United States Government Accountability Office

Report to Congressional Committees

April 2014

NASA

Assessments of Selected Large-Scale Projects

GAO-14-338SP

GAO Highlights

Highlights of GAO-14-338SP, a report to congressional committees

April 2014

NASA

Assessments of Selected Large-Scale Projects

Why GAO Did This Study

This is GAO's annual assessment of NASA's major projects. This report provides a snapshot of how well NASA is planning and executing its major acquisitions. In 2013, GAO reported that the performance of NASA's major projects had improved since GAO's first assessment in 2009, due, in part, to some underperforming projects launching and some demonstrating progress meeting practices that GAO has reported decrease cost and schedule risk.

In response to an explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009, this report assesses (1) the current status of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies (3) efforts NASA has taken to improve design stability of its projects, and (4) any challenges to NASA's management of the portfolio. GAO assessed 2013 and 2014 data on NASA's 18 major projects and the Commercial Crew program all with an estimated life-cycle cost of over $250 million, such as data on the projects' cost, schedule, technology maturity, design stability, and contracts; analyzed monthly project status reports; and interviewed NASA and contractor officials.

What GAO Recommends

GAO is not making any new recommendations in this report, but provides further evidence to support the importance of continuing to take action on recommendations GAO has made in prior reports. NASA generally agreed with GAO's findings.

View GAO-14-338SP. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The National Aeronautics and Space Administration's (NASA) total portfolio of major projects saw cost and schedule growth that remains low compared to GAO's first review of the portfolio. Some projects in this year's portfolio launched within their cost and schedule baselines; however, several others are undergoing replans, which could temper the portfolio's positive performance. For example, the Mars Atmosphere and Volatile EvolutioN project launched on time and cost about $35 million less than its baseline estimate, but NASA officials are reporting that issues with the Ice, Cloud, and Land Elevation Satellite-2 project's primary instrument are driving costs to exceed the original baseline by at least 15 percent, and that the project will miss its committed launch date.

NASA projects have continued to make progress in maturing technologies prior to the preliminary design review. This year, 63 percent of projects met this standard, up from only 29 percent of projects in 2010. For example, in preparation for its upcoming confirmation review, one project has matured all 10 of its critical technologies, which GAO's past work has shown is important to decrease the likelihood of cost and schedule growth. NASA's heightened awareness of reducing technology risk is further evidenced by new guidance aimed at ensuring continued focus on technical maturity. As NASA continues to undertake more complex projects it will be important to maintain heightened attention to best practices to lessen the risk of technology development and continue positive cost and schedule performance.

NASA projects are maintaining steady performance toward meeting GAO's best practices for design stability, and the agency has also increased its focus on design stability. GAO has found over past several years that projects have consistently reported higher percentages of drawings releasable at the critical design review and lower percentages of drawing growth after that time, which indicates that project design stability has increased overall. NASA has taken steps to enhance its ability to assess design maturity. For example, NASA implemented three technical indicators to assess design maturity, and projects in the portfolio are tracking the required indicators. Additionally, experts in the space community have identified other design stability metrics, which can be used in tandem with GAO's and NASA's indicators in order to provide a more complete and robust assessment of a project's design stability.

NASA faces several challenges that could impact its ability to effectively manage its portfolio. A primary challenge in the next few years will be to complete a series of complex and expensive projects within constrained budgets and competing priorities. Any cost or schedule growth on NASA's largest, most complex projects, such as the James Webb Space Telescope, could have a ripple effect across the portfolio. While NASA has implemented a plan for improving its acquisition management, monitoring NASA's performance against that plan over time will be important in determining if the agency's efforts to improve its acquisition management practices have become institutionalized. For example, in 2013, two projects experienced significant issues immediately after being confirmed, indicating that neither project had completed an adequate assessment of risk which is necessary to ensure that the project's cost and schedule baseline estimates were realistic.

Contents

Tables

Figures

Abbreviations

AFB	Air Force Base
AFS	Air Force Station
ATLAS	Advanced Topographic Laser Altimeter System
CCP	Commercial Crew Program
CCDev	Commercial Crew Development
CCDev 2	Commercial Crew Development Round 2
CCiCap	Commercial Crew Integrated Capability
CCtCap	Commercial Crew Transportation Capabilities phase
CDR	critical design review
CNES	Centre National d'Etudes Spatiales (French Government Space Agency)
CSA	Canadian Space Agency
DCI	Data Collection Instrument(s)
DLR	German Aerospace Center
EFT-1	The first Exploration Flight Test for the Orion vehicle, scheduled for September 2014
EM-1	Exploratory Mission 1, the first non-crewed launch of the Space Launch System and Orion vehicle, planned for December 2017
EM-2	Exploratory Mission 2, the first crewed launch of the Space Launch System and the Orion vehicle, planned for August 2021
EMTGO	ExoMars Trace Gas Orbiter
ESA	European Space Agency
EVM	earned value management
FAR	Federal Acquisition Regulation
FPI	Fast Plasma Instrument
GFZ	German Research Center for Geosciences
GLAST	Gamma-ray Large Area Space Telescope
GNC LIDAR	guidance, navigation, and control light detection and ranging instrument
GPM	Global Precipitation Measurement (mission)
GRACE-FO	Gravity Recovery and Climate Experiment Follow On
GRAIL	Gravity Recovery and Interior Laboratory
ICESat-2	Ice, Cloud, and Land Elevation Satellite-2
ICPS	Interim Cryogenic Propulsion Stage
InSight	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport
ISIM	Integrated Science Instrument Module
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JCL	Joint Cost and Schedule Confidence Level
JWST	James Webb Space Telescope

KaRIn	Ka-band Radar Interferometer
KDP	key decision point
LADEE	Lunar Atmosphere and Dust Environment Explorer
LDCM	Landsat Data Continuity Mission
LRI	Laser Ranging Interferometer
LRO	Lunar Reconnaissance Orbiter
MAVEN	Mars Atmosphere and Volatile EvolutioN
MMS	Magnetospheric Multiscale
MDR	mission definition review
MSL	Mars Science Laboratory
NASA	National Aeronautic and Space Administration
NGIMS	Neutral Gas and Ion Mass Spectrometer
NPP	NPOESS Preparatory Project
NPR	NASA Procedural Requirements
OCFO	NASA Office of the Chief Financial Officer
OCO	Orbiting Carbon Observatory
OCO-2	Orbiting Carbon Observatory 2
OMB	Office of Management and Budget
Orion	Orion Multi-Purpose Crew Vehicle
OSIRIS-REx	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
PDR	preliminary design review
RBSP	Radiation Belt Storm Probes
SDO	Solar Dynamics Observatory
SDR	system definition review
SGSS	Space Network Ground Segment Sustainment
SIR	system integration review
SLS	Space Launch System
SMAP	Soil Moisture Active and Passive
SMD	NASA Science Mission Directorate
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPP	Solar Probe Plus
SWOT	Surface Water and Ocean Topography
SwRI	Southwest Research Institute
TBD	to be determined
TDRS	Tracking and Data Relay Satellite
TRL	technology readiness level(s)
WISE	Wide-field Infrared Survey Explorer

GAO U.S. GOVERNMENT ACCOUNTABILITY OFFICE

441 G St. N.W.
Washington, DC 20548

April 15, 2014

Congressional Committees

This is GAO's sixth annual assessment of the National Aeronautics and Space Administration's (NASA) major projects. Due to persistent cost and schedule growth associated with its major projects, this area is on GAO's high risk list. Last year we reported a positive trend in reducing cost and schedule growth.[1] For example, NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) project launched in November 2013 on schedule and a cost of approximately $35 million less than estimated. This year's report includes assessments of NASA's key priorities: the development of the Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle (Orion) to carry astronauts beyond low-Earth orbit, the transportation of astronauts to the International Space Station (ISS) by commercial companies, and the continued development of the James Webb Space Telescope (JWST).

The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009 required GAO to prepare project status reports on selected large-scale NASA programs, projects, or activities.[2] This report responds to that mandate. Specifically, we assess (1) the current status of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies, (3) efforts NASA has taken to improve the design stability of its projects, and (4) any remaining challenges to NASA's management of the portfolio. We are highlighting several key areas for NASA management's attention, including continued focus on implementing positive management practices. We have, however, made prior recommendations aimed at improving oversight of NASA's projects including improving the use of earned value management, implementing best practices for design stability and technology maturity, and providing more transparency into

---

[1] GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-13-276SP (Washington, D.C.: Apr 17, 2013).

[2] See Explanatory Statement, 155 Cong. Rec. H1653, 1824-25 (daily ed., Feb. 23, 2009), to the Omnibus Appropriations Act, 2009, Pub. L. No. 111-8. In this report, we refer to these projects as major projects rather than large-scale projects as this is the term used by NASA.

project costs.[3] We are not making any new recommendations but we believe this report provides further evidence to support the importance of taking action on recommendations that GAO made in prior reports on improving acquisition management.

Our approach included an examination of 18 major projects and the Commercial Crew program, each with an estimated life-cycle cost of over $250 million.[4] Three projects are being assessed for the first time this year: (1) Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight); (2) Surface Water and Ocean Topography (SWOT); and (3) Gravity Recovery and Climate Experiment Follow On (GRACE-FO).

In order to assess the current status of NASA projects in terms of cost and schedule, we compared the project's baseline cost and schedule data with current cost and schedule data for the 15 projects in implementation phase during our review.[5] The remaining 3 projects were in an early stage of development called formulation where there are still unknowns about requirements, technology, and design. For those projects, NASA provided preliminary cost ranges and schedule estimates. We reviewed and compared the 15 projects' current cost and schedule data to previously established cost and schedule baselines and characterized growth as significant if it exceeded the thresholds that trigger cost or schedule reporting to certain congressional committees by law.[6] For the Commercial Crew program, we reviewed Space Act Agreement values for each of the three funded partners, as well as both

[3] GAO, *Earned Value Management Implementation Across Major Spaceflight Projects is Uneven,* GAO-13-22 (Washington, D.C.: Nov. 19, 2012); *Additional Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects*, GAO-11-364R (Washington, D.C.: Mar. 3, 2011); and *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes*, GAO-06-218 (Washington, D.C.: Dec. 21, 2005).

[4] The Commercial Crew program is NASA's effort to facilitate the private demonstration of safe, reliable, and cost effective transportation services to low-Earth orbit by providing a fixed investment in each partner's development of their systems.

[5] NASA provided updated cost and schedule data for 14 projects in implementation in Feburary 2014 and one project in March 2014.

[6] NASA is required to report to certain committees in the House and Senate if the development cost of a program is likely to exceed the baseline estimate by 15 percent or more, or if a milestone is likely to be delayed by 6 months or more. 51 U.S.C. § 30104(e).

partner and NASA generated information and partner milestone performance and schedules and NASA information on program risks and partner performance. To assess NASA's progress in developing and maturing its critical technologies, we identified the number of technologies each project was developing and compared them against historical levels, and compared projects' technology maturity against GAO best practices and NASA policy on technology maturity.[7] To understand efforts taken by NASA to improve project's design stability, we assessed design stability by reviewing historical data on past projects and compared it to current performance. We also reviewed criteria for knowledge-based acquisitions, as well as NASA's new design stability metrics and metrics identified by a group of experts at a meeting convened by GAO.[8] We compared projects' design stability against these criteria to the extent possible. To identify any remaining challenges to NASA's management of the portfolio, we reviewed outstanding issues identified in our prior work on NASA, such as cost and schedule growth on one of NASA's most technologically advanced and costly projects, and assessed NASA's efforts to make progress on these issues. We examined how NASA is managing its large and complex missions within the current budget environment by analyzing budget data and interviewing officials to understand the effects of sequestration and other budget uncertainties. We also assessed the extent to which NASA has made progress in improving its acquisition management; for example, through examination of NASA's progress toward meeting metrics related to its high risk designation.

We interviewed project officials and analyzed information provided by project officials to identify other types of challenges that can affect project outcomes and reported on these challenges in the project summaries. This list of challenges is not exhaustive, and we believe these challenges will evolve, as they have in previous years, as we continue this work in the future. We took appropriate steps to address data reliability, such as

---

[7] GAO, *Best Practices: Using a Knowledge-Based Approach to Improve Weapon Acquisition.* GAO-04-386SP (Washington, D.C.: Jan. 1, 2004). NASA Procedural Requirements 7123.1B, NASA Systems Engineering Processes and Requirements Appendix E (Apr. 18, 2013).

[8] GAO-04-386SP. GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes,* GAO-02-701 (Washington, D.C.: July 15, 2002). NASA, *NASA Space Flight Program and Policy Management Handbook.* (Washington, D.C.: January 2014). GAO awarded a contract to the National Academy of Sciences to convene a meeting of experts. For more information about this meeting, please see appendix I.

clarifying data discrepancies. We determined that the data were reliable for the purposes of this report. The individual project offices were given an opportunity to provide comments and technical clarifications on our assessments prior to their inclusion in the final product, and their comments were incorporated as appropriate. Appendix I contains detailed information on our scope and methodology.

We conducted this performance audit from May 2013 to April 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

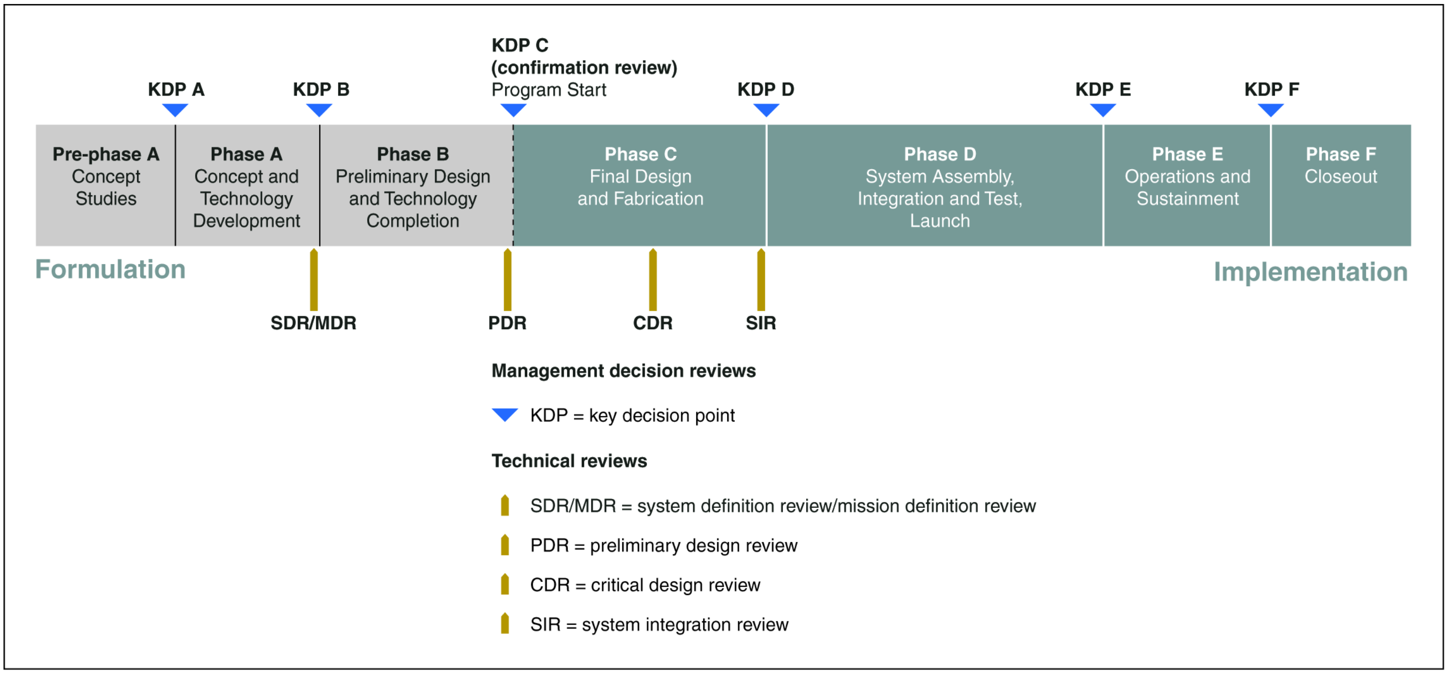
Background

NASA's Life Cycle for Flight Systems

NASA's life cycle for flight systems is defined by two phases—formulation and implementation—and several key decision points.[9] These phases are then further divided into incremental pieces: phase A through phase F. See figure 1 for a depiction of NASA's life cycle for flight systems.

[9] NASA defines the formulation phase as the identification of how the program or project supports the agency's strategic goals; the assessment of feasibility, technology, concepts, and performance of trade studies; risk assessment and possible risk mitigations and continuous risk management processes; team building, development of operations concepts and acquisition strategies; establishment of high-level requirements, requirements flow down, and success criteria; assessing the relevant industrial base/supply chain to ensure program or project success, the preparation of plans, budgets, and schedules essential to the success of a program or project; and the establishment of control systems to ensure performance of those plans and alignment with current agency strategies. *NASA Procedural Requirements (NPR) 7120.5E*, paragraph 1.3.1.a (Aug. 14, 2012). The implementation phase is defined as the execution of approved plans for the development and operation of the program or project, and the use of control systems to ensure performance to approved plans and requirements and continued alignment with the agency's strategic goals. NPR 7120.5E, paragraph 1.3.1.c (Aug. 14, 2012).

Figure 1: NASA's Life Cycle for Flight Systems



Source: NASA data and GAO analysis.

Project formulation consists of phases A and B, during which the projects develop and define requirements and the cost/schedule basis and design for implementation, including developing an acquisition strategy. Prior to entering phase B, projects utilize a probabilistic analysis to develop a range of the project's expected cost and schedule which is used to inform the budget planning for that project. During the end of the formulation phase, leading up to the preliminary design review, the project team completes its preliminary design and technology development.[10] NASA Procedural Requirements 7120.5E, NASA Space Flight Program and Project Management Requirements, specifies that during formulation, the project must complete a formulation agreement to establish the technical and acquisition work that needs to be conducted during this phase and

[10] According to NPR 7120.5E, Table 2-5 (Aug. 14, 2012), the preliminary design review evaluates the completeness/consistency of the planning, technical, and cost/schedule baselines developed during formulation. It assesses compliance of the preliminary design with applicable requirements, and determines if the project is sufficiently mature to begin the final design and fabrication phase.

define the schedule and funding requirements for that work. The formulation agreement is to identify new technologies and their planned development, the use of heritage technologies, risk mitigation plans, and testing plans to ensure that technologies will work as intended in a relevant environment. During the formulation phase, the project is also to develop programmatic measures and technical leading indicators which track various project metrics such as requirement changes, staffing demands, and mass and power growth. The formulation phase culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are to be established and documented in the agency baseline commitment.[11] Project progress can subsequently be measured against these baselines.

After a project is confirmed, it begins implementation, consisting of phases C, D, E, and F. Senior NASA officials must approve the project before it can proceed from one phase of implementation to another. A second design review, the critical design review, is held during the latter half of phase C in order to determine if the design is stable enough to support proceeding with the final design and fabrication. After the critical design review and just prior to beginning phase D, the project is to complete a system integration review which an external review board uses to evaluate the readiness of the project and associated supporting infrastructure to begin system assembly, integration and test. In phase D, the project performs system assembly, integration, test, and launch activities. Phases E and F consist of operations and sustainment and project closeout.

NASA Projects Reviewed in GAO's Annual Assessment

NASA's mission is to drive advances in science, technology, and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of the Earth. To accomplish this mission, NASA establishes many programs and projects that rely on complex instruments and spacecraft. NASA's portfolio of major projects ranges from space satellites equipped with advanced sensors to study the Earth, to a spacecraft which plans to return a sample from an asteroid, to telescopes intended to explore the universe, to spacecraft to transport humans and

[11] The agency baseline commitment establishes and documents an integrated set of requirements, cost, schedule, technical content, and an agreed-to joint cost and schedule confidence level that forms the basis for NASA's commitment with OMB and Congress. NPR 7120.5E, Appendix A (Aug. 14, 2012).

cargo beyond low-Earth orbit. Some of NASA's projects are expected to incorporate new and sophisticated technologies that must operate in harsh, distant environments.

