no action that would preclude extending operations to allow continued use of the space station for experiments should additional funding be available.

Figure 6.

Effects of Scenario 3: Achieve the Constellation Program's Schedule and Allow the Science Schedule to Slip

Directorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Exploration Systems							Ares 1's and Orion's IOC	▼				Humans' Return to the Moon	▼					
Space Operations		Space Shuttle's Retirement	▼					End of Support for ISS	▼									
Science																		
Number of Planned Missions	12	7	3	5	5	7	6	5	6	3	6	3	6	2	5	4	3	3
Number of Missions Under Scenario 3	12	5	3	4	4	4	5	5	4	3	5	3	4	2	4	4	3	2
Cumulative Reduction		-2	-2	-3	-4	-7	-8	-8	-10	-10	-11	-11	-13	-13	-14	-14	-14	-15

Source: Congressional Budget Office based on data provided by the National Aeronautics and Space Administration (NASA).

Notes: IOC = initial operating capability; ISS = International Space Station.

The scenario incorporates cost growth that averages 50 percent, which is the amount that occurred for 72 of NASA's past programs.

funding averaging about \$1.4 billion annually from 2016 to 2020, according to CBO's projections based on data provided by the agency. Finally, part of the \$23.8 billion required each year under this scenario would be an additional \$450 million that, by CBO's projections, would be required to fully fund NASA's estimates of required maintenance of and upgrades to its facilities.

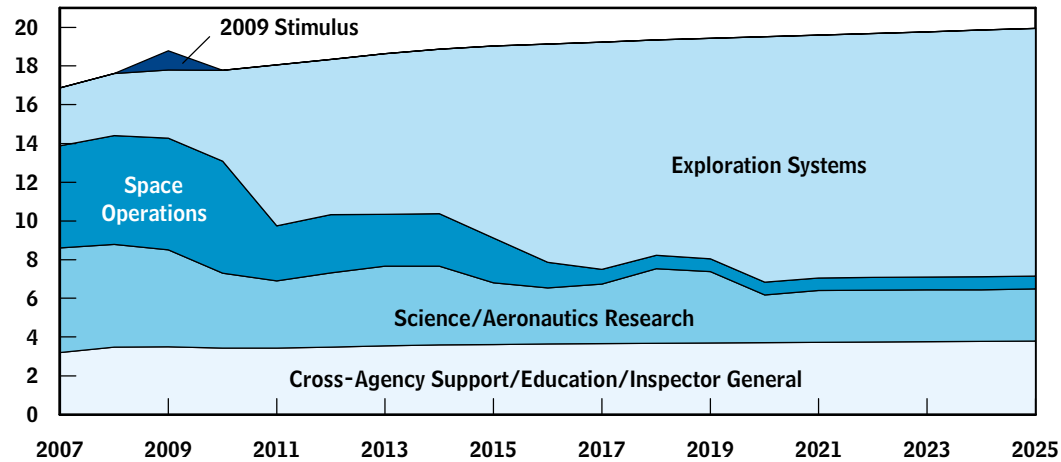
Scenario 3: Achieve the Constellation Program's Schedule and Allow the Science Schedule to Slip

CBO also estimated the additional funding that would be required under a scenario in which NASA seeks increased budgets to accommodate cost growth (at the historical average) for only the spacecraft development activities conducted within the Constellation program. In this scenario, CBO did not include funding for cost growth in the Science mission directorate, nor for the additional projects included in the previous scenario. According to CBO's projections, under this scenario NASA would require, on average, \$21.1 billion annually, or an increase of about 10 percent relative to the amount needed for its current plans (with NASA's 25 percent reserves taken into account). The additional funding needed to accommodate cost growth in the Constellation program would be about \$1 billion in 2010 and would grow to about \$2.7 billion in 2025.

Figure 7.

Projected Funding Under Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: NASA received stimulus funding in February 2009 under the American Recovery and Reinvestment Act.

Under this scenario, because no additional funds would be included to accommodate projected cost growth for the Science mission directorate, 15 fewer of its missions could be conducted by 2025 (if they faced cost growth at the historical average) (see Figure 6). Furthermore, additional funds to extend operation of the space shuttle and support of the space station would not be available under this scenario, and CBO assumed that NASA would forgo any of the shuttle's planned missions that did not occur by September 30, 2010.

Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics

As a final scenario, CBO considered the budgetary impact of NASA's choosing to accommodate cost growth in the Constellation program by reducing its budgets for the Science and Aeronautics Research mission directorates. In this scenario, NASA's total funding would remain at \$19.1 billion annually, but the agency would reduce the budgets for those two directorates by about \$1 billion in 2010 and by amounts growing to about \$2.7 billion in 2025 (see Figure 7).¹⁷ Reductions in funding for science would be about \$900 million in 2010 and would rise to about \$2.4 billion by

17. CBO assumed that the reductions would be split between the Science and Aeronautics Research directorates in proportion to their planned budgets (and therefore allocated at roughly 90 percent and 10 percent, respectively).

Figure 8.

Effects of Scenario 4: Absorb Cost Growth to Achieve Constellation’s Schedule by Reducing Funding for Science and Aeronautics

Directorate	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
Exploration Systems							Ares 1's and Orion's IOC					Humans' Return to the Moon							
Space Operations		Space Shuttle's Retirement					End of Support for ISS												
Science Number of Planned Missions	12	7	3	5	5	7	6	5	6	3	6	3	6	2	5	4	3	3	
Number of Missions Under Scenario 4	12	3	2	3	3	3	2	3	3	2	3	2	3	2	3	3	2	2	
Cumulative Reduction		-4	-5	-7	-9	-13	-17	-19	-22	-23	-26	-27	-30	-30	-32	-33	-34	-35	

Source: Congressional Budget Office based on data provided by the National Aeronautics and Space Administration (NASA).

Notes: IOC = initial operating capability; ISS = International Space Station.

The scenario incorporates cost growth that averages 50 percent, which is the amount that occurred for 72 of NASA's past programs.

2020. Such reductions would result in 35 fewer missions through 2025 than under NASA's current plans (see Figure 8). Reductions in funding for aeronautics research would be about \$100 million in 2010 and would rise to \$270 million by 2020.¹⁸ For this scenario, CBO also assumes that NASA would forgo any of the planned missions for the space shuttle that did not occur by the end of September 2010.

Table 3 summarizes the funding changes that would occur under the scenarios CBO considered.

Comparison of the Constellation and Apollo Programs

In its September 2004 study of NASA's vision for space exploration, CBO compared NASA's estimates of the costs of the Constellation program with the costs of the Apollo program and of other proposals for human exploration of the moon. Here, CBO updates those comparisons using NASA's current estimates of the costs of the Constellation program.

18. NASA officials indicate that those funding reductions would significantly delay the agency's contributions to the Next Generation (NextGen) Air Transportation System and would require lessening planned research into environmental improvements for aviation.

Table 3.**Projected Average Annual Funding for NASA Under Alternative Scenarios**

(Billions of 2009 dollars)

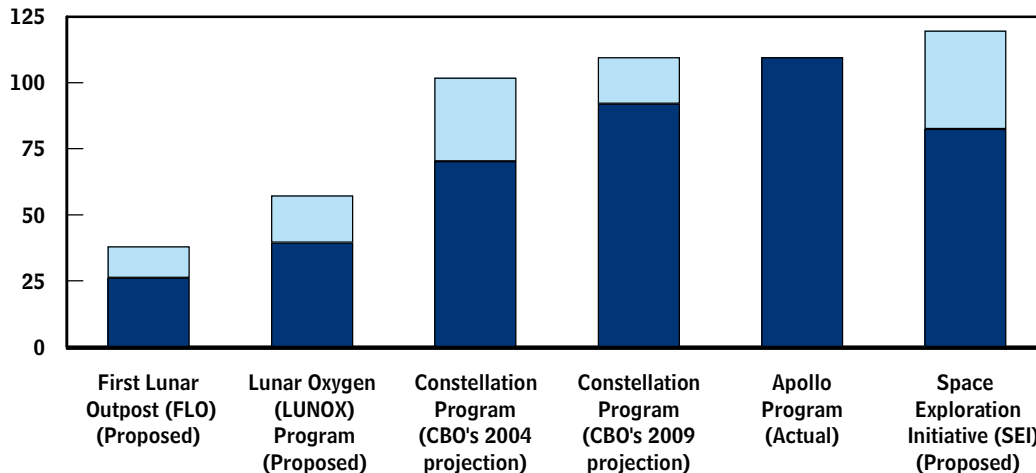
	2010- 2013	2014- 2017	2018- 2021	2022- 2025	2010- 2025
Scenario 2: Execute NASA's Current Plans and Extend Operation of the Shuttle and Space Station					
NASA's Plans	18.2	19.1	19.5	19.8	19.1
Cost Growth for Exploration	+1.1	+1.8	+2.1	+2.7	+1.9
Extension of Space Shuttle to 2015	+2.5	+1.7	0	0	+1.0
Extension of Support for Space Station to 2020	0	+0.8	+1.2	+0.1	+0.5
Cost Growth for Science	+0.6	+0.7	+0.7	+0.7	+0.7
Fully Funded Maintenance and Upgrades to Facilities	+0.4	+0.4	+0.4	+0.4	+0.4
Total	23.0	24.5	23.9	23.7	23.8
Scenario 3: Achieve the Constellation Program's Schedule and Allow Science Schedule to Slip					
NASA's Plans	18.2	19.1	19.5	19.8	19.1
Cost Growth for Exploration	+1.1	+1.8	+2.1	+2.7	+1.9
Total	19.3	20.9	21.6	22.5	21.1
Scenario 4: Absorb Cost Growth to Achieve Constellation's Schedule by Reducing Funding for Science and Aeronautics					
NASA's Plans	18.2	19.1	19.5	19.8	19.1
Cost Growth for Exploration	+1.1	+1.8	+2.1	+2.7	+1.9
Cuts in the Science Directorate	-1.0	-1.7	-1.9	-2.4	-1.7
Cuts in the Aeronautics Research Directorate	-0.1	-0.2	-0.2	-0.3	-0.2
Total	18.2	19.1	19.5	19.8	19.1

Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Figure 9.

Comparison of the Constellation, Apollo, and Other Programs

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Notes: The top portion of each bar represents CBO's projected cost growth above NASA's estimates. For the Apollo program, actual costs are shown.

For details on the estimates for the FLO, LUNOX, and Apollo programs and the SEI, see Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration* (September 2004).

The Constellation program plans to develop capabilities greater than those developed under the Apollo program. In particular, the Constellation program will eventually develop systems capable of performing not just the relatively short-duration mission to the moon conducted under the Apollo program but operation of a lunar outpost for relatively long periods of time. Consequently, for the purpose of a like comparison of the Constellation and Apollo programs, CBO excluded funding for activities in the Constellation program not associated with a short-duration mission to the moon.

CBO also compared funding for the Constellation program with the costs estimated by NASA to conduct other human lunar missions that the agency considered, including the Space Exploration Initiative (SEI), the Lunar Oxygen (LUNOX) program, and the First Lunar Outpost (FLO) program. NASA proposed the SEI in 1989; the initiative consisted of three components: returning humans to the moon, establishing a lunar outpost, and sending astronauts to Mars. NASA proposed the FLO program in 1992; it consisted of a mission to return humans to the moon and provide a lunar habitat module delivered by a robotic lander. NASA proposed the LUNOX program in 1993; it consisted of a mission to return humans to the moon but sought to reduce costs by producing liquid oxygen on the moon, thereby reducing the size and cost of

the launch vehicle. In all cases, CBO's comparison includes only the costs for systems needed to return humans to the moon for a short stay.

According to NASA's current plans for the Constellation program, the agency would require \$92 billion in funding to return humans to the moon in 2020. If 50 percent cost growth occurred, that figure would rise to \$110 billion. Those costs can be compared with the analogous estimates provided in CBO's September 2004 analysis of the Constellation program as it was envisioned then (\$40 billion to \$57 billion), the Apollo program (\$110 billion), the SEI (\$83 billion to \$120 billion), the LUNOX program (\$40 billion to \$57 billion), and the FLO program (\$26 billion to \$38 billion) (see Figure 9).¹⁹ The lower values in the ranges reflect NASA's estimates, and the higher values reflect figures incorporating about 50 percent growth in costs. The smaller range that currently exists for the Constellation program results from the fact that NASA now explicitly incorporates in its plans reserves that would accommodate 25 percent cost growth.

19. For details on those estimates, see Congressional Budget Office, *A Budgetary Analysis of NASA's New Vision for Space Exploration*.

Appendix: Details of NASA's Plans, by Directorate and Function

The National Aeronautics and Space Administration's (NASA's) budget is divided into seven accounts: one for each of the agency's four mission directorates—Exploration Systems, Space Operations, Science, and Aeronautics Research—and one each for cross-agency support, education, and its inspector general.