This year, we assessed 18 major projects—3 projects in formulation and 15 projects in implementation. Four of the 15 projects in implementation covered in this year's review—Global Precipitation Measurement (GPM) Mission, Lunar Atmosphere and Dust Environment Explorer (LADEE), Mars Atmosphere and Volatile EvolutioN (MAVEN), and Tracking and Data Relay Satellite Replenishment (TDRS K and L)—successfully launched during 2013 and 2014. We also included our assessment of the Commercial Crew program—NASA's effort to facilitate the private demonstration of safe, reliable, and cost effective transportation services to low-Earth orbit. The year after a project launches or reaches full operational capability, we no longer include a project summary in our annual report. When NASA determines that a project will have a life-cycle cost estimate of more than $250 million, we include that project in the next review. See figure 2 for information on the projects we reviewed in this year's assessment, and appendix II for a list of projects that we have reviewed from the inception of this review (2009) to present.

Figure 2: Selected Major NASA Projects Reviewed in GAO's 2014 Assessment

Interactive Graphic — Roll mouse over project name for more information. See Appendix III for the printed version.

Projects in formulation

	Project	Name	Preliminary estimate of project life-cycle cost:
	Orion	Orion Multi-Purpose Crew Vehicle	$8.53 – $10.29 billion
	SLS	Space Launch System	$7.65 – $8.59 billion
	SWOT	Surface Water and Ocean Topography	$642 – $752 million

Projects in implementation

	Project	Name	Latest estimate of total project cost
●	GPM	Global Precipitation Measurement Mission	$928.1 million
	GRACE-FO	Gravity Recovery and Climate Experiment Follow On	$431.9 million
○	ICESat-2	Ice, Cloud, and Land Elevation Satellite-2	$860.3 million
	InSight	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport	$675.1 million
	JWST	James Webb Space Telescope	$8.83 billion
●	LADEE	Lunar Atmosphere and Dust Environment Explorer	$281.5 million
	MMS	Magnetospheric Multiscale	$1.08 billion
●	MAVEN	Mars Atmosphere and Volatile EvolutioN	$636.5 million
	OCO-2	Orbiting Carbon Observatory 2	$467.5 million
	OSIRIS-REx	Origins–Spectral Interpretation-Resource Identification-Security-Regolith Explorer	$1.06 billion
	SMAP	Soil Moisture Active and Passive	$914.6 million
	SPP	Solar Probe Plus	$1.55 billion
○	SGSS	Space Network Ground Segment Sustainment	$493.9 million
	SOFIA	Stratospheric Observatory for Infrared Astronomy	$2.99 billion
●	TDRS	Tracking and Data Relay Satellite Replenishment K/L	$426.5 million

Commercial crew

	Company	Vehicle	Space Act Agreement total
	Boeing	CST-100	$480.0 million
	Sierra Nevada	Dream Chaser	$227.5 million
	SpaceX	DragonRider	$460.0 million

● Launched
○ Under review

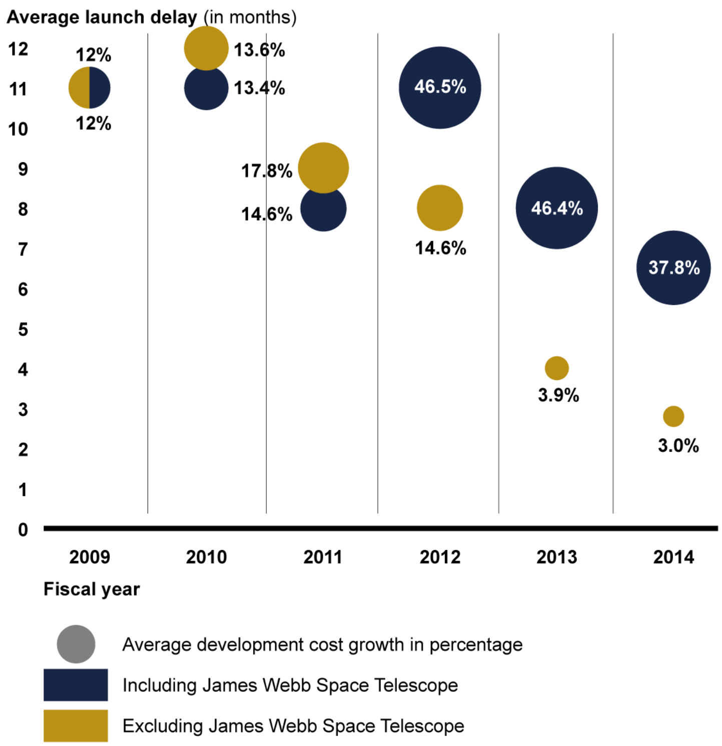
Source: GAO analysis of NASA data.

Positive Cost and Schedule Trends Continue, but Project Replans Weaken Overall Performance

Cost and schedule growth measured across projects remains low compared to previous GAO reviews as some projects in this year's portfolio have launched within their cost and schedule baselines. NASA's positive trends, however, could be tempered as several projects are currently undergoing replans that could lead to cost growth, schedule delays, or diminished capability. As seen in figure 3 below, the portfolio of projects in implementation—excluding JWST—has an average development cost growth from original baseline estimates of 3.0 percent, a decrease of 0.9 percentage points from 2013, and an average launch delay of 2.8 months, a decrease of 1.2 months from 2013.[12] Since they were originally baselined, 8 of 15 projects have experienced cost or schedule growth, but this year, only 3 projects experienced cost or schedule growth. These figures reflect three projects that were recently confirmed and established cost and schedule baseline estimates. Therefore, no growth is to be expected and the overall average growth of the portfolio is lessened. Table 1 provides a breakdown of each project's development cost and schedule growth.

[12] We excluded JWST cost and schedule growth from the portfolio cost and schedule growth calculations because including it masks any changes in the rest of the portfolio's projects, since the magnitude of JWST, both its overall budget and its cost growth, are significantly larger than the other projects in the portfolio that are in implementation.

Figure 3: Average Development Cost and Schedule Growth of Selected Major NASA Projects in Implementation Phase, Both Including and Excluding JWST



Source: GAO analysis of NASA data.

Note: In fiscal year 2009, NASA did not provide cost or schedule information for JWST, although the project had begun implementation.

Table 1: Development Cost and Schedule Growth of Selected Major NASA Projects Currently in the Implementation Phase

Project Name	Cumulative development cost growth (millions)	Percentage cost growth	Development cost growth in last year (millions)	Cumulative launch delay (months)	Launch delay reported in last year (months)
GPM[a]	-45.3	-8.2	0	7	-4
GRACE-FO[b]	0	0	0	0	0
ICESAT-2[c]	84.0	15.0	84.0	Under review	Under review
InSight[b]	0	0	0	0	0
LADEE[d]	23.2	13.8	15.3	-2	-2
MAVEN	-77.8	-13.7	-62.3	0	0
MMS	-0.7	-0.1	-0.6	0	0
OCO-2	122.6	49.2	-0.2	24	0
OSIRIS-REX	-57.0	-7.3	-57.0	0	0
SOFIA[e]	200.3	21.8	-8.6	4	-8
SGSS[c]	0	0	0	Under review	Under review
SMAP	4.3	0.9	4.3	0	0
SPP[b]	0	0	0	0	0
TDRS Replenishment	-24.8	-11.8	0	1	-1
Portfolio excluding JWST					
Average	16.3	3.0	-1.8	2.8	-1.3
Portfolio including JWST					
JWST	3,609.3	139.8	-7.5	52	0
Average	255.9	37.8	-2.2	6.6	-1.2

Source: GAO analysis of NASA data

Note: Shaded rows indicate projects that were rebaselined. None of these projects have experienced cost or schedule growth since they were rebaselined, and all three have since reduced their development costs.

[a]GPM launched in February 2014, 4 months earlier than the project's schedule baseline.

[b]GRACE-FO, InSight, and SPP received their individual cost and schedule baselines in 2014.

[c]Project currently undergoing a replan which will likely affect project cost and/or schedule. For ICESat-2, these are preliminary results and reflect the minimum cost or schedule growth expected by the project.

[d]LADEE launched in September 2013, 2 months earlier than the project's schedule baseline.

[e]SOFIA expected to reach Full Operating Capability in April 2014, 8 months earlier than the project's schedule baseline.

In the past year, several other projects in the portfolio have performed better than their confirmed baselines. For example, following its November 2013 launch, the MAVEN project returned approximately $35 million of its budget to NASA's Science Mission Directorate. Similarly, the GPM project launched in February 2014 and anticipates returning a portion of its budget to NASA's Science Mission Directorate.[13] Finally, the TDRS Replenishment project office has estimated that TDRS L's cost at completion will show that it also launched within cost and schedule baselines.

This positive cost and schedule performance could be tempered as several projects are currently being replanned, which could lead to increases in costs, delays in schedule, or reductions in capability.

- Since our last report, ICESat-2's performance prompted NASA to notify Congress of its intention to replan cost and schedule baseline estimates for the project. NASA officials reported that they expected to exceed their original cost baseline by at least 15 percent and they did not expect to launch by their committed launch date in May 2017. Currently, NASA headquarters officials have begun to review the project's new cost and schedule proposals. Senior NASA officials told us that the need to replan ICESat-2 stemmed mainly from insufficient understanding of the systems engineering for the project's primary instrument, which resulted in a poor analysis of the risks associated with the instrument's design as the project prepared for its recent confirmation review.

- The SGSS project's most likely estimate at completion exceeds the project's confirmed agency baseline commitment and the project reports a lack of adequate funding for activities planned for fiscal year 2014. NASA managers had reviewed and noted concerns about the contractor's plans and estimates as they confirmed cost and schedule baselines for SGSS in April 2013. One month later, the project reported all fiscal year 2013 reserves were consumed as a result of significant issues with the contractor's performance, including expansion of planned design activities leading to slips in sub-system critical design reviews and unrealistic staffing estimates. As a result, project officials have started to replan the project's baselines. One replanning option under consideration by the project office involves no change to the current planned budget, but a reduction in the scope of the project, which would satisfy fewer mission requirements.

[13]As of the GPM project's February 2014 KDP E review, the project office's projections indicated that the mission would launch without consuming its entire budget. They expect to update these projections in April 2014. The project office descoped one of GPM's two planned science instruments in an October 2011 rebaseline effort.

- In Spring 2013, the MMS project encountered a significant testing failure with a key instrument. Since the mission involves four spacecraft each carrying identical instrument payloads, MMS requires 288 of the parts identified as the source of the failure.[14] Additionally, the project incurred 1 month of schedule delay during the October 2013 government shutdown. Currently, project managers are planning to slip from their manifest launch date, October 2014, to March 2015, which is the agency committed launch readiness date. The project has estimated that this launch delay will exceed their cost baseline by at least $26 million.

NASA Has Made Progress in Meeting GAO's Best Practice of Maturing Project Technology Prior to the Preliminary Design Review

Over the past 2 years, major projects in the portfolio have continued to improve in meeting best practices for maturing technology. Our best practices work has shown that a technology readiness level (TRL) of 6—demonstrating a technology as a fully integrated prototype in a relevant environment that simulates the harsh conditions of space—is the level of technology maturity that can minimize risks for space systems entering product development.[15] Demonstrating that technologies—critical and heritage—will work as intended in a relevant environment serves as a fundamental element of a sound business case, and projects falling short of this standard before preliminary design review often experience subsequent technical problems, which can increase the risk of cost growth and schedule delays.[16] In our review, 63 percent of projects that have held a preliminary design review have met the best practices standards for technology maturity, which is a significant improvement over prior years—particularly 2010, when only 29 percent of projects met the standards (see figure 4). Furthermore, of the 13 projects in our

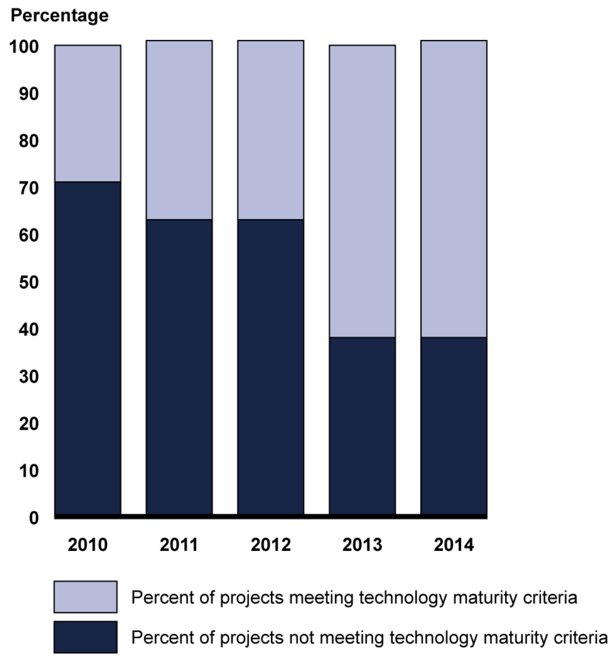
[14] NASA has defined a payload as an assembled group of subsystems designed to perform a specified mission in space.

[15] Appendix IV provides a description of the metrics used to assess technology maturity and appendix V contains detailed information about the project attributes highlighted by knowledge-based metrics at each stage of systems development.

[16] NASA distinguishes critical technologies from heritage technologies. NASA officials do not believe that heritage technologies are the same as critical technologies because they believe critical technology does not rely on existing technology. GAO best practices describe critical technologies as those that are required for the project to successfully meet customer requirements, regardless of whether or not they are based on existing or heritage technology. For the purposes of this review, we distinguish between the two types because NASA did not report heritage technologies as critical technologies in our data collection instrument.

sample with critical technologies, 11 (or 85 percent) matured all of their critical technologies by preliminary design review.

Figure 4: Percentage of Major Projects Meeting GAO Technology Maturity Criteria at the Preliminary Design Review

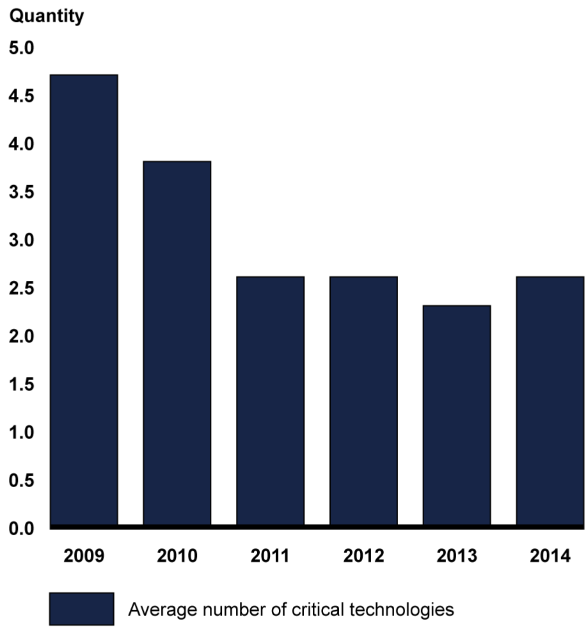


Source: GAO analysis of NASA data.

Note: Totals may not add to 100 percent due to rounding.

While there was a slight increase in the number of critical technologies per project in this year's portfolio, NASA continues to develop fewer critical technologies than it has historically. This year, NASA is developing an average of 2.6 critical technologies per project, down from 4.7 critical technologies per project in 2009 (see figure 5).

Figure 5: Average Number of Critical Technologies for Projects in Implementation



Source: GAO analysis of NASA data.

NASA's increased focus on technology maturity is consistent with the recent decrease in cost and schedule growth in the portfolio compared to historical levels. However, over the past 6 years, the majority of new projects added to NASA's portfolio have generally relied on the use of existing technology and planned less technology development. Two exceptions are SWOT and SPP, which rely on 4 and 10 new critical technologies respectively. NASA managed the technology risk for SPP by maturing all 10 critical technologies to a TRL 6 by the project's preliminary design review. The agency is focused on reducing technology risk in the future as NASA's Science Mission Directorate recently issued new guidance that would ensure continued focus on technical maturity.[17] For example, the guidance seeks to increase the credibility of cost and schedule estimates by more fully understanding the maturity of the

[17] The Science Mission Directorate (SMD) engages the science community, sponsors scientific research, and develops and deploys satellites and probes in collaboration with NASA's partners around the world to answer fundamental questions requiring the view from and into space. Excluding the Commercial Crew program, SMD houses 14 of the 18 projects in our review in its four divisions: Earth Science, Planetary Science, Astrophysics and Heliophysics.

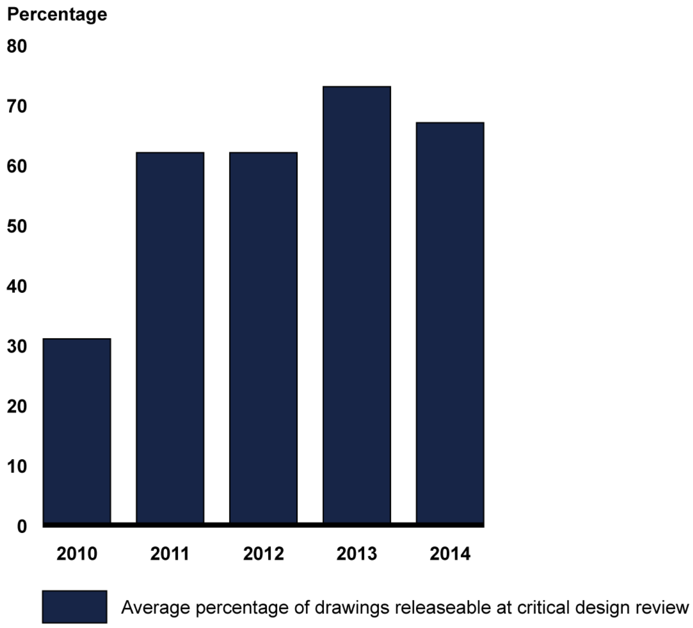
technologies that will be used and whether back up options exist, are feasible, and included in cost estimates. As NASA continues to add more complex projects with a high number of new critical technologies to its portfolio, such as SWOT, it will be important to maintain heightened attention to best practices to lessen the risk of technology development and continue positive cost and schedule performance.

NASA Has Increased Focus on Design Stability by Tracking Several Metrics

Over the past 4 years, we have seen NASA increase its focus on ensuring that projects regularly report on metrics that are intended to provide stakeholders with an indication of design stability. Our best practices work on product development has shown that at least 90 percent of engineering drawings should be releasable by the critical design review to lower the risk of subsequent cost growth and schedule delays.[18] NASA's Systems Engineering Handbook mirrors this metric. Despite nearly all of the projects not meeting the 90 percent metric, in general, over the past 4 years, projects have consistently reported higher percentages of drawings releasable at the critical design review than in 2010. Specifically, the nine projects in this year's portfolio that completed their critical design reviews averaged 67 percent of engineering drawings releasable at the time of that review, while projects at the same stage of development only averaged 31 percent in 2010. One project, ICESat-2, released 91 percent of their drawings at the critical design review. The project delayed this review three times over one year in order to complete engineering models for its primary instrument—which is currently undergoing a replan due to integration challenges. The knowledge gained during these delays should help to reduce risks to the project moving forward (see figure 6).

[18] Appendix V contains detailed information about the project attributes highlighted by knowledge-based metrics at each stage of systems development. Engineering drawings are considered to be a good measure of the demonstrated stability of a product's design because the drawings represent the language used by engineers to communicate to the manufacturers the details of a new product design—what it looks like, how its components interface, how it functions, how to build it, and what critical materials and processes are required to fabricate and test it. Once the design of a product is finalized, the drawing is "releasable." Because the critical design review is the time in the project's life cycle when the integrity of the project design and its ability to meet mission requirements is assessed, it is important that a project's design is stable enough to warrant continuing with the final design and fabrication phase. A stable design allows projects to "freeze" the design and minimize changes prior to beginning the fabrication of hardware, after which time re-engineering and re-work efforts due to design changes can be costly to the project in terms of time and funding.

Figure 6: Average Percentage of Releasable Engineering Drawings at Critical Design Review

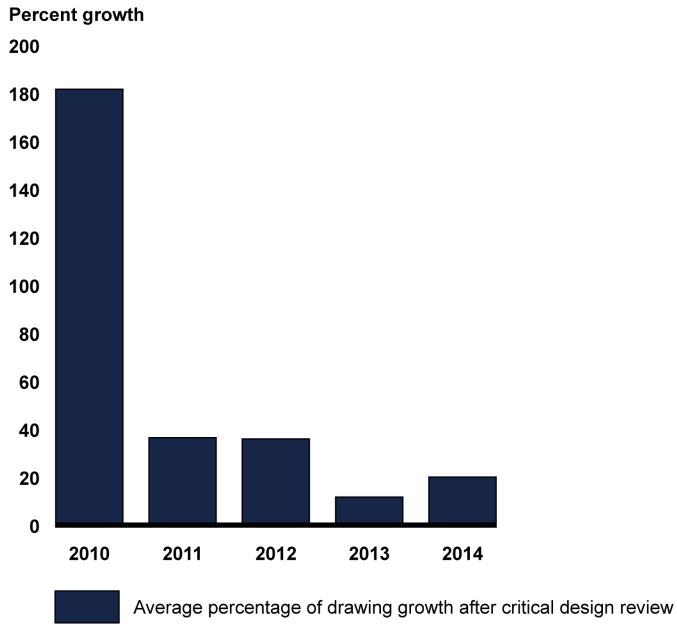


Source: GAO analysis of NASA data.

In addition, while assessing this metric at the critical design review is a good way to understand the risks associated with the project's design going forward to assist in decision making, experts we met with, and some project officials, also find it a useful metric to assess progress toward maturing the project design at various points in the project lifecycle by measuring the number of drawings planned to be released versus the actual number released. For example, NASA officials from the SLS program are closely monitoring design drawing release as a key indicator of the core stage's readiness for its critical design review. If projects are not adhering to the planned drawing release schedule, it can be an indicator that will allow officials to determine if the project is tracking to its plan and the work will be completed on time or if significant deviations have occurred and the work will be delayed, increasing the potential for cost and schedule effects.

Growth in the number of drawings after the critical design review can also provide an ongoing assessment of whether the stability of the design is being compromised late in the development cycle. We have tracked this metric for NASA's projects since 2010 and projects have generally improved in maintaining stability following the critical design review. For example, 10 projects that held their critical design review prior to 2010 averaged a 181.6 percent increase in engineering drawings after that review, whereas this figure has fallen to 20 percent for the 9 projects in this year's review (see figure 7).

Figure 7: Average Percentage of Drawing Growth after Critical Design Review for Selected Projects from Fiscal Year 2010 through 2014



Source: GAO analysis of NASA data.

Apart from metrics related to design drawings, in 2012, NASA established three technical leading indicators to assess design maturity. The indicators are (1) the percentage of actual mass margin versus planned mass margin, (2) the percentage of actual power margin versus planned power margin, and (3) the percentage of overdue requests for action.[19] NASA has updated its project management policy and its systems

[19] Mass is a measurement of how much matter is in an object. It is related to an object's weight, which is mathematically equal to mass multiplied by acceleration due to gravity. Margin is the spare amount of mass or power allowed or given for contingencies or special situations. A request for action is a formal written request sponsored by the review panel asking for additional information or action by the project team. It is generally developed as a result of insufficient safety, technical, or programmatic information being available at the time of the review.

engineering policy to require projects to track these metrics. Projects in the portfolio are tracking the applicable metrics and most have met their recommended mass and power margins.[20]

Experts in the space community have also identified other metrics that can be useful to assess the design stability of unique space systems.[21] For example, some of these metrics include:

- the program's level of funding reserves and schedule margin at various points in the development life cycle;
- whether the project's top level requirements, that define mission success criteria and are imposed by NASA, to requirements at the sub-system level, are defined by the time of preliminary design review;
- the percent complete of verification and validation plans at the preliminary and critical design reviews; and
- the percentage of actual mass margin versus planned mass margin over time.

Many of these metrics focus on an ongoing assessment of project progress and are less associated with measurement at any one point in a project's life cycle. In our discussion with NASA projects, we found that projects utilize various metrics to track design stability. For example, some projects monitor the completion of plans to verify and validate that requirements are met in the time period between the preliminary and critical design reviews and some projects monitor the amount of mass margin over time. We believe that our metrics, in conjunction with NASA's technical leading indicators and those identified by the experts in the space community, can be used together in order to provide a robust assessment of a project's design stability.

[20] JWST, one of NASA's most costly science missions, had to secure a waiver to the recommended margins because the project did not comply with the new Goddard Space Flight Center standards for mass margin at the time of the critical design review.

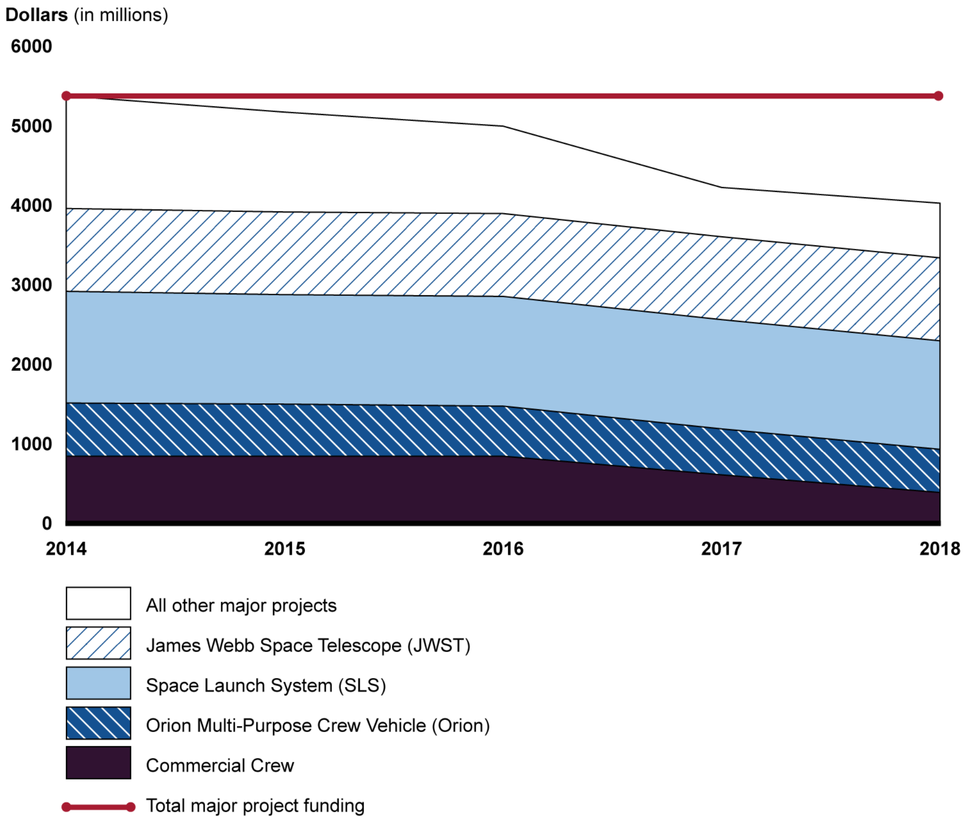
[21] In February 2013, we convened a meeting of experts to enhance our best practice criteria. Details on the panel are explained in appendix I.

NASA Faces Several Challenges That Could Impact Management of the Portfolio

Managing Competing Priorities within the Context of Constrained Budgets is a Primary Challenge

Within the context of constrained budgets, a primary challenge for NASA is effectively managing competing priorities, while completing a series of complex projects. Overall, the current portfolio of major projects is expected to require less funding over the next several years as projects are completed and launched. As figure 8 shows, 74 percent of the major project budget is consumed by only four projects—SLS, Orion, JWST, and the Commercial Crew program.

Figure 8: Fiscal Year 2014 Budget Request for JWST, Orion, SLS, Commercial Crew, and All Other Major NASA Projects, 2014 through 2018



Source: GAO analysis of NASA data.

Note: Budget data are from the fiscal year 2014 President's budget request. Total line indicates the 2014 request for major projects included in the current portfolio and assumes a relatively flat investment in future years for other major projects based on flat or declining budget estimates for all included projects.

The remaining wedge of funding available—the difference between anticipated budgets and the current portfolio's budget requirements—increases over the next 5 years. However, this wedge of funding is intended to fund new projects and will also be needed to cover any cost growth that may occur on NASA's largest, most complex projects, such as JWST, SLS, and Orion. Any cost or schedule overrun on NASA's largest, most complex projects could have a ripple effect on the portfolio and has the potential to postpone or even cancel altogether projects in earlier development stages. As an illustration, JWST will soon enter integration and testing—the point at which cost growth and schedule delays are most likely. We also recently reported that JWST is generally executing to its September 2011 revised cost and schedule baseline; however, monthly progress declined in fiscal year 2013 and several challenges remain.[22] Additionally, there are questions about the realism of the SLS and Orion cost estimates. For example, according to NASA's Aerospace Safety Advisory Panel, the agency needs to ensure that budget forecasting for SLS and Orion is realistic as there are continued concerns that there is a mismatch between program planning and budget realities.[23] An additional factor that makes planning difficult is the fact that—especially in the case of large projects such as SLS and Orion—it is possible for the agency to invest billions of dollars during project formulation before the full cost of the project is known. Both SLS and Orion are only accounting for preliminary capabilities—such as the first flight of each system—not the full life cycle cost that is associated with each of the respective systems. If any of these projects exceed their budgets, the agency will be confronted with allocating out year funding to these projects.

Budgetary Uncertainty Presents Additional Challenges

Budget uncertainty is creating an environment that makes planning for NASA more difficult. During fiscal year 2013, NASA faced mandatory across-the-board spending cuts, also known as sequestration, but the effects on the agency were relatively minor because the agency planned for lower budget levels. According to agency officials, by adjusting the Commercial Crew and Space Technology accounts, the agency was able to absorb the budget cuts without causing any major setbacks to the projects reviewed here. However, according to officials, future capabilities could be impacted as a result of these cuts. For projects that had been confirmed, transfers and reprogramming allowed NASA to maintain committed cost and schedule baselines.[24] However, sequestration, the cancellation of budgetary resources previously provided by law, may complicate the agency's ability to effectively plan over the next several

[22]GAO, *James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Progress*, GAO-14-72 (Washington, D.C.: Jan. 8, 2014).

[23] NASA Aerospace Safety Advisory Panel, *Annual Report for 2013* (Washington, D.C.: Jan. 15, 2014).

[24] Reprogramming involves the movement of funds within the same appropriation account, while transfer is the movement of funds from one appropriation account to another.

years. According to NASA's financial officials, the majority of NASA's major projects require significant budget planning across several years and this uncertainty prevents the agency from planning as effectively as possible.

Additional budget uncertainties outside of NASA are also affecting NASA's ability to execute. For example, some of the agencies that NASA partners with to share the cost associated with its major projects may not be able to continue providing support. For example, as we found last year, ICESat-2 was initially planned to be launched along with a Department of Defense satellite and funding for that project was preliminarily established accordingly.[25] However, the Department of Defense program was delayed in 2012 and NASA had to add $84 million to ICESat-2's budget to allow the project to acquire its own launch vehicle. Commercial Crew program officials have also explained that varying budget levels each fiscal year have affected their ability to manage the program. For example, the level of funding available in fiscal year 2014 could affect the program's ability to make a planned contract award before the end of 2014.

Lastly, in October 2013, several major NASA projects were affected by the government shutdown that occurred due to a lapse in appropriations for fiscal year 2014. The shutdown resulted in schedule delays for JWST and OSIRIS-REx—which they were able to absorb through existing reserves—but, as a result, the projects are now carrying additional minor risks with unknown future implications. Additionally, the shutdown affected MMS and ICESat-2, which were already facing serious schedule, cost, and technical challenges. MMS had a very tight schedule prior to the shutdown, but as a result of the shutdown the project must now delay the project's planned launch date. Additionally, ICESat-2 was experiencing significant technical issues with its ATLAS instrument prior to the shutdown, which were causing cost and schedule effects for the project. As a result of the shutdown, the project has had to account for additional cost and schedule growth as part of its replanning effort that was initiated prior to the shutdown.

[25] GAO-13-276SP.

NASA's Acquisition Management Remains a Concern, but Progress Has Been Made on Project Oversight

GAO has designated NASA's acquisition management as a high risk area because of NASA's history of persistent cost growth and schedule slippage in the majority of major projects. In 2013, we found that NASA implemented a plan for improving its acquisition management, which included points of accountability and metrics to assess progress.[26] These metrics state that NASA will

1. maintain a cost performance level for its portfolio of major development projects that is within 110 percent of the budget-weighted aggregate cost baseline by 2013;
2. meet the baseline schedule goals for its portfolio of major development projects, with aggregate schedule slippage falling within 110 percent of baseline by 2013; and
3. sustain mission success by staying on-course to meet primary requirements for 90 percent of its portfolio of major projects by 2013.

NASA reported that all of the criteria for the reporting period ending September 2013 were met. However, NASA's analysis does not consistently use original baseline data for measuring outcomes, including for JWST, one of the most expensive and complex projects in the portfolio, which underwent a significant rebaseline in 2011. According to NASA officials, this approach is a result of the evolving nature of their business and management practices. While excluding JWST may be an appropriate approach given the magnitude of the increases, it could hinder our ability to measure NASA's progress to improve its acquisition management. Baselines allow decision makers to measure and monitor progress by comparing the current estimates for performance, cost, and schedule goals against a baseline. Identifying and reporting deviations from the baseline in cost, schedule, or performance as a program proceeds provides valuable information for oversight by identifying areas of program risk and its causes to decision maker. Excluding original baseline information from its analysis does not make cost or schedule growth apparent and renders the metrics meaningless to determine real progress. We will continue to work with NASA to ensure the most appropriate reporting mechanism to enable assessment of progress towards improving acquisition management and we will report on these efforts in the next update to our High Risk report.

[26] GAO, *High Risk Series: An Update*, GAO-13-283 (Washington, D.C.: Feb 2013).

Additionally, it is unclear whether the steps NASA has taken to improve acquisition management have been fully implemented across the agency, as we continue to see projects being approved for implementation without an adequate assessment of the resources necessary to address the known risks. For example, both ICESat-2 and SGSS experienced significant issues immediately after being confirmed. For both projects, an adequate assessment of risk was not completed to ensure that the baseline estimates of cost and schedule were realistic and risks that were raised were not fully understood. More specifically, project officials for ICESat-2 acknowledged that important information at KDP-C was likely overlooked as evidenced by how quickly the project's cost and schedule posture worsened in the months immediately following the milestone decision. Another example is SGSS, in which the Standing Review Board raised issues related to cost growth and declining schedule performance at KDP-C, but despite these concerns, the project was confirmed. Shortly after project confirmation, the project experienced significant cost growth. This growth necessitated a replan for the project, which is currently under way, and the project will experience either a delayed schedule and increased costs or a diminished capability as a result.

To improve the management and oversight of its spaceflight projects, we previously recommended that NASA improve its earned value management (EVM) system.[27] EVM is a project management tool that, when properly used, can provide accurate assessments of project progress, produce early warning signs of impending schedule delays and cost overruns, and provide unbiased estimates of anticipated costs at completion. NASA has taken some steps to address these recommendations.[28] For example, NASA has begun rolling out its EVM process on selected major projects, but it has not established a time frame for implementing it across the portfolio of major projects. More time is needed to determine the extent to which positive trends to improve

---

[27] Earned value measures the value of work accomplished in a given period and compares it with the planned value of work scheduled for that period and with the actual cost of work accomplished. Differences in these values are measured in both cost and schedule variances. Positive variances indicate that activities are costing less or are completed ahead of schedule. Negative variances indicate activities are costing more or are falling behind schedule. Cost and schedule variances can also be used in estimating the cost and time needed to complete the project.

[28] GAO-13-22.

acquisition management observed across NASA's major projects have been institutionalized.

NASA has taken other steps to improve its oversight of projects. In January 2009, NASA instituted the joint cost and schedule confidence level (JCL) process, with the goal of ensuring that projects are thoroughly planning for anticipated risks and that the cost and schedule estimates are realistic. The JCL quantifies potential risks and calculates cost, schedule, and reserve estimates based on all available data and is implemented in the last phase of formulation. Currently, of the 15 projects in the portfolio required to have a JCL, 14 have developed a JCL. TDRS Replenishment was not required to develop a JCL due to being at an advanced stage of development when the JCL process was implemented. NASA has previously noted that a key to improving the use of the JCL process is increasing the consistency of practices used by NASA projects in developing their JCLs. To address this concern, NASA officials reported that they have developed additional guidance for projects on formulating JCLs, which is part of NASA's cost estimating handbook and will be issued in early 2014. Additionally, the agency's Science Mission Directorate issued a memo to projects that clarified the need for projects to have credible and reliable integrated cost and schedule estimates and to provide clear accountability for tracking to that estimate. Over the past several years, NASA has provided training to projects on how to develop their JCLs. Adoption of the JCL process has likely contributed to the recent decrease in cost and schedule growth in the portfolio compared to historical levels. However, some projects with JCL's have still faced issues with cost and schedule management. For example, ICESat-2 was confirmed at the 70 percent JCL level; however, the project has recently experienced technical difficulties and will not meet its committed launch with available funding. Additionally, we continue to have concerns about the utility of the JCL that was developed for NASA's most costly science project—JWST. In 2012, we found that the lack of detail in the summary schedule used for the development of JWST's JCL, which provided the basis for the project's new cost and schedule estimates, prevented us from sufficiently understanding how risks were incorporated, calling into question the results of that analysis and, therefore, the reliability of the replanned cost estimate.[29] We recommended that the project redo the

[29] GAO, *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration*, GAO-13-4 (Washington, D.C.: Dec. 3, 2012)

JCL with a more detailed schedule that incorporates current risks. Officials initially concurred with the recommendation; however, the project has since declined to take adequate steps to address our recommendation to develop an updated JCL that is based on current risks and a reliable schedule. Unless properly updated to include a reliable schedule that incorporates known risks, the current cost estimate will not provide decision makers with accurate information to assess the current status of the project. Thus we continue to believe our recommendation has merit and should be fully implemented and we raised this issue as a matter for Congressional Consideration in January 2014.[30] In addition, the MMS project's 70 percent JCL level established a total budget to support a committed launch date of March 2015. While the project is working toward its earlier October 2014 manifest launch date, technical and schedule challenges have necessitated a launch delay to March 2015, the agency's baseline commitment date for launch. The project's committed level of funding is insufficient to cover the delay to its actual committed launch date, and, as a result, project costs are expected to exceed the agency baseline cost commitment by at least $26 million. The funding for the project at the 70 percent JCL level should have enabled the project to reach a March 2015 launch date with no additional funding required. The current estimated overrun calls into question how well the project's schedule and funding profile are integrated. We plan to continue to monitor this project and gain additional insight into this issue.

NASA has also taken steps to improve early transparency into cost estimates and allow for better planning, oversight, and congressional insight on projects. For example, in response to our 2011 recommendation, NASA includes preliminary cost estimates at KDP-B in the annual budget submission.[31] These estimates are preliminary in nature as projects have yet to reach the point in development that allows for sufficient knowledge of risks and associated costs in order to commit to a specific baseline, but are used as the basis of long term budget planning. To date, NASA has provided us with initial cost estimates for eleven projects. Six of the eleven projects received a committed agency baseline within the preliminary life cycle cost estimate range and the remaining five projects established baselines that were, on average, 15.5 percent higher than the upper end of the preliminary range estimate.

[30] GAO-14-72.

[31] GAO-11-364R.