Exploration Systems Mission Directorate

The Exploration Systems mission directorate is responsible for developing NASA's new human spaceflight vehicles to conduct missions to the moon, Mars, and other destinations. In the near term, NASA's Constellation program is developing the Ares 1 crew launch vehicle and the Orion crew exploration vehicle along with required ground support, infrastructure, and mission operations. Later, the agency will develop the Ares 5 cargo launch vehicle and the Altair lunar lander. For missions to the moon, Ares 1 will boost Orion into low-Earth orbit, and Ares 5 will do the same for Altair; Orion will then rendezvous with Ares 5 and Altair, and Ares 5 will make use of what is termed its earth departure stage to propel the two crew vehicles to the moon. In NASA's plans, Ares 1 and Orion will achieve their initial operating capability by March 2015. At that time, they will be used for missions to the International Space Station. Ares 5 and Altair will reach their initial operating capability by 2020 for humans' return to the moon. Beyond 2020, the agency's plans call for the establishment of a lunar outpost that will be a proving ground for human exploration of Mars.

Under NASA's plans, the budgets for the Exploration Systems mission directorate increase from about \$3.5 billion in 2009 to over \$10 billion by 2017. The increases arise as a result of plans to retire the space shuttle after September 2010 and plans to end support for the space station after December 2015. In 2009, funding primarily supports the development of Ares 1 (\$1.0 billion) and Orion (\$1.1 billion), along with associated ground and mission operations systems. For Ares 1, planned funding reaches a peak of about \$2.0 billion in 2011 and levels off at about \$1.0 billion by 2015, once development is complete and regular operations begin. Similarly, for Orion, planned funding peaks at around \$1.7 billion in 2011 and levels off at about \$0.7 billion by 2015. For Ares 5, planned funding starts at \$0.4 billion in 2011, peaks at \$1.9 billion in 2017, and levels off at \$1.4 billion beginning in 2021. For Altair, planned funding starts at \$0.1 billion in 2011, peaks at \$1.1 billion in 2016, and levels off at \$0.9 billion by 2019. At some point, NASA plans to shift funding for opera-

tion of the Constellation program vehicles back to the Space Operations mission directorate, but the agency has not yet stated when that change will occur.¹

Space Operations Mission Directorate

The Space Operations mission directorate conducts the operation of the space shuttle and the International Space Station, along with other activities. Over the 2010–2025 period, the planned funding for the directorate decreases substantially.

In 2010, total planned funding for space operations is about \$5.8 billion. The funding drops to \$2.8 billion in 2011 because of the retirement of the space shuttle. NASA's current plans call for retiring the space shuttle no later than September 30, 2010, but experience suggests that the agency may not be able to complete all of the missions on the space shuttle's launch manifest by that date.² NASA officials have indicated that any missions that cannot be conducted by that time could be canceled so that funding can be shifted to the Constellation program in 2011, as planned.

The funding for the directorate drops further in 2016 and 2017, as support for the space station ends. By 2018, the planned annual funding falls to about \$0.7 billion, for activities in four categories: space communications and navigation (about \$500 million), launch services (about \$85 million), testing of rocket propulsion (about \$45 million), and the health and safety of crews (less than \$9 million).

See Figure A-1 and Table A-1 for depictions of the plans for the Exploration Systems mission directorate and the Space Operations mission directorate.

Science Mission Directorate

NASA's Science mission directorate is responsible for developing systems for conducting scientific exploration in four categories, or "themes": Earth science, planetary science, astrophysics, and heliophysics.

- In pursuing earth science, NASA conducts missions to "study Earth from space to advance scientific understanding and meet societal needs." Examples of missions of this type include the Ocean Surface Topography Mission, the Aquarius satellite to measure salinity at oceans' surfaces, and the Glory satellite for climate and atmospheric research.