While it is a positive step that NASA is more realistically baselining its projects at KDP-C, the agency could better rely on the preliminary range estimates for planning purposes, consistent with our 2011 recommendation, if more was done to ensure projects are adequately taking in to account unknown risks that will likely affect projects. Without doing so, NASA could be at risk of starting more projects than it can afford to adequately fund.

Project Assessments

The individual assessments of the projects we reviewed provide a profile of each project and are tailored in length, from 1 to 3 pages, to capture information about the project.

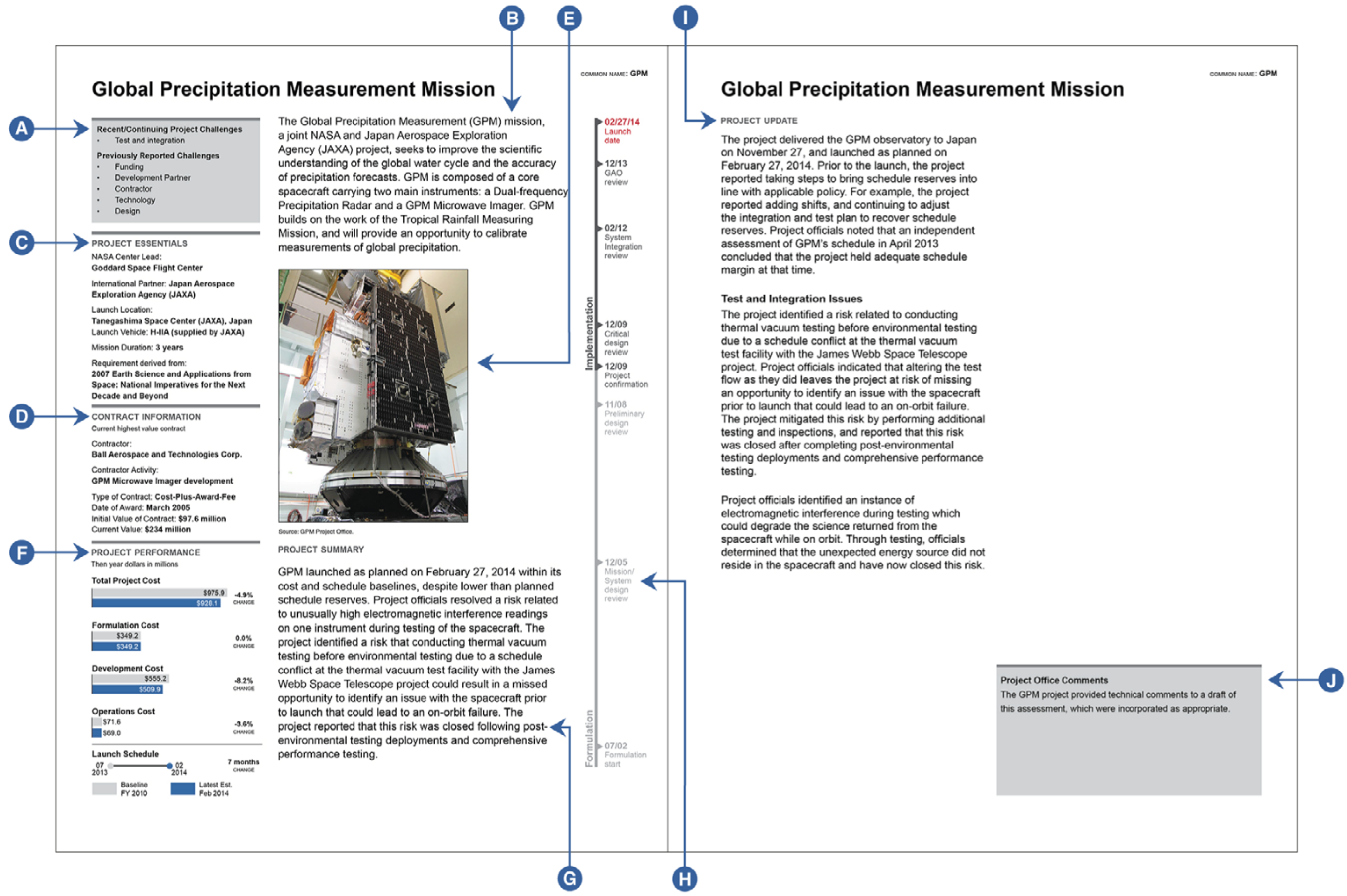
Each project assessment includes a description of the project's objectives, information about the related NASA center, primary contractor(s), and/or external partners involved in the project, the project's cost and schedule performance, a timeline identifying key project dates,[32] and a brief narrative describing the current status of the project. The two-page assessments—15 in total—describe the challenges we identified this year, as well as challenges that we have identified in the past. On the first page, the project profile presents the standard information listed above. On the second page of the assessment, we provide an analysis of the project challenges, and outline the extent to which each project faces cost, schedule, or performance risk because of these challenges, if applicable. The one-page assessments—3 in total—are structured similarly to the two-page assessments and capture the same information with the exception of an in-depth review of the program challenges since several projects that we reviewed had few, if any, challenges to report. As needed, the challenges are captured on the first page, in the project summary section. For the three-page assessment of the Commercial Crew program, we focused on each of the three funded partners' current status, milestone timelines, and challenges. NASA project offices were provided an opportunity to review drafts of the assessments prior to their inclusion in the final product, and the projects provided both technical corrections and more general comments. We integrated the technical

[32] The manifested launch date is the launch date which the project is working toward, and when a launch vehicle is available to launch the project. This date is only a goal launch date for the project, not a commitment that they will launch on this date. The committed launch readiness date is determined through a launch readiness review that verifies that the launch system and spacecraft/payloads are ready for launch.

corrections as appropriate and summarized the general comments below the project update.

See figure 9 for an illustration of a sample assessment layout.

Figure 9: Illustration of a Sample Project Assessment



- **A** **Project Challenges** Summary listing of the challenges facing the project
- **B** General description of the mission's objectives
- **C** **Project Essentials** Programmatic information including the responsible NASA center, international or domestic partners, launch information, mission duration, and the driver for the mission's requirements
- **D** **Contract Information** Current highest value contractor, contractor activity, the type of contract and when it was awarded, and initial and current value of the contract
- **E** Illustration of the spacecraft, aircraft or ground system
- **F** **Project Performance** Cost and schedule baseline estimates and the latest estimate updates
- **G** **Project Summary** Brief narrative describing the current status of the project
- **H** Schedule timeline identifying key dates for the project including when the project began formulation, major design reviews, confirmation to begin the implementation phase, and launch or operating capability information
- **I** **Project Update** Analysis of the project challenges and the extent to which each project faces cost, schedule, or performance risk because of these challenges
- **J** **Project Office Comments** General comments provided by the cognizant project office

Source: GAO analysis.

Global Precipitation Measurement Mission

Recent/Continuing Project Challenges
- Test and integration

Previously Reported Challenges
- Funding
- Development Partner
- Contractor
- Technology
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **Japan Aerospace Exploration Agency (JAXA)**

Launch Location:
Tanegashima Space Center (JAXA), Japan
Launch Vehicle: **H-IIA (supplied by JAXA)**

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond

CONTRACT INFORMATION

Current highest value contract

Contractor:
Ball Aerospace and Technologies Corp.

Contractor Activity:
GPM Microwave Imager development

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **March 2005**
Initial Value of Contract: **$97.6 million**
Current Value: **$234 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$975.9
$928.1
-4.9% CHANGE

Formulation Cost
$349.2
$349.2
0.0% CHANGE

Development Cost
$555.2
$509.9
-8.2% CHANGE

Operations Cost
$71.6
$69.0
-3.6% CHANGE

Launch Schedule
07 2013 — 02 2014
7 months CHANGE

Baseline FY 2010
Latest Est. Feb 2014

The Global Precipitation Measurement (GPM) mission, a joint NASA and Japan Aerospace Exploration Agency (JAXA) project, seeks to improve the scientific understanding of the global water cycle and the accuracy of precipitation forecasts. GPM is composed of a core spacecraft carrying two main instruments: a Dual-frequency Precipitation Radar and a GPM Microwave Imager. GPM builds on the work of the Tropical Rainfall Measuring Mission, and will provide an opportunity to calibrate measurements of global precipitation.

Source: GPM Project Office.

PROJECT SUMMARY

GPM launched as planned on February 27, 2014 within its cost and schedule baselines, despite lower than planned schedule reserves. Project officials resolved a risk related to unusually high electromagnetic interference readings on one instrument during testing of the spacecraft. The project identified a risk that conducting thermal vacuum testing before environmental testing due to a schedule conflict at the thermal vacuum test facility with the James Webb Space Telescope project could result in a missed opportunity to identify an issue with the spacecraft prior to launch that could lead to an on-orbit failure. The project reported that this risk was closed following post-environmental testing deployments and comprehensive performance testing.

Implementation
- **02/27/14** Launch date
- **12/13** GAO review
- **02/12** System Integration review
- **12/09** Critical design review
- **12/09** Project confirmation

Formulation
- **11/08** Preliminary design review
- **12/05** Mission/ System design review
- **07/02** Formulation start

Global Precipitation Measurement Mission

PROJECT UPDATE

The project delivered the GPM observatory to Japan on November 27, and launched as planned on February 27, 2014. Prior to the launch, the project reported taking steps to bring schedule reserves into line with applicable policy. For example, the project reported adding shifts, and continuing to adjust the integration and test plan to recover schedule reserves. Project officials noted that an independent assessment of GPM's schedule in April 2013 concluded that the project held adequate schedule margin at that time.

Test and Integration Issues

The project identified a risk related to conducting thermal vacuum testing before environmental testing due to a schedule conflict at the thermal vacuum test facility with the James Webb Space Telescope project. Project officials indicated that altering the test flow as they did leaves the project at risk of missing an opportunity to identify an issue with the spacecraft prior to launch that could lead to an on-orbit failure. The project mitigated this risk by performing additional testing and inspections, and reported that this risk was closed after completing post-environmental testing deployments and comprehensive performance testing.

Project officials identified an instance of electromagnetic interference during testing which could degrade the science returned from the spacecraft while on orbit. Through testing, officials determined that the unexpected energy source did not reside in the spacecraft and have now closed this risk.

Project Office Comments

The GPM project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Gravity Recovery and Climate Experiment Follow On

Project Challenges
- Development Partner (new)

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **German Research Center for Geosciences (GFZ)**

Launch Location:
Baikonur Cosmodrome, Kazakhstan
Launch Vehicle: **Dnepr**

Mission Duration: **5 years**

Requirement derived from:
2007 NASA 2010 Climate Plan (Directed Mission)

CONTRACT INFORMATION

Current highest value contract

Contractor: **Astrium**

Contractor Activity: **Satellite Buses**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **January 2012**
Initial Value of Contract: **$118.2 million**
Current Value: **$121.4 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$431.9
$431.9
0.0% CHANGE

Formulation Cost
$107.4
$107.4
0.0% CHANGE

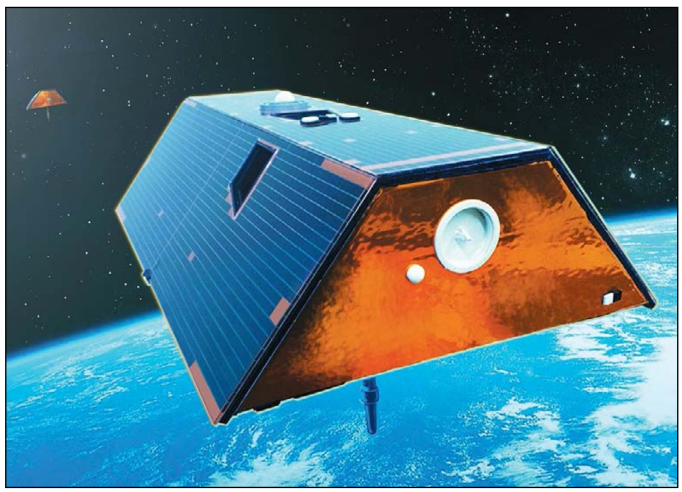
Development Cost
$264
$264
0.0% CHANGE

Operations Cost
$60.5
$60.5
0.0% CHANGE

Launch Schedule
02 2018

Baseline FY 2014
Latest Est. Feb 2014

The Gravity Recovery and Climate Experiment Follow On (GRACE-FO) is a follow on to the original GRACE mission, which launched in 2002 and is still in operation. GRACE-FO is a joint effort with the German Research Center for Geosciences (GFZ) that will provide global high-resolution models of Earth's gravity field at a precision and temporal sampling equivalent to that achieved with GRACE. This information will provide insight into water movement on and beneath the Earth's surface over a 5-year mission period. The system operates as an observatory with two spacecraft and instruments working concurrently to obtain the science measurements. The mission also includes a technology demonstration— a new Laser Ranging Interferometer (LRI), which performs the same ranging measurements as the mission's microwave instrument but with 20 times greater precision.



Source: NASA.

PROJECT SUMMARY

The project is tracking technical risks which include those related to the LRI, such as the availability of the interface specifications. In order to provide early warning for potential problems, the project is also tracking a risk that the LRI could exceed available cost and schedule resources if additional technical risks are realized. Officials stated that the LRI could be de-scoped from the project in the event that its development exceeded available budget, schedule, or technical margins because the LRI is not necessary to meet the mission's science requirements. The planned development and addition of the LRI have been accommodated in the overall system design. Project officials stated that if the instrument is descoped, the project will replace it with dummy masses, and no further impact to system design are anticipated.

Implementation

02/18 Committed launch readiness date

08/17 Projected launch date

06/15 System Integration review

01/15 Critical design review

02/14 Project confirmation

Formulation

01/14 Preliminary design review

12/13 GAO review

07/12 Mission/ system definition review

01/12 Formulation start

Gravity Recovery and Climate Experiment Follow On

PROJECT UPDATE

The project entered Phase C—the final design and fabrication phase of implementation—in February 2014. The project plans to utilize existing technologies—upgraded as needed to address obsolescence issues—from the GRACE mission to complete its mission, with the addition of the LRI technology demonstration effort. GRACE-FO includes a similar partnership with Germany as the original GRACE mission. Specifically, GFZ will be contributing the launch vehicle and launch services, flight operations, and ground stations, as well as the optics components of the LRI. NASA is contributing program and project management services, satellites, the microwave instrument, and the electronic components of the LRI.

Development Partner Issues

The project is tracking a risk that the development of the LRI could exceed available cost and schedule resources, which could impact the baseline mission. The project is also tracking technical risks with the instrument's development, such as the availability of interface specifications which describe how the LRI will be integrated with the spacecraft. Officials stated that the LRI could be de-scoped from the project in the event that its development exceeds available cost, schedule, or technical margins because it is not essential to meet the project's science requirements. The project plans to resolve any conflicts related to LRI accommodation and functional requirements in favor of the primary science instruments and mission objectives. The planned development and addition of the instrument, which has multiple components distributed throughout the spacecraft and in some cases, more stringent requirements than that of the spacecraft, has been incorporated into the overall system design. Project officials stated that if the instrument is descoped, the project will replace it with dummy masses with no further impact to system design, or project cost and schedule. Project officials report that they maintain close contact with GFZ in order to ensure that the project's schedule proceeds as planned. This communication includes involvement in manufacturing readiness reviews, design reviews, and regularly scheduled status meetings. According to project officials, the decision to descope the LRI would be a joint decision between NASA and GFZ.

Project Office Comments

The GRACE FO project provided technical comments to a draft of this assessment, which were incorporated as appropriate. The project reported that it continues to have excellent coordination among participants with focus on risk mitigation and has continued the close partnership with GFZ on the selection of the provided launch service, Mission and Ground Operations planning activities, and the development of the German elements of the LRI. The project further stated that the spacecraft and science instruments developments and accommodations are proceeding well with minimal risk and have all successfully passed their respective preliminary design reviews. In addition, the LRI went through a technology maturity assessment in December 2013 to verify status prior to the project preliminary design review.

Ice, Cloud, and Land Elevation Satellite-2

Recent/Continuing Project Challenges
- Design (new)
- Schedule (new)
- Funding

Previously Reported Challenges
- Launch
- Workforce

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **None**

Launch Location: **Vandenberg AFB, CA**
Launch Vehicle: **Delta II**

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital Sciences Corp.**

Contractor Activity: **Spacecraft development**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **September 2011**
Initial Value of Contract: **$135.1 million**
Current Value: **$146.9 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost[a]
$860.3
~~$860.3~~
~~0.0%~~ CHANGE

Formulation Cost
$248.8
$248.8
0.0% CHANGE

Development Cost[a]
$558.9
~~$558.3~~
~~0.0%~~ CHANGE

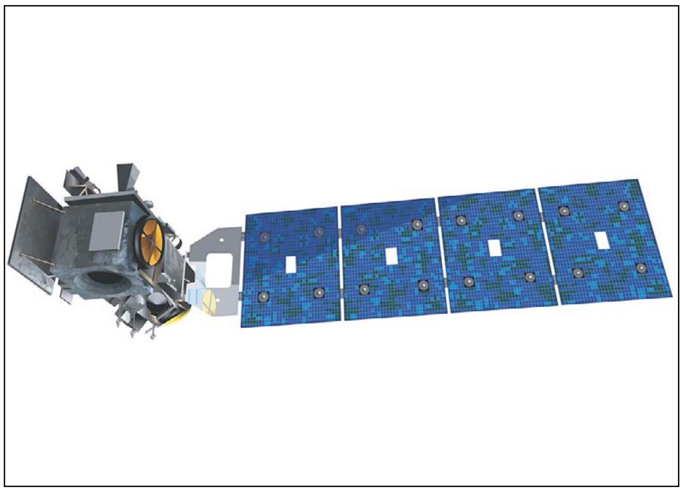
Operations Cost[a]
$52.9
~~$52.6~~
~~0.6%~~ CHANGE

Launch Schedule
05 2017 | 05 2017[a]
0 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2014[a]

[a]The project is undergoing a replan, and final cost and schedule information is not available.

NASA's Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) is a follow-on mission to ICESat, tasked with using space-borne altimetry measurements to measure changes in polar ice-sheet mass, in order to better understand mechanisms that drive change and the associated impact of change on global sea level. ICESat-2 will utilize a micro-pulse multi-beam laser instrument with a photon counting approach to measurement. This process will allow for dense cross-track sampling with a high repetition rate, allowing ICESat-2 to provide better elevation estimates than ICESat over high slope and rough areas.



Source: Orbital Sciences Corporation.

PROJECT SUMMARY

Due to ongoing design and development issues with the Advanced Topographic Laser Altimeter System (ATLAS) instrument – the project's single instrument that is being developed at Goddard Space Flight Center – the ICESat-2 project is undergoing a replan of its cost and schedule. As a result, preliminary estimates indicate that the project will exceed the agency baseline cost commitment by at least 15 percent and the committed launch readiness date of May 2017 will not be achieved. According to project officials, progress was slower than expected because, although the ATLAS subsystems were well understood individually, the project's overall systems engineering analysis was not mature enough to ensure that they would work together as a fully integrated instrument. To address these issues, Goddard Space Flight Center has replaced the instrument management team and added new technical expertise and resources.

Implementation
- **05/17** Committed launch readiness date (under review)
- **05/15** System integration review
- **02/14** Critical design review
- **12/13** GAO review
- **12/12** Project confirmation

Formulation
- **05/11** Mission/ System definition review
- **12/09** Formulation start

Ice, Cloud, and Land Elevation Satellite-2

PROJECT UPDATE

Design Issues

As a result of ongoing design and development issues with the ATLAS instrument – the project's single instrument – the ICESat-2 project is undergoing a replan of its cost and schedule. The project noted that the instrument's performance began to degrade in January 2013, one month after its plan was baselined at confirmation. The project is currently monitoring multiple risks related to the ATLAS instrument including delivery delays of some of ATLAS's 20 subsystems and development problems. For example, according to project officials, the instrument's most challenging subsystem is the optics subsystem, due to its very strict requirements. The project recently reported identifying several areas where requirements could be relaxed, which benefited multiple subsystems.

According to project officials, progress was slower than expected because, although the ATLAS subsystems were well understood individually, the project's overall systems engineering analysis was not mature enough to ensure that they would work together as a fully integrated instrument. To address these issues, Goddard Space Flight Center has replaced the instrument management team and added new technical expertise and resources. The Standing Review Board, which is formulated to independently assess NASA projects throughout their life cycles at designated reviews and when a special review is convened, will also conduct an assessment of the project's updated plan once complete. The ATLAS instrument is the basis of the ICESat-2 mission, so any risk to its completion, subsystem performance, or delivery has serious implications for the project launching on schedule and meeting its science goals.

Schedule Issues

Because of the ongoing cost and schedule replan of the ATLAS instrument, preliminary estimates indicated that the project's committed launch readiness date of May 2017 will not be achieved. The project critical design review was delayed in order to accommodate ATLAS delays, and the eventual integration and testing activities for the observatory will also be affected by the ATLAS delay. Recent estimates indicate that ATLAS has used all of its schedule reserve and is now planned for delivery in March 2016—nine months later than originally needed for integration onto the spacecraft.

The project's contractor has also developed a plan to revise the integration and test schedule for the observatory to conduct as many activities as possible ahead of ATLAS delivery, such as vibration testing utilizing an ATLAS mock-up. Although some tests, such as the thermal vacuum testing, would have to be repeated when ATLAS becomes available, project officials indicated that this plan could shorten the length of time required for integration and testing between the delivery of ATLAS and launch by as much as three months. According to agency officials, the evaluation of these proposals is on hold pending the ATLAS replan, and no contractual changes have been initiated.

Funding Issues

Based on the preliminary estimates, the project office reported that the ICESat-2's estimate at completion for development is expected to exceed its agency baseline cost commitment by more than 15 percent – $84 million at minimum. NASA's Science Mission Directorate has been notified by letter of the pending cost growth based on the preliminary estimates from the ATLAS instrument team that will be evaluated by center and agency management.

Project Office Comments

The ICESAT-2 project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

Project Challenges

- Funding (new)

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **Centre National d'Etudes Spatiales (France)and German Aerospace Center (DLR)**

Launch Location: **Vandenburg AFB, CA**

Launch Vehicle: **Atlas V**

Mission Duration: **2.5 years**

Requirement derived from:
NASA Strategic Plan

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft development**

Type of Contract: **Cost-Plus-Fixed-Fee and Cost-Plus-Award-Fee**
Date of Award: **October 2012**
Initial Value of Contract: **$208.8 million**
Current Value: **$220.2 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$675.1
$675.1
0.0% CHANGE

Formulation Cost
$98.9
$98.9
0.0% CHANGE

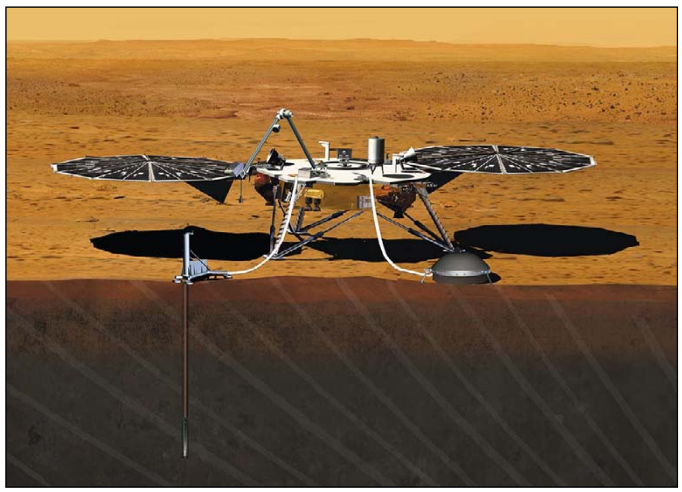
Development Cost
$541.8
$541.8
0.0% CHANGE

Operations Cost
$34.4
$34.4
0.0% CHANGE

Launch Schedule
03 2016 03 2016
0 months CHANGE

Baseline FY 2014
Latest Est. Feb 2014

The Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) is a Mars lander based on the Phoenix lander's design. The first objective is to understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars by determining the size, composition, and physical state of the core; the thickness of the crust; and the composition and structure of the mantle, as well as the thermal state of the interior. The second objective is to determine the present level of tectonic activity—the magnitude, rate, and geographical distribution of internal seismic activity—and the meteorite impact rate on Mars.



Source: NASA/Jet Propulsion Laboratory.

PROJECT SUMMARY

Project officials report that they are closely monitoring issues that could result in delays because missing the current launch window would delay the project by 26 months and increase project costs. According to the project office, cost increases are not a viable option for the project because it is planned as a low cost mission under NASA's Discovery Program and its costs have been capped. The project recently requested to rephase funds from later fiscal years to fiscal year 2014 in order to cover long lead item procurements identified by the contractor and other activities. However, according to project officials, as a result of price increases in subcontract and materials cost, overall planned project costs have increased. Project officials stated they addressed the cost increases by reducing procurement of selected hardware components and eliminating one redundant element.

Implementation

03/16 Committed launch date

10/14 System Integration review

06/14 Critical design review

03/14 Project confirmation

12/13 GAO review

10/13 Preliminary design review

Formulation

07/12 Formulation start

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

PROJECT UPDATE

The project held a confirmation review meeting in December 2013, and received formal approval to enter the implementation phase in March 2014.

Funding Issues

Project officials report that they closely monitor schedule issues because missing the current launch window would delay the project by 26 months and increase project costs. According to the project office, cost increases are not a viable option for the project because it is planned as a low cost mission under NASA's Discovery Program and its costs have been capped.

The project requested to rephase funds from fiscal years 2015 and 2016 into fiscal year 2014 to cover risk reduction activities, such as long lead procurements, early design work, and build of additional development hardware in order to maintain desired schedule margin. Overall planned project costs have increased due to increases in subcontract components and materials procurements. Project officials stated that they addressed the cost increases by reducing the procurement of selected high cost hardware components and eliminating one redundant element.

Other Issues to be Monitored

The project is currently tracking risks related to its mass and energy margins. For example, as a result of design changes to the existing spacecraft from the Phoenix project, as well as design changes to InSight payload elements, the project is concerned about mass growth. Specifically, the project is particularly concerned about the projected mass of the spacecraft upon entry, descent, and landing on Mars. The project is also concerned with the amount of energy the spacecraft will have to conduct science experiments on Mars due to dust storms which could reduce power and impact scientific capabilities.

The anticipated path on which the spacecraft will travel does not allow for tracking via only the Deep Space Network—NASA's world-wide network of large antennas and communication facilities that supports interplanetary missions. Without supplemental measurements from the European Space Agency (ESA) or Japan Aerospace Exploration Agency tracking stations, the spacecraft might not meet the required target location on Mars. Therefore, NASA is in discussions with ESA and the Japanese Space Agency regarding the feasibility and approach for utilizing their tracking stations.

Project Office Comments

The InSight project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

James Webb Space Telescope

Recent/Continuing Project Challenges

- Design/Technology
- Funding
- Test and Integration

Previously Reported Challenges

- Contractor

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partners:
European Space Agency, Canadian Space Agency
Launch Location: **Kourou, French Guiana**
Launch Vehicle: **Ariane 5 (ESA Supplied)**

Mission Duration: **5 years (10 year goal)**

Requirement derived from:
2001 Astrophysics Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Northrop Grumman Aerospace Systems**

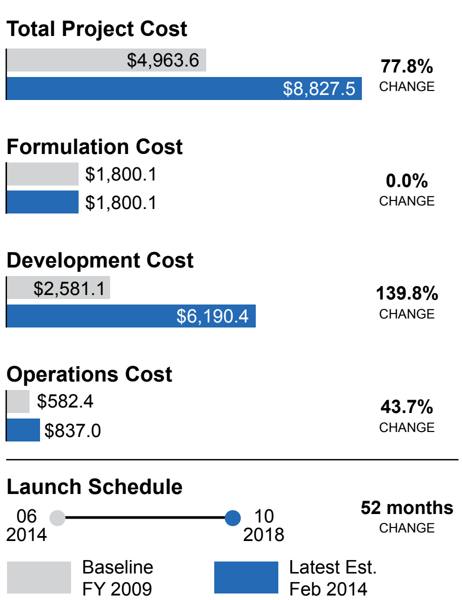
Contractor Activity: **Spacecraft development and other components**

Type of Contract: **Cost-Plus-Award-Fee/ Incentive-Fee**

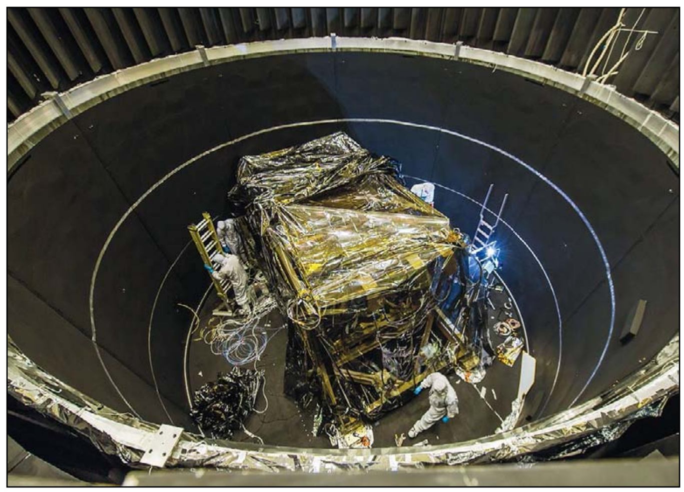
Date of Award: **2002**
Initial Value of Contract: **$824.8 million**
Current Value: **$3.54 billion**

PROJECT PERFORMANCE

Then year dollars in millions



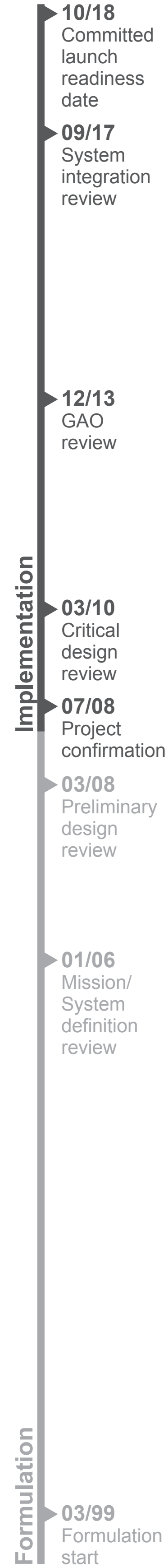
The James Webb Space Telescope (JWST) is a large, infrared-optimized space telescope that is designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, the formation of stars and planetary systems, and characteristics of planetary systems. JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range. JWST will have a large primary mirror composed of 18 smaller mirrors and a sunshield that is the size of a tennis court. Both the mirror and sunshield will unfold and open once JWST is in outer space. JWST will reside in an orbit about 1 million miles from the Earth.



Source: NASA JWST Program Office.

PROJECT SUMMARY

JWST is generally executing to its September 2011 revised cost and schedule baseline and maintaining 13.25 months of funded schedule reserve. However, monthly performance has declined more recently in fiscal year 2013. The project has made progress addressing some technical challenges reported last year but, several challenges—such as cryocooler development—remain that could affect continued progress. In addition, while overall the project is maintaining a significant amount of cost reserves, low levels of near-term cost reserves could limit its ability to meet future cost and schedule commitments. Additionally, GAO's analysis of three subsystem schedules determined that the reliability of the project's integrated master schedule—which is dependent on the reliability of JWST's subsystem schedules—is questionable.



James Webb Space Telescope

PROJECT UPDATE

In January 2014, GAO issued a report on JWST and made two recommendations on the project's cost reserves and lack of schedule risk analyses. GAO also advised that Congress require NASA to conduct an updated joint cost and schedule confidence level analysis based on a reliable schedule and current risks. Overall performance data from the prime contractor indicate that generally work is being accomplished on schedule and at the cost expected. Below is a summary of key issues identified in that report.[a]

Design/Technology Issues

The project has made progress addressing some technical challenges such as inadequate spacecraft mass margin, but others have persisted, causing subsystem development delays and cost increases. For example, the development and delivery schedule of the cryocooler—which cools one JWST instrument—was delayed due to technical issues. Its contract was modified in August 2013 for the second time in less than 2 years with a cumulative 120 percent increase in contract costs. While contractor officials state that they believe they understand the causes of the technical issues, execution of the cryocooler remains a concern given that performance and schedule issues persist.

Funding Issues

More recent monthly performance data by the prime contractor has declined in fiscal year 2013 as the project approached the last critical design review in January 2014 on the spacecraft bus. Overall the project is maintaining a significant amount of cost reserves; however, low levels of near-term cost reserves could limit its ability to meet future cost and schedule commitments. Development challenges have required the project to allocate a significant portion of cost reserves in fiscal year 2014. Adequate cost reserves for the prime contractor are also a concern in fiscal years 2014 and 2015. Limited reserves could require work to be extended or deferred—a contributing factor to the project's prior performance issues that led to the project being rebaselined in 2011 with a 78 percent increase to the life-cycle cost estimate—now $8.8 billion—and a launch delay of 52 months—now October 2018.

[a] *GAO, James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress, GAO-14-72 (Washington, D.C.: Jan. 4, 2014).*

Test and Integration Issues

The project is maintaining 13.25 months of funded schedule reserve as it conducts the first of five integration and test efforts. According to the project, an Integrated Science Instrument Module (ISIM) cryo-vacuum risk reduction test had to be truncated due to the government shutdown in October 2013 and not all planned work was completed. While the project reported many of the test objectives were completed before the shutdown, this increases the risk of the second ISIM cryo-vacuum test, planned for later in 2014, not finishing on schedule and delaying other critical activities that occur after the test.

Other Issues to be Monitored

GAO's analysis of three subsystem schedules determined that the reliability of the project's integrated master schedule—which is dependent on the reliability of JWST's subsystem schedules—is questionable. GAO's analysis in 2012 came to the same conclusion on the integrated master schedule. In addition, reliable schedule risk analyses of the Optical Telescope Element, the cryocooler, and the Integrated Science Instrument Module schedules were not performed. A schedule risk analysis is a best practice that gives confidence that estimates are credible based on known risks so the schedule can be relied upon to track progress.

Project Office Comments

The JWST project provided technical comments to a draft of this assessment, which were incorporated as appropriate. Project officials also commented that NASA has concluded that its monthly cost/risk assessments and schedules risk analysis on existing schedules of critical JWST elements are credible and sufficient enough to not warrant conducting a new joint cost and schedule confidence level analysis.

Lunar Atmosphere and Dust Environment Explorer

Previously Reported Challenges

- Test and Integration
- Launch
- Technology
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Ames Research Center

Partners: **U.S. Air Force (Launch Vehicle) and NASA Goddard Space Flight Center (Science Payloads)**

Launch Location: **Wallops Flight Facility, VA**
Launch Vehicle: **Minotaur V**

Mission Duration: **180 days**

Requirement derived from:
Scientific Context for the Exploration of the Moon

CONTRACT INFORMATION

Current highest value contract

Contractor: **Space Systems Loral**

Contractor Activity: **Spacecraft Propulsion**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **January 2010**
Initial Value of Contract: **$9.3 million**
Current Value: **$12.5 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2010	Latest Est. Feb 2014	Change
Total Project Cost	$262.9	$281.5	7.1%
Formulation Cost	$79.5	$79.5	0.0%
Development Cost	$168.2	$191.4	13.8%
Operations Cost	$15.2	$10.6	-30.3%
Launch Schedule	11 2013	09 2013	-2 months

The Lunar Atmosphere and Dust Environment Explorer (LADEE) mission is planned to assess the global density, composition, and time variability of the lunar atmosphere. LADEE's measurements should determine the size, charge, and spatial distribution of electrostatically transported dust grains. Additionally, LADEE is designed to carry an optical laser communications demonstrator that will test high-bandwidth communication from lunar orbit.

Source: LADEE Project.

PROJECT SUMMARY

The LADEE project successfully launched on September 6, 2013 as planned. The project office reported that on August 2, 2013 LADEE completed Key Decision Point E review, when an additional $18.6 million was added to the project's budget total. The additional funds included $4.2 million for increased mission operations costs and $783,000 to ensure that data returned from the mission conforms to NASA standards, which will put the science data into context for future use and analysis. Project officials reported that the new life cycle cost estimate approved at KDP E also would have allowed LADEE to launch as late as October 14, 2013. In January 2014, NASA announced that LADEE was approved for a 28 day mission extension. The spacecraft is now expected to impact the lunar surface on or around April 21, 2014 depending on the final trajectory.

Project Office Comments

The LADEE project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Implementation

- **12/13** GAO review
- **09/06/13** Launch date
- **11/12** System integration review
- **05/11** Critical design review
- **08/10** Project confirmation

Formulation

- **07/10** Preliminary design review
- **07/09** Mission/System design review
- **02/09** Formulation start

PAGE INTENTIONALLY LEFT BLANK

COMMON NAME: **MMS**

Magnetospheric Multiscale

Project Challenges

- Funding (new)
- Parts

Previously Reported Challenges

- Test and Integration
- Contractor
- Design
- Development Partner
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partners:
Austria, France, Japan, Sweden

Launch Location: **Kennedy Space Center, FL**
Launch Vehicle: **Atlas V**

Mission Duration: **2 years**

Requirement derived from: **NASA Strategic Plan**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Southwest Research Institute**

Major Contractor: **Instrument development**

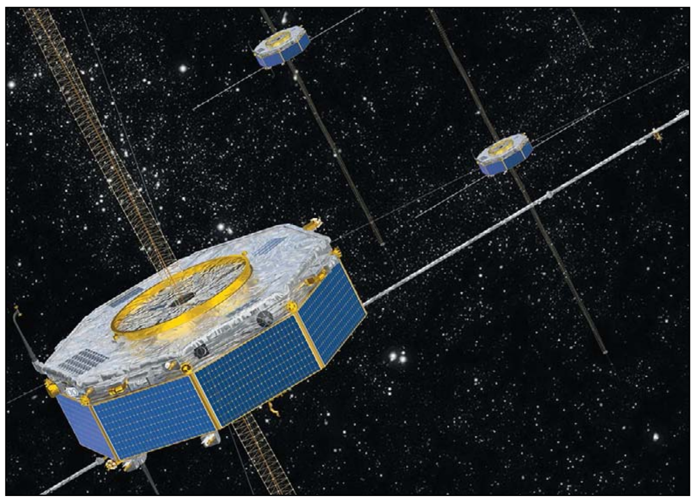
Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **April 2004**
Initial Value of Contract: **$229.4 million**
Current Value: **$224.9 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2009	Latest Est. Feb 2014	Change
Total Project Cost	$1082.7	$1081.1	-0.15%
Formulation Cost	$173.0	$172.9	0.0%
Development Cost	$857.4	$856.7	-0.1%
Operations Cost	$52.3	$51.5	-1.5%
Launch Schedule	03 2015	03 2015	0 months

The Magnetospheric Multiscale (MMS) is comprised of four identical spacecraft—each containing 27 instrument components. The mission is planned to use the Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. Magnetic reconnection is the primary process by which energy is transferred from solar wind to Earth's magnetosphere and is the physical process determining the size of a space weather storm. The four spacecraft will fly in a tetrahedron formation, adjustable over a range of approximately 6 to 250 miles. The data from MMS is intended to be used to help predict space weather in support of terrestrial and space exploration activities.



Source: MMS Project Office.

PROJECT SUMMARY

The project is tracking risks that cost reserves may be inadequate and that the project may overrun its cost baseline. In addition to other challenges encountered during implementation, the project discovered optocoupler failures in some of its four Fast Plasma Instrument (FPI) suites. The project completed the first half of a test program to determine the cause and extent of the failures and resumed the second half in January 2014. As a result of the government shutdown, the project's planned launch date of October 2014 was rescheduled to March 2015, the agency's baseline commitment date for launch. However, the project's committed level of funding is insufficient to cover this slip, and, as a result, project costs are expected to exceed the agency baseline commitment by at least $26 million.