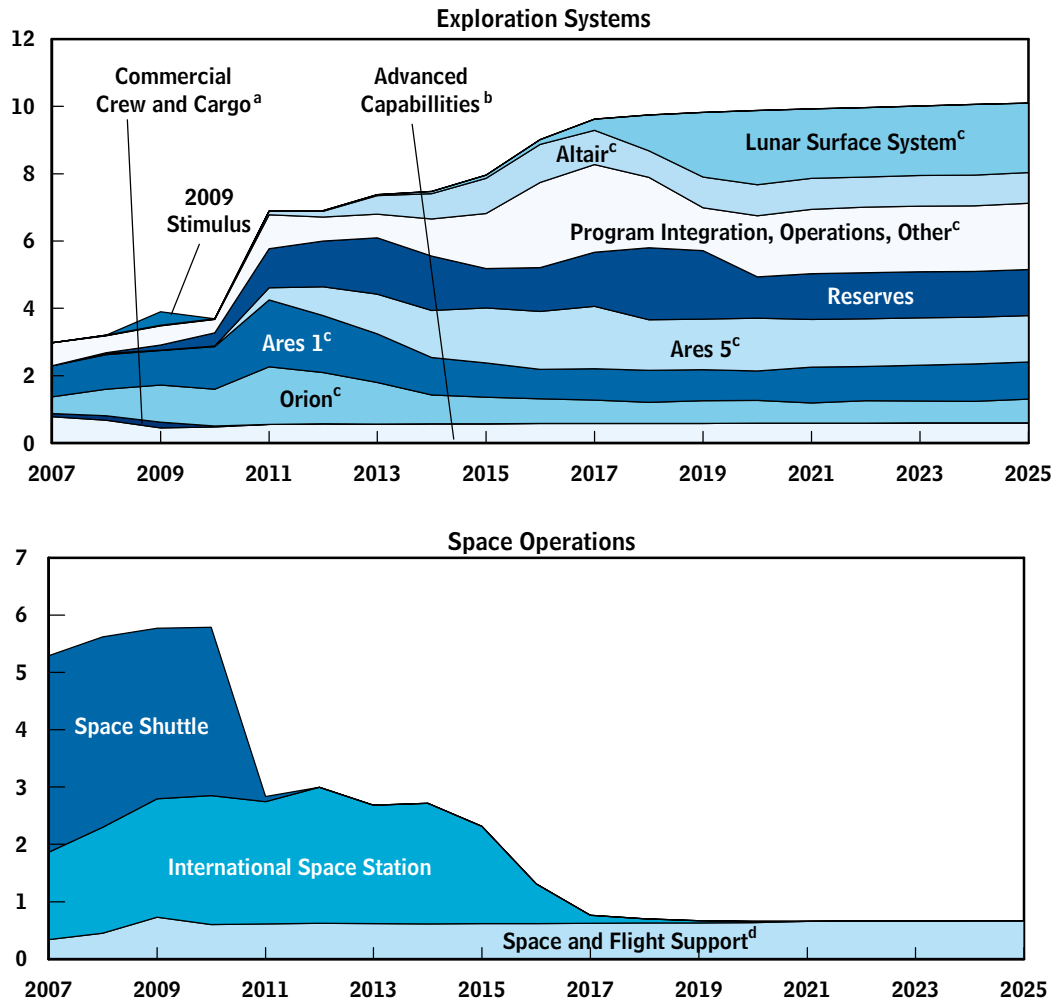
1. Data used for CBO's projections come from *Budget of the United States Government, Fiscal Year 2009* and additional data provided by NASA. CBO's projections beyond 2020 also use data from NASA's Lunar Capability Concept Review. See Geoffrey Yoder and Kent Joosten, National Aeronautics and Space Administration, Exploration Systems Mission Directorate, "Lunar Architecture—Integrated Analyses and Strategy" (presentation, September 25, 2008), available at www.nasa.gov/pdf/278841main_Yoder-JoostenESMDchamber-industry%20day_rev.pdf.

2. See Congressional Budget Office, "An Analysis of NASA's Plans for Continuing Human Spaceflight After Retiring the Space Shuttle," letter to the Honorable Dave Weldon, M.D. (November 3, 2008).

Figure A-1.

Planned Budgets for the Exploration Systems and the Space Operations Mission Directorates

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: NASA received stimulus funding in February 2009 under the American Recovery and Reinvestment Act.

- a. Funding for projects to spur private industry to provide transportation to the International Space Station.
- b. Funding for programs to, among other things, develop new technologies for space exploration and further understanding of the effects of space on human performance.
- c. Within the Constellation program.
- d. Funding for space communications and navigation, civil space launch services, rocket propulsion testing, and the health and safety of crews.

Table A-1.

Projected Average Annual Funding for the Exploration Systems and the Space Operations Mission Directorates

(Billions of 2009 dollars)

	2010- 2013	2014- 2017	2018- 2021	2022- 2025	2010- 2025
Exploration Systems					
Advanced Capabilities ^a	0.5	0.6	0.6	0.6	0.6
Orion ^b	1.4	0.8	0.6	0.7	0.9
Ares 1 ^b	1.6	1.0	0.9	1.1	1.1
Ares 5 ^b	0.6	1.7	1.5	1.4	1.3
Reserves	1.1	1.4	1.7	1.4	1.4
Program Integration, Operations, Other ^b	0.7	2.0	1.8	2.0	1.6
Altair ^b	0.2	1.0	0.9	0.9	0.7
Lunar Surface Systems ^b	0	0.2	1.8	2.1	1.0
Total	6.2	8.5	9.8	10.0	8.7
Space Operations					
Space Shuttle	0.8	0	0	0	0.2
International Space Station	2.2	1.2	0	0	0.8
Space and Flight Support ^c	0.6	0.6	0.6	0.7	0.6
Total	3.6	1.8	0.7	0.7	1.7

Source: Congressional Budget Office based on *Budget of the United States, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

- a. Funding for programs to, among other things, develop new technologies for space exploration and further understanding of the effects of space on human performance.
- b. Within the Constellation program.
- c. Funding for space communications and navigation, civil space launch services, rocket propulsion testing, and the health and safety of crews.