Magnetospheric Multiscale

PROJECT UPDATE

After numerous schedule slips, the project reported completing integration of each of the project's four identical mission observatories as well as environmental testing on three of the four observatories. However, as a result of the government shutdown, schedule reserves have fallen below plan, and the project's planned launch date of October 2014 will need to be rescheduled. Due to a crowded launch manifest, the next available launch slot available to the project is in March 2015.

Funding Issues

Project officials are tracking a risk that available funding for MMS may prove inadequate. According to project officials, the project has used cost reserves as planned for integration and test activities. However, the project has consumed nearly its entire available budget but has not yet completed its integration and test phase, where projects typically realize cost and schedule growth. The delay of the project's planned launch from October 2014 to March 2015 would require approximately an additional $39 million in funding. As a result of this delay, the project will exceed its currently available reserves and committed level of funding by at least $26 million, in addition to any further reserves needed to complete remaining integration and test activities or mitigate other issues that arise.

In 2012, NASA requested a new budget from the Southwest Research Institute (SwRI) following cost overruns during previous instrument development efforts. Until August 2013, the project tracked the risk of a cost overrun on the contract with SwRI.

Parts Issues

The MMS project reports that flight-unit testing of the project's Fast Plasma Instrument (FPI) suites resulted in failures in high-voltage electronic parts known as optocouplers. Each observatory's FPI suite includes eight instruments, for a total of 32. Among these instruments, a total of 288 optocouplers are required. As we reported in 2011, optocouplers have caused problems in several other space and missile defense programs.[a] The project office has implemented a program of X-ray and thermal testing of flight-model and spare optocouplers to determine the cause and extent of the failures. The project completed the first half of a test program to determine the cause and extent of the failures, resumed the second half of the planned tests in January 2014, and plans to complete them in May 2014. Based on the results of the first set of tests, the project stated that rework and replacement of the majority of optocouplers is unlikely. However, should such an effort become necessary, it could further exceed the project's available funding. Given that the root cause of the failures is unknown, the project is tracking a risk that the part may fail on orbit, leading to instrument degradation or failure. On-orbit failures of these parts would reduce science returns from the MMS mission. The project office has committed $2.15 million in reserve funds to resolve the FPI optocoupler issue, based on modestly optimistic estimates of the work required to mitigate the risk of lost science returns.

[a]*GAO, Space and Missile Defense Acquisitions: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs,* GAO-11-404 (Washington, D.C.: June 24, 2011).

Project Office Comments

The MMS project provided technical comments to a draft of this assessment, which were incorporated as appropriate. The project also reported that significant progress has recently been made with respect to the optocoupler issues discussed.

Mars Atmosphere and Volatile EvolutioN

Project Challenges
- Parts

Previously Reported Challenges
- Launch
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **Institute of Research for Astrophysics and Planetology, Toulouse, France**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **Atlas V**

Mission Duration: **10-month cruise to Mars and 1-year science mission**

Requirement derived from:
Response to the Mars Scout 2006 and Missions of Opportunity Announcement of Opportunity

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin Space Systems**

Contractor Activity: **Spacecraft development**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **April 2009**
Initial Value of Contract: **$237 million**
Current Value: **$250.6 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$671.2
$636.5
-5.2% CHANGE

Formulation Cost
$63.9
$63.9
0.0% CHANGE

Development Cost
$567.2
$489.4
-13.7% CHANGE

Operations Cost
$40.1
$83.2
107.5% CHANGE

Launch Schedule
11 2013 — 11 2013
0 months CHANGE

Baseline FY 2011 | Latest Est. Feb 2014

The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission, a robotic orbiter mission, is to provide a comprehensive picture of the Mars upper atmosphere, ionosphere, solar energetic drivers, and atmospheric losses. MAVEN is to deliver comprehensive answers to long-standing questions regarding the loss of Mars' atmosphere, climate history, liquid water, and habitability and provide the first direct measurements ever taken to address key scientific questions about Mars' evolution.

Source: ©2013 Lockheed Martin.

PROJECT SUMMARY

MAVEN launched on November 18, 2013, at the project's first launch opportunity. The project's launching on schedule was important because the next available launch opportunity would have occurred 26 months later and a delay would have impacted potential science returns. MAVEN is expected to arrive at Mars on September 22, 2014. The MAVEN project maintained a cumulative cost underrun of about $35 million through launch, as a result of work efficiencies and lower labor costs. Following a cost-to-complete review in February 2013, NASA decided to reallocate $27.5 million initially budgeted for mission development to the mission's operations phase in order to address concerns about the adequacy of planned staffing levels' ability to achieve the project's science objectives.

12/13 GAO review

11/18/13 Launch date

06/12 System integration review

07/11 Critical design review

10/10 Project confirmation

Implementation

07/10 Preliminary design review

09/08 Formulation start

Formulation

Mars Atmosphere and Volatile EvolutioN

PROJECT UPDATE

The MAVEN spacecraft launched successfully at the opening of the project's 20-day launch window on November 18, 2013. Maintaining schedule was important because the next available launch opportunity would have occurred 26 months later and a delay would have impacted potential science returns. MAVEN is expected to arrive at Mars on September 22, 2014.

The MAVEN project maintained a cumulative cost underrun of about $35 million through launch as a result of work efficiencies and lower labor costs. MAVEN indicated that following a cost-to-complete review in February 2013, NASA decided to reallocate $27.5 million initially budgeted for mission development to the mission's operations phase. The project office described this shift as a response to the results of MAVEN's Mission Operations Review, which highlighted concerns about the adequacy of planned staffing to achieve the project's science objectives.

Parts Issues

The project reported that thermal-vacuum testing led to the discovery of unevacuated air in two of the reaction-wheel assemblies—used to control the spacecraft's orientation—which may have restricted the spacecraft's range of motion in case of a failure after launch. The project shipped two of four flight models and a spare to their manufacturer for testing and subsequent rework. Project officials stated that the reworked flight assemblies were reintegrated and regression testing was completed at Kennedy Space Center without affecting the project's cost or schedule margins.

In two of its instruments, MAVEN uses the same optocouplers—high voltage electronic parts—that have recently experienced failures during testing on the Magnetospheric Multiscale (MMS) project. After hundreds of hours of environmental testing on the MAVEN instrument suites, the project office reported no performance by the MAVEN optocouplers that resemble the performance of MMS optocouplers before they failed.

The Neutral Gas and Ion Mass Spectrometer (NGIMS) instrument was removed from the spacecraft at Kennedy Space Center due to a recurrence of a current spike in the radio frequency module that had been observed on only two prior occasions and that the project was unable to duplicate. The radio frequency module was swapped out with the flight spare at Goddard Space Flight Center. NGIMS was reassembled, tested, and returned to Kennedy Space Center for reinstallation. A full regression test and comprehensive performance test were successfully completed at the spacecraft level. Current spikes have not occurred again since the flight spare radio frequency module was installed.

Project Office Comments

The MAVEN project provided technical comments to a draft of this assessment, which were incorporated as appropriate. The project reported that MAVEN is currently in the operations and sustainment phase, having successfully launched at the opening of the launch window on November 18, 2013 from Cape Canaveral Air Force Station. All spacecraft systems continue to perform well. According to project officials, the first trajectory correction maneuver, instrument activations and checkouts, and observations of the comet ISON occurred in December 2013. According to project officials, the post launch assessment review was conducted in January and the Electra telecommunications relay package was activated in February 2014 as planned. The project further commented that MAVEN continues to meet its cost and schedule commitments with adequate reserves.

Orbiting Carbon Observatory 2

Previously Reported Challenges

- Funding
- Parts
- Design
- Launch

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **None**

Launch Location: **Vandenberg AFB, CA**
Launch Vehicle: **Delta II**

Mission Duration: **2 years**

Requirement derived from:
2000-2010 NASA Earth Science Research Strategy

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital Science Corporation**

Contractor Activity: **Spacecraft development**

Type of Contract: **Cost-Plus-Incentive-Fee**
Date of Award: **May 2010**
Initial Value of Contract: **$48 Million**
Current Value: **$69.6 Million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$349.9
$467.5
33.6% CHANGE

Formulation Cost
$60.9
$60.9
0.0% CHANGE

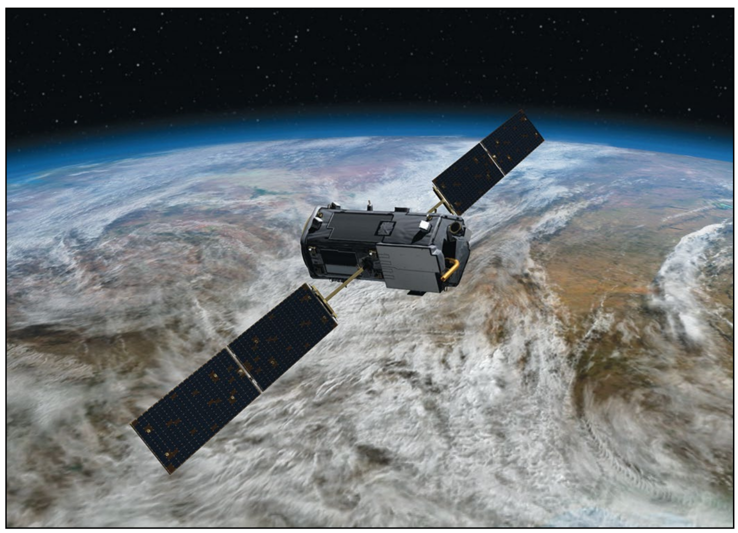
Development Cost
$249.0
$371.6
49.2% CHANGE

Operations Cost
$40.0
$35.0
-12.5% CHANGE

Launch Schedule
02 2013 — 02 2015
24 months CHANGE

Baseline FY 2010 | Latest Est. Feb 2014

NASA's Orbiting Carbon Observatory 2 (OCO-2) is being designed to enable more reliable predictions of climate change and is based on the original OCO mission that failed to reach orbit in 2009. It is planned to make precise, time-dependent global measurements of atmospheric carbon dioxide. These measurements will be combined with data from a ground-based network to provide scientists with information needed to better understand the processes that regulate atmospheric carbon dioxide and its role in the carbon cycle. NASA expects enhanced understanding of the carbon cycle will improve predictions of future atmospheric carbon dioxide increases and the potential impact on the climate.



Source: Jet Propulsion Laboratory (artist depiction).

PROJECT SUMMARY

The OCO-2 life cycle cost estimate remained stable following last year's cost growth and schedule delay stemming from the late selection of the Delta II as the project's launch vehicle. According to project officials, the spacecraft is currently scheduled to arrive at its launch site, Vandenberg Air Force Base in California, on April 24, 2014 for a planned launch in July 2014. Project officials report that they resolved the risk that launch-related hardware such as the payload attach fitting will be delivered later than initially expected and that all necessary hardware has now been delivered.

02/15 Committed launch readiness date

07/14 Manifested launch date

12/13 GAO review

05/12 System integration review

Implementation

09/10 Project confirmation

Formulation

03/10 Formulation start

Orbiting Carbon Observatory 2

PROJECT UPDATE

Issue Update

The project reported that the launch vehicle provider has delivered all necessary hardware, such as the payload attach fitting, which includes the payload separation system and allows the spacecraft to interface with the launch vehicle. A launch date of July 1, 2014 has been coordinated with the Vandenberg Air Force Base in California.

Project officials reported that the project is operating within the new funding profile established last year as a result of a change in launch vehicle plans. However, according to project officials, the project's Phase D was replanned due to the lateness of the change, and as a result, the contract value increased by about $15 million.

Last year, the project identified a risk of potential failure with its reaction wheel assemblies—rotating wheels used to control the spacecraft's orientation—that led to the project selecting new wheels. Project officials reported that the wheels have been successfully replaced and integrated onto the spacecraft at a cost of roughly $3 million—$2.9 million for the wheels plus an additional $158 thousand for expediting the procurement—which was fully covered by project reserves. The observatory is currently undergoing final assembly test and launch operations testing, which is expected to be complete in early 2014.

Project Office Comments

The OCO-2 project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer

Recent/Continuing Project Challenges

- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **Canadian Space Agency**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **ATLAS V**

Mission Duration: **7 years**

Requirement derived from: **NASA Strategic Plan Goal 2.3; 2013 Agency Performance Goal 2.3.1.2**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin Space Systems Company**

Contractor Activity: **Spacecraft development**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **January 2012**
Initial Value of Contract: **$315.9 million**
Current Value: **$321.8 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$1121.4
$1064.2
-5.1% CHANGE

Formulation Cost
$144.3
$144.3
0.0% CHANGE

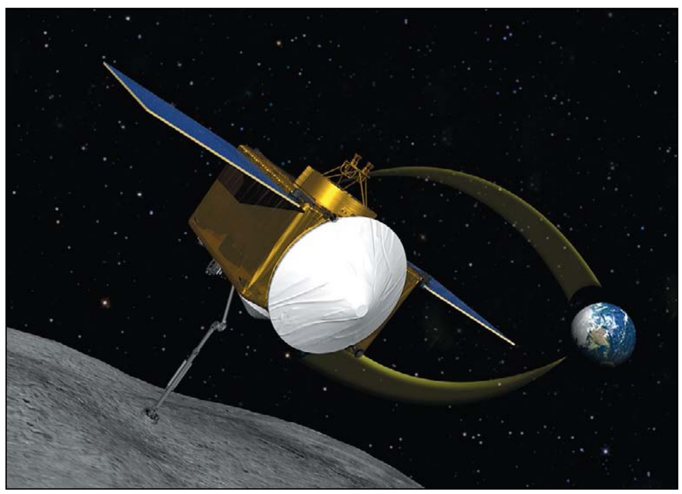
Development Cost
$778.6
$721.6
-7.3% CHANGE

Operations Cost
$198.5
$198.3
-0.1% CHANGE

Launch Schedule
10 2016 | 10 2016
0 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2014

The Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) spacecraft will travel to a near-Earth asteroid and use a robotic arm to retrieve samples that could better explain our solar system's formation and how life began. The OSIRIS-REx mission has five planned science objectives: (1) return and analyze a sample, (2) document the sample site, (3) create maps of the asteroid, (4) measure forces on the asteroid's orbit that makes it an impact threat to the Earth, and (5) compare the asteroid's characteristics with ground-based telescopic data of the entire asteroid population. If successful, OSIRIS-REx will be the first U.S. mission to return samples from an asteroid to Earth.



Source: OSIRIS-Rex Project Office, NASA/GSFC.

PROJECT SUMMARY

The project was approved to enter its final design and fabrication phase in May 2013 with a life-cycle cost estimate of $1.121 billion. The project is tracking several issues related to the delivery of instruments and key flight hardware components. For example, the laser altimeter being developed by the Canadian Space Agency will likely be delivered past its need date for integration onto the spacecraft, and the guidance, navigation, and control light detection and ranging (GNC LIDAR) instrument may not complete development in time for spacecraft integration and testing. Due to its criticality to the mission, the project is pursuing a back up approach for the GNC LIDAR that would prevent a launch delay if delivery of the LIDAR is late. The mission's destination requires a launch during its 39 day window between September and October 2016 because the project's available budget could not accommodate the back-up launch windows in 2017 or 2022.

Implementation

10/16 Committed launch readiness date

02/15 System integration review

04/14 Critical design review

12/13 GAO review

05/13 Project confirmation

03/13 Preliminary design review

Formulation

05/12 Mission/ System design review

05/11 Formulation start

Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer

PROJECT UPDATE

The project successfully passed its key decision point C review and entered the final design and fabrication phase of implementation in May 2013 with a life-cycle cost estimate of $1.121 billion. According to project officials, at the project's confirmation review, adequate funding was identified to retain all five planned science instruments and all associated science requirements were finalized.

Development Partner Issues

Project officials reported that the Canadian Space Agency's (CSA) laser altimeter instrument—one of the five planned mission instruments which will be used to create a 3-dimensional model of the asteroid—will likely be delivered past its need date for integration onto the spacecraft due to the CSA receiving the funds later than expected from the Canadian government. As a result, integration and test activities will be adjusted to accommodate the late delivery. Project officials stated they are working with CSA to recover schedule margin where possible. For example, the project is providing excess parts to CSA from other project elements.

Other Issues to be Monitored

The project is currently tracking a risk regarding the potential impact of a late delivery of the guidance, navigation, and control light detection and ranging (GNC LIDAR) instrument, which uses a light sensing technology to guide the spacecraft toward the asteroid. The project is concerned that the GNC LIDAR units may either miss delivery to the spacecraft for integration or fail on orbit as a result of the small company building these units for a long duration of flight for the first time. Currently, the project is reporting 20 working days of schedule reserve to the date the LIDAR is required for integration and test in February 2015. If the GNC LIDAR is not ready to be integrated on the spacecraft on time, then costs could increase in order to accommodate a late delivery or launch readiness could be missed. However, the project is pursuing a back up approach that will use camera-based natural feature tracking of the asteroid to provide the same type of range data as the GNC LIDAR. The project has allocated $6.9 million of its reserve funding to cover the cost of the cameras and development of the natural feature tracking algorithms and software and system testing.

The project maintains a 39-day launch window between September and October 2016, and officials stated that the mission could also launch during a back-up window of similar duration approximately one year later; however the spacecraft would have to carry more fuel for maneuvering in space because it would not receive an assist from Earth's gravity as in the planned window. Further, project officials stated that the current project budget would not support a one-year launch delay. After 2017, the next opportunity for launch would occur in 2022, when the Earth and the asteroid orbit phasing returns to a favorable alignment.

Project Office Comments

The OSIRIS-REx project provided technical comments to a draft of this assessment, which were incorporated as appropriate. The project also noted that the project assessment accurately reflects the current status of the project.

Orion Multi-Purpose Crew Vehicle

Recent/Continuing Project Challenges

- Funding
- Design

PROJECT ESSENTIALS

NASA Center Lead: **Johnson Space Center**

International Partner: **European Space Agency**

Launch Location: **Kennedy Space Center, FL**
Launch Vehicle: **Space Launch System**

Mission Duration: **Varied based on destination**

Requirement derived from: **NASA Authorization Act of 2010 Public L. No. 111-267, §§ 303, 304**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft Development**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **February 2014**
Initial Value of Contract: **$6.66 billion**
Current Value: **$11.76 billion**

PROJECT PERFORMANCE

Then year dollars in billions

Preliminary estimate of Project Life Cycle Cost*

Latest: **Feb 2014** **$8.5 - $10.3 BILLION**

**This estimate is preliminary as the project is in formulation and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes*

Launch Schedule

First Non-Crewed Launch Date: **Dec 2017**
First Crewed Launch Date: **Aug 2021**

Orion is being developed to conduct in-space operations beyond low Earth orbit and to service the International Space Station if necessary. Under the Orion program, NASA is continuing to advance development of the human safety features, designs, and systems of the former Orion project under the Constellation program which was cancelled in February 2010. Orion is planned to launch atop NASA's Space Launch System. The current design of Orion consists of a crew module, service module, and launch abort system.

Source: Space City Films.

PROJECT SUMMARY

The Orion program is developing and building hardware for its first exploration flight test (EFT-1) in September 2014, but development challenges continue to threaten the program. The mass of the spacecraft remains a top program risk. Despite mass reduction efforts, the spacecraft could be up to 2,800 pounds over the maximum lift-off mass requirement for the un-crewed first exploration mission flight (EM-1) of the Space Launch System in 2017. The program has made changes to the heat shield's design in order to address the possibility of cracks between its ablative material and the underlying shield structure due to thermal expansion during its initial test flight in 2014; however, the spacecraft is expected to undergo more stressful temperatures during later launches.