- Missions in planetary science are to “advance scientific knowledge of the origin and history of the solar system, the potential for life elsewhere, and the hazards and resources present as humans explore space.” Examples of missions include the Dawn mission to Ceres and Vesta in the asteroid belt, the Juno New Frontiers Mission to Jupiter, the Gravity Recovery and Interior Laboratory Discovery mission to the moon to determine the structure of the moon from its crust to its core, and the Mars Science Laboratory.
- Missions in astrophysics are to “discover the origin, structure, evolution, and destiny of the universe, and search for Earth-like planets.” Examples of such missions include the Fermi gamma ray observatory, the Kepler exoplanet exploration mission, and the James Webb space telescope.

- In heliophysics, NASA conducts missions to “understand the Sun and its effects on Earth and the solar system.” Examples include the Solar Dynamics Observatory; the Radiation Belt Storm Probes mission to study Earth’s radiation belts, ionosphere, and thermosphere to better understand the sun’s influence on Earth; and the Interstellar Boundary Explorer to detect the edge of the solar system.

The planned funding for the Science mission directorate is about \$4.7 billion annually between 2010 and 2025. NASA intends to apportion the planned budgets thus annually: \$1.3 billion for Earth science, \$1.6 billion for planetary science, \$1.1 billion for astrophysics, and \$0.7 billion for heliophysics.

Aeronautics Research Mission Directorate

The Aeronautics Research mission directorate performs basic research through four programs devoted to aviation safety, airspace systems, fundamental aeronautics, and aeronautics testing:

- The aviation safety program performs research to improve the “intrinsic safety attributes of current and future air vehicles.”
- The airspace systems program performs research on managing air traffic, focusing on the Next Generation (NextGen) Air Transportation System.
- The fundamental aeronautics program performs long-term research in four types of flight: subsonic for rotary-wing aircraft, subsonic for fixed-wing aircraft, supersonic, and hypersonic.
- The aeronautics testing program manages the agency’s ground and flight test assets, including wind tunnels, propulsion testing facilities, and test aircraft.

The planned funding for the directorate is about \$460 million annually between 2010 and 2025. Of that amount, \$66 million is for aviation safety, \$77 million for airspace systems, \$240 million for fundamental aeronautics, and \$78 million for aeronautics testing.

See Figure A-2 and Table A-2 for depictions of the plans for the Science mission directorate and the Aeronautics Research mission directorate.