Implementation

- **08/21** First crewed launch date
- **12/17** First non-crewed launch date
- **04/15** Critical design review
- **12/14** Project confirmation

Formulation

- **09/14** First exploration flight
- **08/14** Orion preliminary design review
- **12/13** GAO review
- **02/12** Orion formulation start
- **02/10** Orion cancelled under Constellation Program
- **08/09** Orion preliminary design review
- **07/06** Orion Project formulation start

Orion Multi-Purpose Crew Vehicle

PROJECT UPDATE

Funding issues

According to NASA, constrained funding has forced the program to adopt an incremental development approach. For example, to stay within budget, the program deferred a second round of testing for the launch abort system, which carries the crew away from the launch vehicle in case of a failed launch. NASA originally scheduled this test for 2014, about 7 years before the first crewed flight (EM-2) in 2021. Now, the test is scheduled for 2018, or 3 years prior to the crewed flight. By delaying this test some 4 years, NASA will have only about half the amount of time to address any issues discovered during the 2018 test. The program is willing to accept this risk based on prior testing and intends for EFT-1 to help mitigate technical issues. However, the program also indicated that, should unexpected technical issues arise, there is increased risk of cost increases and schedule delays for the crewed EM-2 flight in 2021.

Design Issues

Program documents indicate that, even with mass reduction efforts ongoing through 2013, the spacecraft could be up to 2,800 pounds over the maximum lift-off mass requirement of 73,500 pounds for the Space Launch System's EM -1 in December 2017. According to program officials, no additional dedicated mass reduction efforts will occur prior to EM-1 because the Orion can perform assigned EM-1 and EM-2 exploration missions within the currently- predicted mass of the Orion and expected performance of the Space Launch System. Instead, the program plans to relieve mass issues by utilizing performance margins they anticipate to be available on the Space Launch System and by adjusting mission parameters, such as load, crew size, and mission duration. Officials stated that, if NASA or the Administration defined a yet-unspecified mission requiring the Orion to meet allocated lift-off mass, design changes to the spacecraft could be required.

The program expects to downgrade a risk associated with the Orion heat shield, but design challenges with this technology remain. Program officials continue to track a risk that the thermal protection system could develop cracks between its ablative material and the underlying shield structure due to thermal expansion prior to the Orion's reentry into the Earth's atmosphere. According to the officials, additional coating has been added to the shield and delivery is on schedule. They noted, however, that the spacecraft will encounter hotter, more stressful temperatures during reentry, when the crew module returns from lunar destinations. As a result, some risk remains beyond EFT-1. Officials stated that the program will continue to monitor and mitigate any issues with the heat shield and thermal protection system.

Additionally, the Orion service module, which supplies propulsion, life support, and power and is being provided by ESA, is experiencing design issues. The preliminary design review for the module slipped some 10 months to allow more time to complete design trade-offs, increase design maturity, and identify potential mass reduction opportunities. Program officials stated that the ESA module will be used in EM-1, but a second module not yet on contract will be required for EM-2.

Other Issues to be Monitored

Development of Orion continues under a contract awarded in 2006 for development of the Orion vehicle under the Constellation program. Pursuant to contract modification in February 2014, this contract is currently valued at $11.76 billion for work through December 2020.

Project Office Comments

The program provided technical comments to a draft of this assessment, which were incorporated as appropriate. Additionally, officials noted that Orion achieved a major milestone in 2013 by reaching the preliminary design phase, and that they anticipate completion of preliminary design and integration activities in 2014. The agency also stated that the program is focused on implementing the Orion design and flying the capsule's missions within established cost and schedule commitments and, as future missions are defined, the design could evolve based on flight experience and a block upgrade development approach.

Soil Moisture Active and Passive

Project Challenges

- Parts/Test and Integration (new)

Previously Reported Challenges

- Launch
- Design
- Funding
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partner: **None**

Launch Location: **Vandenberg AFB, CA**
Launch Vehicle: **Delta II**

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Northrop Grumman Aerospace Systems**

Contractor Activity: **Reflector Boom Assembly development**

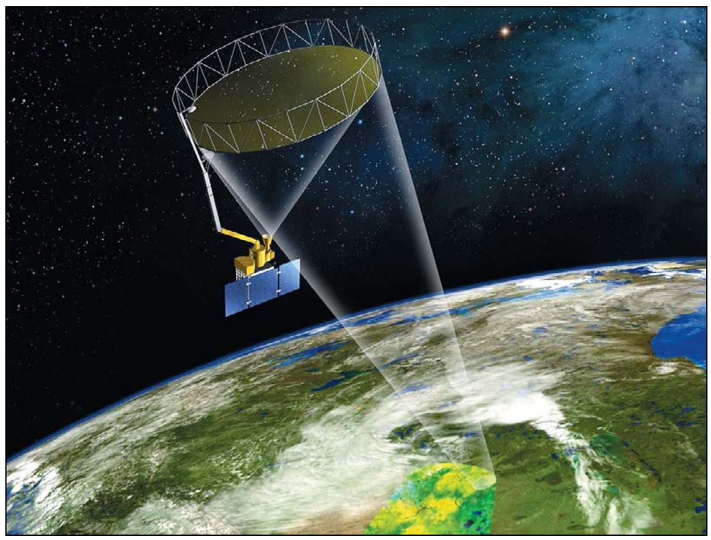
Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **June 2009**
Initial Value of Contract: **$20.0 million**
Current Value: **$47.0 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2012	Latest Est. Feb 2014	Change
Total Project Cost	$916.5	$914.6	-0.2% CHANGE
Formulation Cost	$388.2	$388.2	0.0% CHANGE
Development Cost	$485.7	$490.0	0.9% CHANGE
Operations Cost	$42.6	$36.4	-15% CHANGE
Launch Schedule	03 2015	03 2015	0 months CHANGE

NASA's Soil Moisture Active and Passive (SMAP) mission leverages previous Earth Science missions and is based on the soil moisture and freeze/thaw mission concept developed by an earlier mission known as Hydros. SMAP is designed to provide new information on global soil moisture and its freeze/thaw state enabling new advances in hydrospheric science and applications. These measurements will improve understanding of regional and global water cycles and climate changes, and improve the accuracy of weather, flood, and drought forecasts.



Source: 2011 California Institute of Technology/Jet Propulsion Laboratory.

PROJECT SUMMARY

The spacecraft's subsystems are being completed on or ahead of schedule, which enabled integration and testing to begin 7 weeks earlier than planned—however, there have been several delayed instrument sub-system deliveries due to manufacturing and testing challenges. For example, the reflector boom assembly was delivered in December 2013, one month later than initially planned due to design issues encountered last year with the assembly's deployment mechanism and slow technical progress. Following the late delivery, technical issues with the reflector boom assembly and other components have occurred during testing, and as a result, mitigation activities are expected to severely impact cost and schedule resources. According to the project, the current completion plan is realistic, but there will be little margin to accommodate any further slippage.

Implementation

- **03/15** Committed launch readiness date
- **11/14** Manifested launch date
- **12/13** GAO review
- **04/13** System integration review
- **07/12** Critical design review
- **06/12** Project confirmation

Formulation

- **10/11** Preliminary design review
- **02/09** Mission/ System design review
- **09/08** Formulation start

Soil Moisture Active and Passive

PROJECT UPDATE

Parts/Test and Integration Issues

Subsystems for the spacecraft were completed on schedule or earlier which enabled the spacecraft integration and testing to begin 7 weeks early. However, several instrument-related subsystem deliveries were delayed because of manufacturing and testing challenges. For example, the reflector boom assembly was delivered to the project in December, one month later than planned due to design issues encountered last year with the assembly's deployment mechanism and slow technical progress. The project used engineering models to mitigate testing risk, and replanned the integration and test schedule since the reflector boom assembly was not needed at the beginning of integration and testing on the observatory. Following the late delivery of the reflector boom assembly, technical issues with it and other components have occurred during testing, and as a result, mitigation activities are expected to severely impact cost and schedule resources. The planned integration and test activities for the observatory have been further adjusted to accommodate these delays, and the project continues to look for additional opportunities to recover schedule margin. According to the project, the current completion plan is realistic, but there will be little margin to accommodate any further slippage.

Project Office Comments

The SMAP project provided technical comments to a draft of this assessment, which were incorporated as appropriate. Project officials reported that all spacecraft and instrument subsystems are now delivered. The reflector boom assembly was shipped to the Jet Propulsion Laboratory in December to complete acceptance testing (consistent with contingency plans.) The project also stated that observatory integration and test began in January as scheduled.

Solar Probe Plus

Recent/Continuing Project Challenges
- Funding (new)
- Parts/Test and Integration (new)

Previously Reported Challenges
- Launch
- Technology
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **None**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **TBD**

Mission Duration: **7 years**

Requirement derived from:
2003 Solar and Space Physics Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Johns Hopkins University Applied Physics Laboratory**

Contractor Activity: **Aerospace Research Development and Engineering Support**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **May 2010**
Initial Value of Contract: **$218.6 million**
Current Value: **$237.7 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2014	Latest Est. March 2014	Change
Total Project Cost	$1,553.4	$1,553.4	0.0% CHANGE
Formulation Cost	$247.1	$247.1	0.0% CHANGE
Development Cost	$1,055.7	$1,055.7	0.0% CHANGE
Operations Cost	$250.6	$250.6	0.0% CHANGE
Launch Schedule	08 2018	08 2018	0 months CHANGE

Solar Probe Plus (SPP) is designed to explore the Sun's outer atmosphere, or corona, as it extends into space. The spacecraft will orbit the Sun 24 times and its instruments will observe the generation and flow of solar winds from very close range. By observing the corona, where solar energetic particles are energized, there is potential to further the science of heliophysics by shedding light on the origin and evolution of solar wind and why the Sun's outer atmosphere is so much hotter than the visible surface. In order to achieve its mission, parts of the spacecraft must be able to withstand temperatures exceeding 2,500 degrees Fahrenheit, as well as endure blasts of extreme radiation.

Source: 2012 Johns Hopkins University/Applied Physics Lab (artist depiction).

PROJECT SUMMARY

The project entered Phase C—the final design and fabrication phase of implementation—in March 2014. Prior to the confirmation review, the project reported concerns with the phasing of project funds; however, these issues were resolved as part of the confirmation review process. The project also reported recently closing several technological risks related to the Thermal Protection System including the potential inability to meet launch load requirements. However, several risks continue to be tracked, such as the potential inability to remove a sufficient amount of heat to keep the system cool enough to function properly. Additionally, the project validated the performance of the solar cell and array in advance of the project's preliminary design review in January 2014.

Implementation
- **08/18** Committed launch date
- **06/16** System integration review
- **03/15** Critical design review
- **03/14** Project confirmation

Formulation
- **01/14** Preliminary design review
- **12/13** GAO review
- **11/11** Mission/ System design review
- **12/09** Formulation start

Solar Probe Plus

PROJECT UPDATE

The project entered Phase C—the final design and fabrication phase of implementation—in March 2014. Prior to the confirmation review, the project reported concerns with the phasing of project funds being heavily weighted in later years and lacking sufficient funding for the near term. These issues were resolved as part of the confirmation review process.

Parts/Test and Integration Issues

The SPP project includes several critical technologies, such as its Thermal Protection System, which allows the instruments on the spacecraft to operate at near room temperature despite their proximity to the Sun. The project reported recently closing a risk related to the Thermal Protection System's potential inability to meet launch load requirements. However, several risks continue to be tracked, such as the potential inability to remove a sufficient amount of heat to keep the system cool enough to function properly. The project conducted numerous tests to determine mitigation steps necessary to address these risks and mature the technology sufficiently prior to the project's preliminary design review. The project also reported validating the performance of another critical technology—the solar cell and array, which is linked to SPP's power and cooling systems. Underperformance of the technology could compromise the performance and temperature of other systems on the spacecraft. To mitigate this risk, the contractor conducted a series of tests on a secondary array to make sure that the array will be able to support the power and cooling systems on the spacecraft. Officials reported that the performance of the solar array was demonstrated at greater than maximum expected intensities for the planned mission.

Project Office Comments

The SPP project provided technical comments to a draft of this assessment, which were incorporated as appropriate. Officials stated that all of the new technologies necessary to execute the project have been successfully matured to a technology readiness level 6, and that this accomplishment has been independently validated.

Space Launch System

Recent/Continuing Project Challenges
- Funding
- Schedule (new)
- Integration of Existing Hardware (new)

Previously Reported Challenges
- Design
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Marshall Space Flight Center

Partner: **None**

Launch Location: **Kennedy Space Center, FL**

Mission Duration:
Varied based on destination

Requirement derived from:
NASA Authorization Act of 2010 and the NASA 2011 Strategic Plan

CONTRACT INFORMATION

Current highest value contract

Contractor: **ATK Launch Systems, Inc.**

Contractor Activity: **SLS booster element**

Type of Contract: **Cost-Plus-Award-Fee/Incentive-Fee/Fixed-Fee**
Date of Award: **August 2003**
Initial Value of Contract: **$2.81 billion**
Current Value: **$2.82 billion**

**The contract with Boeing for stages development is expected to be highest value contract, but is not currently definitized.*

PROJECT PERFORMANCE

Then year dollars in billions

Preliminary estimate of Project Cost through first non-crewed launch*

Latest: **Feb 2014** **$7.65 – $8.59** BILLION

**As the project is in formulation and there is uncertainty regarding the costs associated with the design options being explored, NASA uses these estimates for planning purposes.*

Launch Schedule
First non-crewed launch (EM-1): **2017**
First crewed launch (EM-2): **2021**

The Space Launch System (SLS) is intended to be the nation's first human heavy-lift launch vehicle since the Saturn V was developed for the Apollo program. SLS is planned to launch NASA's Orion vehicle and service the International Space Station if necessary. The vehicle is being designed to provide an initial lift capacity of 70 metric tons to low-Earth orbit and be evolvable to 130 metric tons. The initial 70 metric ton capability will include a core stage, powered by 4 RS-25 engines and two five-segment boosters. The 130 metric ton capability will include a core stage, a new upper stage and engine, and advanced boosters.

Source: SLS Project Office (artist depiction).

PROJECT SUMMARY

The SLS program completed preliminary design reviews at the system and element level in late summer 2013 and is expected to enter the program implementation phase in April 2014. Based on current budget estimates, program officials have expressed concern that the first launch in 2017 could be delayed. Additionally, the integration of existing hardware with new hardware could pose technical and schedule challenges during system engineering and integration efforts. According to officials, though the program is addressing affordability concerns by utilizing existing hardware, NASA must make adjustments to ensure existing and new hardware integrate properly and meet requirements.

Implementation

2021 First crewed launch date

12/17 First non-crewed launch date

01/15 - 03/15 Critical design review

4/14 Project confirmation

Formulation

12/13 GAO review

07/13 - 09/13 Preliminary design review

07/12 Mission/System design review

11/11 Formulation start

Space Launch System

PROJECT UPDATE

The program plans to reach Key Decision Point (KDP) -C in April 2014 and enter the implementation phase of the NASA acquisition life cycle. At that point, NASA will establish cost, schedule, and performance baselines for the initial version of the SLS, the 70-metric ton launch vehicle, through its first test flight, EM-1, in December 2017, plus 3 months for data analysis.

Funding Issues

Funding remains a top program risk. Although the agency plans to spend about $6.8 billion to develop the SLS in fiscal years 2014 through 2018, the budget requested is flat across all years and, as a result, some sub-system managers have expressed concern about adequacy of funding in some years to support planned development work. Because the SLS is an evolvable development effort, the flat budget profile NASA is proposing may not fully reflect the funding level required at various stages in the development cycle.

Schedule Issues

NASA's schedule for the core stage is aggressive. The core stage is the SLS program's only new development effort and it represents the critical path—the set of developmental activities that must be completed for the program to stay on schedule—for the SLS program as a whole. Unlike the existing booster and engine subsystems, designs and hardware for the core stage as well as the production facility are not yet complete. According to program officials, NASA has compressed the core stage development schedule, including making early decisions about long lead items such as manufacturing materials and tooling, in order to meet the December 2017 EM-1 flight test date. While compressing development creates schedule margin, it places NASA at increased risk of late cycle rework if problems are encountered during development.

Integration of Existing Hardware

The SLS program faces challenges integrating existing hardware into a new system with different operational environments and requirements. In the case of the RS-25 engines from the Space Shuttle, the engines were designed to start using fuel slightly warmer than the fuel they will receive from the new SLS core stage fuel tank. NASA's plans for integration include adding heaters to the fuel lines because that is a less expensive and time-consuming effort than recertifying the engine to start with cooler fuel. Similarly, according to program officials, some portions of the Shuttle-era solid rocket boosters may require redesign due to the increased loads anticipated in the SLS operating environment. For example, NASA is concerned that the forward skirt of the solid rocket boosters is not qualified to withstand the loads it will encounter during SLS flight. So NASA plans to conduct structural tests of the forward skirt to determine if it needs to be redesigned. Additionally, NASA plans to use a propulsion subsystem, called the Interim Cryogenic Propulsion Stage (ICPS), originally developed for the Delta IV launch vehicle. However, according to agency officials, this subsystem is not certified to meet NASA's requirements for human spaceflight. For example, the ICPS currently cannot be steered by launch vehicle crew, which is a human spaceflight requirement. As a result, NASA tailored the ICPS requirement to allow for the crew to manually shutdown ICPS. The full extent of challenges associated with integrating existing hardware into new operating environments and their associated impacts on cost, schedule, and performance, including mass, is likely to remain uncertain until the program's critical design review, currently planned for 2015.

Other Issues to be Monitored

Over 2 years after being established as a program, many of the SLS program contracts remain undefinitized, placing the program at risk of unanticipated costs. Additionally, SLS cost baselines do not include the likely full costs of the SLS program.

Project Office Comments

The SLS project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Space Network Ground Segment Sustainment

Project Challenges
- Contractor
- Funding

Previously Reported Challenges
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **None**

Mission Duration: **9 years**

Requirement derived from:
March 2008 Space Network modernization concept study

CONTRACT INFORMATION

Current highest value contract

Contractor: **General Dynamics C4 Systems, Inc.**

Contractor Activity: **Modernizing the Ground System and Network**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **June 2010**
Initial Value of Contract: **$626.2 million**
Current Value: **$663 million**

The Space Network Ground Segment Sustainment (SGSS) project plans to develop and deliver a new ground system that will enable the Space Network—which provides essential communications and tracking services to NASA and non-NASA missions—to continue safe, reliable, and cost efficient operations for the next several decades. Existing ground systems are based on 1980s technology and software and are becoming obsolete and unsustainable. Updated systems and equipment will allow the Space Network to maintain critical communications services to customer missions while reducing operations and maintenance costs.

Source: NASA.

06/17 Final acceptance review (under review)

12/13 GAO review

Implementation

06/13 Critical design review

04/13 Project confirmation

09/12 Preliminary design review

12/11 Mission/ system design review

Formulation

11/11 Formulation start

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost[a]

$493.9
~~$493.9~~
~~0.0%~~ CHANGE

Formulation Cost

$125.8
$125.8
0.0% CHANGE

Development Cost[a]

$368.1
~~$368.1~~
~~0.0%~~ CHANGE

Operations Cost

$0
~~$0~~
~~0.0%~~ CHANGE

Launch Schedule

06 2017 | 06 2017[a]
0 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2014[a]

[a]*The project is undergoing a replan, and final cost and schedule information is not available.*

PROJECT SUMMARY

Due in part to recent performance issues, the project held a cost and management review in November 2013 at which the contractor's performance and updated estimates at completion were evaluated. The estimates indicated the project's cost and schedule would likely exceed the agency baseline commitment. As a result, agency officials directed the project to develop replan options to be presented to agency leadership in Spring 2014. Project officials reported that the project consumed all fiscal year 2013 reserves to address contractor performance issues, and as a result, could not absorb a $2.3 million sequestration cut in fiscal year 2013. The Space Communication and Navigation program—of which SGSS is a component—added $20 million in funding for fiscal year 2013. However, planned funding for fiscal year 2014 and beyond is expected to be insufficient, based on the updated contractor estimates. As a result, the project may have to delay or descope planned capability or capacity.