Cross-Agency Support, Education, and Inspector General

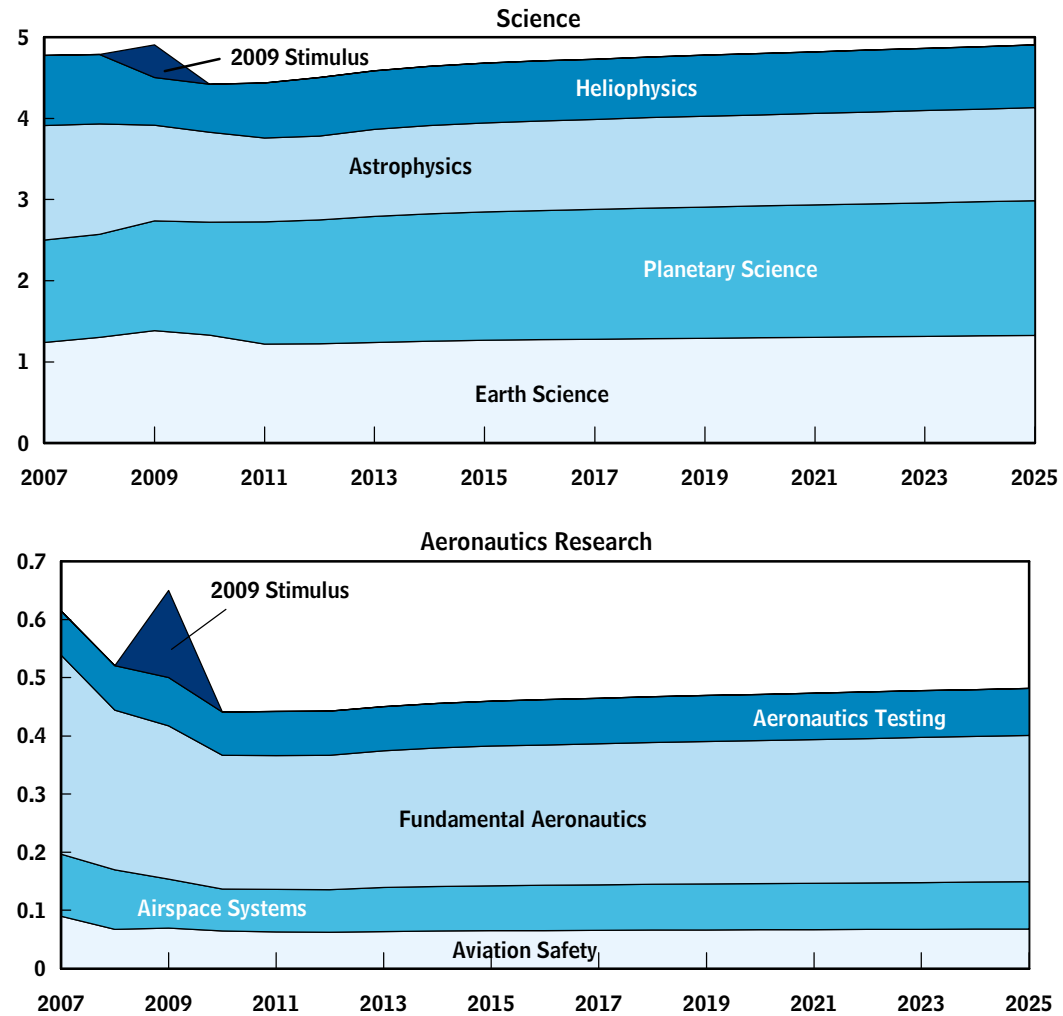
The remaining accounts of NASA’s budget are for cross-agency support, education, and the agency’s inspector general.

Planned funding for cross-agency support averages \$3.5 billion annually from 2010 to 2025. Such support falls into three categories: management and operation of field centers (\$2.2 billion), management and operation of the agency

Figure A-2.

Planned Budgets for the Science and the Aeronautics Research Mission Directorates

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: NASA received stimulus funding in February 2009 as part of the American Recovery and Reinvestment Act.

Table A-2.**Projected Average Annual Funding for the Science and the Aeronautics Research Mission Directorates**

(Billions of 2009 dollars)

	2010- 2013	2014- 2017	2018- 2021	2022- 2025	2010- 2025
Science					
Earth Science	1.3	1.3	1.3	1.3	1.3
Planetary Science	1.5	1.6	1.6	1.6	1.6
Astrophysics	1.1	1.1	1.1	1.1	1.1
Heliophysics	0.7	0.7	0.8	0.8	0.7
Total	4.5	4.7	4.8	4.9	4.7
Aeronautics Research					
Aviation Safety	0.1	0.1	0.1	0.1	0.1
Airspace Systems	0.1	0.1	0.1	0.1	0.1
Fundamental Aeronautics	0.2	0.2	0.2	0.3	0.2
Aeronautics Testing	0.1	0.1	0.1	0.1	0.1
Total	0.4	0.5	0.5	0.5	0.5

Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

otherwise (\$1.0 billion), and what the agency terms institutional investments (\$0.3 billion). The nine field centers are:

- Ames Research Center, near San Francisco, California;
- Dryden Flight Research Center, at Edwards Air Force Base, California;
- Glenn Research Center, in Cleveland, Ohio;
- Goddard Space Flight Center, in Maryland, outside Washington, D.C.;
- Johnson Space Center, in Houston, Texas;
- Kennedy Space Center, at Cape Canaveral, Florida;
- Langley Research Center, in Hampton, Virginia, near Norfolk;
- Marshall Space Flight Center, in Huntsville, Alabama; and
- Stennis Space Center, in Mississippi, near New Orleans, Louisiana.

Table A-3.**Projected Average Annual Funding for NASA's Cross-Agency Support**

(Billions of 2009 dollars)

	2010- 2013	2014- 2017	2018- 2021	2022- 2025	2010- 2025
Center Management and Operations	2.1	2.2	2.2	2.3	2.2
Agency Management and Operations	0.9	0.9	1.0	1.0	1.0
Institutional Investments ^a	0.3	0.3	0.3	0.3	0.3
Total	3.3	3.5	3.5	3.6	3.5

Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Note: For the 2010–2025 period, planned funding for education averages \$120 million and for NASA's inspector general, \$39 million.

a. NASA's phrase "institutional investments" refers to the maintenance of and upgrades to its facilities that are not associated with specific projects by the mission directorates.

The funding for field centers covers a range of activities, including facility operations and maintenance, security, environmental management, safety services, information technology, management, legal services, work promoting equal employment opportunity, public affairs, procurement and financial services, and human resources services. The funding does not, however, cover project-specific technical work conducted at the centers; that work is funded by the mission directorates. Funding for management and operation of the agency otherwise covers, among other things, those activities for NASA headquarters and agencywide safety activities. Under the category of institutional investments, NASA funds construction, repair, rehabilitation, and modification of the agency's basic facilities that are not associated with specific projects by the mission directorates.

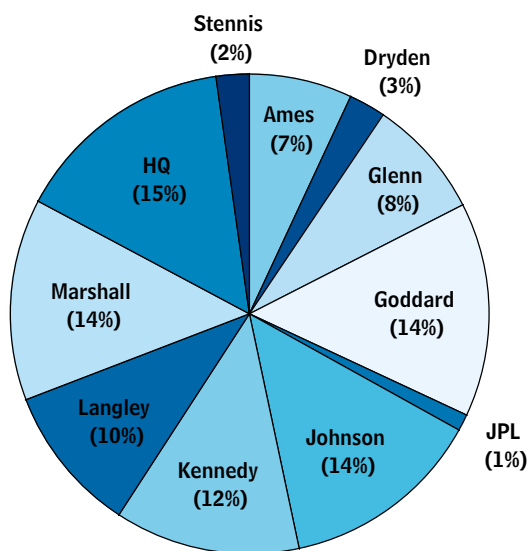
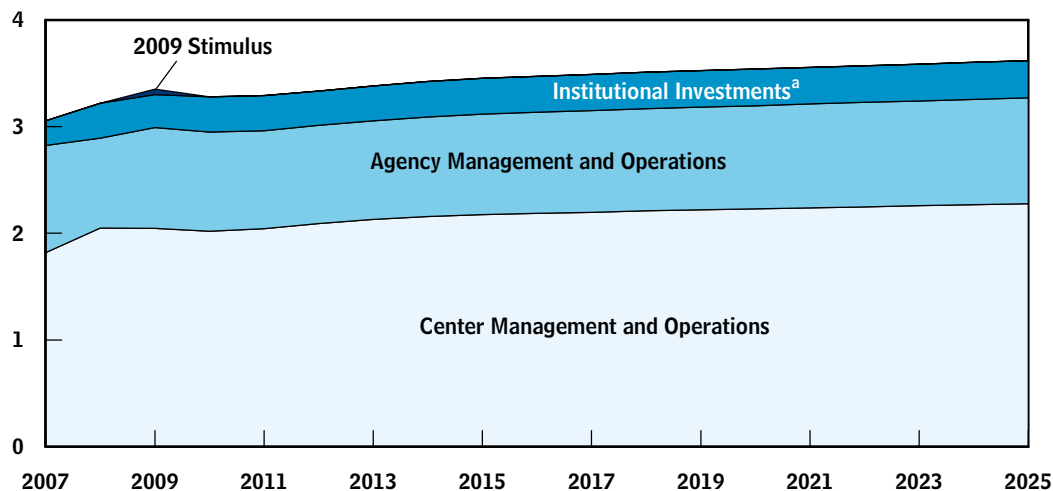
For education, planned funding averages about \$120 million annually from 2010 to 2025. The funding supports three major goals: strengthening the nation's future workforce; attracting and retaining students in science, technology, engineering, and mathematics; and engaging Americans in NASA's mission. For the inspector general's office, planned funding is \$39 million each year.

See Table A-3 and Figure A-3 for depictions of NASA's plans for cross-agency support, education, and its inspector general.

Figure A-3.

Planned Budgets for Cross-Agency Support

(Billions of 2009 dollars)



Source: Congressional Budget Office based on *Budget of the United States Government, Fiscal Year 2009* and data provided by the National Aeronautics and Space Administration (NASA).

Notes: HQ = NASA headquarters; JPL = Jet Propulsion Laboratory.

NASA received stimulus funding in February 2009 as part of the American Recovery and Reinvestment Act.

a. NASA's phrase "institutional investments" refers to the maintenance of and upgrades to its facilities that are not associated with specific projects by the mission directorates.