Space Network Ground Segment Sustainment

PROJECT UPDATE

Contractor Issues

Project officials reported that contractor performance sharply declined following the preliminary design review. For example, additional detailed design activities led to a three-month slip in sub-system critical design reviews. According to project officials, as a result of this delay and an unrealistic staffing plan, the contractor delayed delivery of several project elements to testing by an additional three months. The contractor absorbed the delay in its schedule by eliminating the final planned test increment which was intended to serve as a placeholder in the event that additional unanticipated testing needed to be completed. However, this approach increases risk because as noted by project officials, upcoming test increments will be the most challenging and the project will not have the placeholder test increment to use if unanticipated testing needs arise. Furthermore, the project office reported that the contractor significantly underestimated costs associated with infrastructure technologies such as routers, processors, and servers. The project assembled a team of experts to work with the contractor to develop more realistic cost estimates which were examined at a cost and management review in November 2013. The preliminary estimates developed by the contractor indicated the project's cost and schedule would likely exceed the agency baseline commitment. As a result, agency officials directed the project to develop replan options to be presented to agency leadership in Spring 2014. The technical portion of the critical design review was completed in June 2013; however the cost and schedule portion of the review has been postponed, pending decisions on the project's replan.

Funding Issues

Prior to the confirmation review in April 2013, project officials noted concerns with the contractor's optimistic assumptions in the remaining phases of the project. Since the confirmation review, the risks previously identified have been realized, and there have been significant performance issues. Project officials have been working with the contractor since prior to the confirmation review to mitigate these risks; however, according to project officials, based on the results of the November cost and management review, the project may have to consider delaying or descoping the project's planned capability or capacity. The project is also implementing mechanisms to limit contractor costs in fiscal years 2014 and 2015, such as reductions in staffing levels and materials purchases, while also minimizing the overall cost and schedule impact of such changes.

According to project officials, due to the performance issues, the project had no remaining cost reserves in fiscal year 2013 and could not absorb a $2.3 million sequestration impact. To ensure completion of planned activities for 2013, the Space Communications and Navigation program—of which SGSS is a component—added $20 million in funding. However, according to project officials, planned funding for fiscal year 2014 and beyond is insufficient to execute the project based on the most recent estimates at completion.

Project Office Comments

The SGSS project provided technical comments to a draft of this assessment, which were incorporated as appropriate. According to project officials, the contractor's updated plan includes more realistic projections of productivity and materials costs than the previous plan. The project is currently assessing optimization of the processes, staffing approaches, and organizational structure for the remaining phases of SGSS and is working with the contractor to improve cost and schedule performance before considering descopes to content.

Stratospheric Observatory for Infrared Astronomy

Previously Reported Challenges

- Design
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Armstrong Flight Research Center

International Partner:
German Aerospace Center (DLR)

Aircraft: **Boeing 747SP**

Sortie Location:
Dryden Aircraft Operations Center, CA

Requirement derived from:
1991 Decadal Survey for Astronomy and Astrophysics, National Research Council

CONTRACT INFORMATION

Current highest value contract

Contractor: **Universities Space Research Association**

Contractor Activity: **Provide the SOFIA Science Center and the science missions operations**

Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **December 1996**
Initial Value of Contract: **$484 Million**
Current Value: **$589 Million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$2,954.4
$2,999.3
1.5% CHANGE

Formulation Cost
$35.0
$35.0
0.0% CHANGE

Development Cost
$919.5
$1,119.8
21.8% CHANGE

Operations Cost
$2,000.0
$1,844.4
-7.8% CHANGE

Launch Schedule
12 2013 — 12 2014
12 months CHANGE

Baseline FY 2007 | Latest Est. Feb 2014

SOFIA is a joint project between NASA and the German Aerospace Center to install a 2.5 meter telescope in a specially modified Boeing 747SP aircraft. This airborne observatory is designed to provide routine access to the visual, infrared, far-infrared, and sub-millimeter parts of the electromagnetic spectrum. Its mission objectives include studying many different kinds of astronomical objects and phenomena, including star birth and death; the formation of new solar systems; planets, comets, and asteroids in our solar system; and black holes at the center of galaxies. Interchangeable instruments of the observatory are being developed to allow a range of scientific measurement to be taken by SOFIA.

Source: NASA.

PROJECT SUMMARY

SOFIA has projected reaching full operating capability, defined by the project as the commissioning of four of seven total planned science instruments by April 2014. According to project officials, the final technical objective for full operating capability was achieved in February, and this achievement will be certified though the project's next key decision point process. However, continuing challenges such as uncertain financial support and the loss of expertise from the German space agency could impact project costs. Further, the need to fund infrastructure and procurements for continued maintenance and operation is a concern. As a result of these challenges and budget constraints, NASA's fiscal year 2015 budget request proposes placing SOFIA in storage; however, according to project officials, the planned fiscal year 2015 budget is insufficient to prepare the observatory for storage.

Project Office Comments

The SOFIA project provided technical comments to a draft of this assessment which were incorporated as appropriate. The project stated that SOFIA completed the procurement of four spare engines in fiscal year 2013, and funding for fuel and staff to support all planned flights is covered in the current budget. They also reported that DLR, the German space agency, has signed a contract to ensure continued support and adequate staffing levels.

12/14 Full operational capability (committed)

04/14 Full operational capability (projected)

12/13 GAO review

12/10 Initial operational capability

08/00 Critical design review

Implementation

11/95 Project confirmation

Formulation

10/91 Formulation start

PAGE INTENTIONALLY LEFT BLANK

Surface Water and Ocean Topography

Project Challenges
- Development Partner (new)

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **Centre National d'Etudes Spatiales (France), Canadian Space Agency**

Launch Location: **Vandenburg AFB, CA**
Launch Vehicle: **TBD**

Mission Duration: **3 years**

Requirement derived from:
2007 National Research Council Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **TBD**

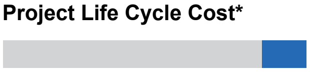
Contractor Activity: **TBD**

Type of Contract: **TBD**
Date of Award: **TBD**
Initial Value of Contract: **TBD**
Current Value: **TBD**

PROJECT PERFORMANCE

Then year dollars in millions

Preliminary estimate of Project Life Cycle Cost*

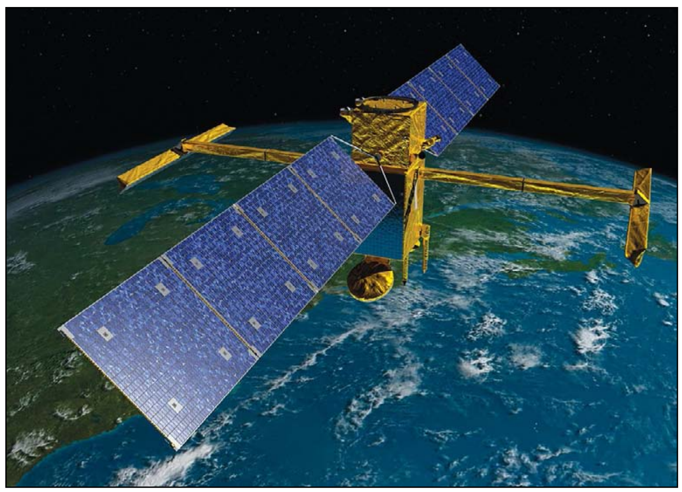


Latest: **Feb 2014** **$642 – $742**

**This estimate is preliminary, as the project is in formulation and there is uncertainty regarding the costs associated with the design options being explored. NASA uses these estimates for planning purposes.*

Launch Schedule **10/2020**

The Surface Water and Ocean Topography Mission (SWOT) is a joint project between NASA and the French Space Agency—the Centre National d'Etudes Spatiales (CNES)—with additional components provided by the Canadian Space Agency. SWOT will use its wide-swath altimetry technology to take repeated high-resolution measurements of the world's oceans and freshwater bodies to develop a global survey. This survey will make it possible to estimate water discharge into rivers more accurately, and help improve flood prediction. It will also provide global measurements of ocean surface topography which will improve prediction of weather and climate as well as variations in ocean currents.



Source: Source: Jet Propulsion Laboratory (artist depiction).

PROJECT SUMMARY

SWOT officials are working toward the project's scheduled preliminary design review in January 2016 and maturing instruments to fulfill the mission's science requirements. The project is monitoring a risk that the French-provided nadir altimeter may have to be de-scoped in the event of cost overruns. The project is assessing options to address this issue, such as enhancing the design of the NASA-developed Ka band Radar Interferometer (KaRIn) to function as a replacement. The KaRIn instrument will require significant development work in order for it to reach maturity by the preliminary design review. Development of this instrument is also a risk due to the complexities involved in managing multiple international partners.

Implementation

10/20 Projected launch date

02/19 System Integration review

06/17 Critical design review

03/16 Project confirmation

Formulation

01/16 Preliminary design review

03/14 Mission design review

12/13 GAO review

11/12 Formulation start

Surface Water and Ocean Topography

PROJECT UPDATE

The SWOT mission entered Phase A—the concept and technology development phase of formulation—in November 2012 with a preliminary life cycle cost estimate of $642 to $752 million. SWOT is being jointly developed with the French space agency, CNES, with additional components provided by the Canadian Space Agency. The combined cost of the project, including partner contributions, is approximately $1 billion.

The project will include six instruments that fulfill the project's planned science requirements, including three that perform orbit determination. CNES is providing the spacecraft bus and nadir altimeter instrument, as well as one of three instruments utilized by the spacecraft to determine its orbit. The Canadian Space Agency is contributing a radar transmitter subsystem. NASA is providing the payload module, microwave radiometer instrument as well as the primary science instrument – the Ka band Radar Inteferometer (KaRIn), with participation from both CNES and CSA. This instrument will enable the spacecraft to provide high resolution oceanography and hydrology by taking wide-swath measurements.

Development Partner Issues

Project officials are monitoring the development of the French-provided nadir altimeter due to limited available funding from the French. Project officials reported that the altimeter could be descoped in the event of cost overruns. However, the altimeter is not essential to meeting threshold requirements. As an alternative, the project is assessing the cost and schedule impact of enhancing the KaRIn instrument to function as a nadir altimeter replacement.

Other Issues to be Monitored

The project expects its critical technologies to be mature by the preliminary design review in January 2016. However, the project is closely monitoring several risks related to the development of the KaRIn. For example, the project is concerned about the complexity of managing KaRIn's schedule due to having multiple contributing partners. To mitigate this risk the project plans to define interfaces and test plans early in development and maintain parallel development schedules. The project is also concerned about the lack of redundancy in the instrument. Project officials told us that the project is mitigating this risk by using redundancy in select areas, as well as focusing on obtaining high reliability parts and instituting a robust test program.

Project Office Comments

The SWOT project office provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Tracking and Data Relay Satellite Replenishment

Previously Reported Challenges

- Test and Integration
- Contractor
- Launch
- Technology
- Parts

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **Non-NASA Agencies**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **Atlas V**

Mission Duration: **15 years**

Requirement derived from:
Support and expand existing TDRS System fleet

CONTRACT INFORMATION

Current highest value contract

Contractor: **The Boeing Company**

Contractor Activity: **Spacecraft development**

Type of Contract: **Fixed-Price-Incentive**
Date of Award: **December 2007**
Initial Value of Contract: **$1.384 billion**[a]
Current Value: **$1.151 billion**[a]

[a] *This represents the full cost of the Boeing contract that NASA is managing; however, the cost is shared with NASA's partners and includes options for future versions of the spacecraft.*

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2010	Latest Est. Feb 2014	Change
Total Project Cost	$451.3	$426.5	-5.5%
Formulation Cost	$241.9	$241.9	0.0%
Development Cost	$209.4	$184.6	-11.8%
Operations Cost	$0.0	$0.0	0.0%
Launch Schedule (L)	12 2013	01 2014	1 month

Note: NASA's contract with Boeing covers development of both TDRS K and TDRS L.

The Tracking and Data Relay Satellite (TDRS) System consists of in-orbit communication satellites stationed at geosynchronous altitude coupled with two ground stations located in New Mexico and Guam. The satellite network and ground stations provide mission services for near-Earth user satellites and orbiting vehicles. TDRS K and L are the 11th and 12th satellites, respectively, to be built for the TDRS system. They are planned to contribute to the existing network by providing continuous high-bandwidth digital voice, video, and mission payload data, as well as health and safety data relay services to Earth-orbiting spacecraft such as the International Space Station and the Hubble Space Telescope.

Source: © Boeing (artist depiction).

PROJECT SUMMARY

TDRS K launched in January 2013 and NASA accepted it for deployment as part of the agency's space communications network on August 16, 2013. The project office completed final integrated systems testing on TDRS L in February 2013, and following a 6-month storage period, launched as planned on January 23, 2014. TDRS L will undergo a 3-month on-orbit check out period and additional tests will be conducted before the satellite is put into service. The project office reported progress toward resolving technical challenges noted during TDRS K's on-orbit acceptance period, including issues related to the spacecraft's gyroscope, single-access antenna, satellite coordination and communication with ground stations, and battery. NASA officials told GAO that resolution of these TDRS K issues will provide valuable insights to address potential issues with TDRS L.

Project Office Comments

The TDRS project provided technical comments to a draft of this assessment, which were incorporated as appropriate.

Implementation

- **01/23/14** Launch date (TDRS L)
- **12/13** GAO review
- **01/30/13** Launch date (TDRS K)
- **06/12** System integration review (TDRS L)
- **08/11** System integration review (TDRS K)
- **02/10** Critical design review
- **07/09** Project confirmation

Formulation

- **03/09** Preliminary design review
- **07/08** Mission/System design review
- **02/07** Formulation start

PAGE INTENTIONALLY LEFT BLANK

Commercial Crew Program

Project Challenges

- Funding
- Schedule

PROJECT ESSENTIALS

NASA Center Lead:
Kennedy Space Center

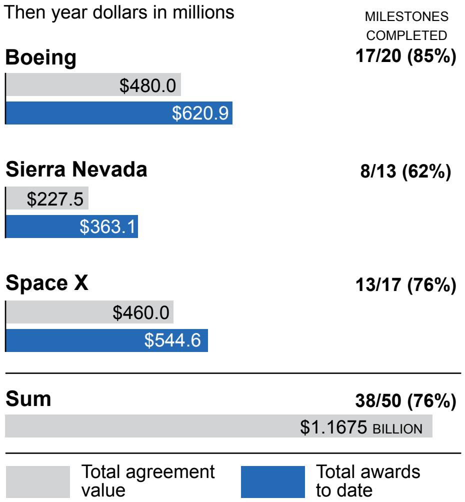
Partners: **Boeing, Sierra Nevada, and SpaceX**

Requirement derived from: **NASA Strategic Plan**

PARTNER ESSENTIALS:

INTEGRATED CAPABILITIES PHASE

Then year dollars in millions



Source: NASA.

The purpose of the Commercial Crew Program (CCP) is to facilitate the development of a safe transportation system, which will enable at least one partner to transport NASA astronauts and cargo to and from the International Space Station. NASA is currently working with three funded industry partners through Space Act Agreements. The National Aeronautics and Space Act of 1958 authorized NASA to enter into agreements with public and private entities outside of the Federal Acquisition Regulation. Agreements entered into under the Act's "other transactions" authority are commonly referred to as Space Act Agreements. The partners – Boeing, Sierra Nevada, and SpaceX – are each responsible for all aspects of design and development of a crew transportation system.

CCP is a multi-phase effort that started in 2010 to stimulate private-sector interest in providing commercial space transportation capabilities. The first phases of the program included the Commercial Crew Development (CCDev) and Commercial Crew Development Round 2 (CCDev 2) which were intended to allow partners to develop transportation system concepts and system elements. This phase was followed by the Commercial Crew Integrated Capabilities (CCiCap) phase—the current phase of the program— with the objective of developing an integrated crew transportation system. Concurrently, partners are working on the Certification Products Contract, the purpose of which is to ensure their space systems meet NASA safety and operational requirements. Finally, the Commercial Crew Transportation Capabilities phase (CCtCap) is a phased acquisition approach that will result in each applicable transportation system's final certification and will include two to six missions to the International Space Station to transfer NASA crew members and provide emergency crew return capability.

PROGRAM CHALLENGES

According to program officials, the biggest challenges that the program faces include funding and technical problems that could impact schedule. Program officials stated that if adequate funding is not received, then competition will be limited moving toward International Space Station (ISS) crew transportation missions. This could result in increased cost of commercially available transportation capabilities. Additionally, program officials state that complications such as development of the system to allow the commercial vehicles to dock with ISS may affect the program's schedule. The program also continues to work toward closing a risk related to Federal Aviation Administration licensing issues. Program delays could increase costs as NASA would need to prolong its reliance on foreign capabilities for transportation services to the ISS.

In March 2013, an independent cost assessment was conducted and found that the program showed evidence of adopting best practices in resource and budget planning. According to the independent assessment, if funding continues as planned, the program should be able to meet the goal of commercial crew capability for one or two partners. After this assessment, NASA exercised optional milestones worth $55 million for the Integrated Capabilities phase, in order to reduce technical risks.

2017 Transportation missions

2014 – 2017 Transportation capabilities phase

2013 Certification products contract

2012 – 2014 Integrated capabilities phase

2010 – 2012 Development phase

Commercial Crew Program


Source: Boeing.

BOEING

Boeing has completed 17 out of 20 milestones for the Commercial Crew Integrated Capabilities (CCiCap) phase of the program while simultaneously working to complete deliverables for the Certification Products Contract for its CST-100 spacecraft. Of the 17 completed milestones, 6 were delayed from the initially planned dates. The design of this spacecraft is going to include a crew as well as a cargo configuration. Additionally, the spacecraft is being designed to be reusable for up to 10 missions. Boeing is making progress on the spacecraft and conducted a critical design review in February 2014 on the primary structures of the capsule. Boeing has chosen the Atlas-V as the initial launch vehicle, but plans to make the CST-100 compatible with multiple launch vehicles. Boeing completed its certification plan review in November 2013.

MILESTONE TIMELINE

11/13	12/13	02/14	04/14	07/14
Certification plan review	Avionics demo test	Primary structures CDR	Software CDR	Spacecraft CDR


Source: © 2013 Sierra Nevada Corporation.

SIERRA NEVADA

Sierra Nevada has completed 8 out of 13 milestones for the integrated capabilities phase of the program while simultaneously working to complete deliverables for the certification products contract for its Dream Chaser spacecraft. Of the 8 completed milestones, 1 was delayed from the initially planned dates—the integrated system review—and one was accelerated. The program reported that a free flight aerodynamics test conducted in October 2013 met the success criteria per the Commercial Crew Development Phase 2 Space Act Agreement, despite an anomaly that caused the spacecraft's left side landing gear to not deploy. Sierra Nevada plans for the spacecraft to launch on an Atlas-V launch vehicle, but upon re-entry it will operate similar to an airplane in that it will glide in and will be able to land at any airport that is capable of handling commercial traffic. The Dream Chaser will be able to transport five crew to and from low earth orbit and will be capable of autonomous flight if needed. The certification plan review was completed in November 2013. Sierra Nevada is working towards risk reduction and technology readiness level advancement testing that is scheduled for June 2014.

MILESTONE TIMELINE

10/13	11/13	04/14	06/14
System safety review	Certification plan review	Wind tunnel testing	Risk reduction and TRL advancement testing

Commercial Crew Program

Source: © 2013 Space Exploration Technologies Corp.

SPACEX

SpaceX has completed 13 out of 17 milestones and is proceeding through the integrated capabilities phase of the program while simultaneously working to complete deliverables for the certification products contract for its modified DragonRider spacecraft. Of the 13 completed milestones, 1 was completed after the initially planned date – the delta ground systems preliminary design review. The cargo version of the Dragon capsule has already carried cargo to the International Space Station. SpaceX completed its on-orbit and entry preliminary design review in July 2013 and demonstrated that it was capable of docking with the International Space Station and that its flight characteristics meet risk and schedule constraints that establish the basis for moving forward with more detailed design work. In November 2013, SpaceX conducted a flight review of the upgraded Falcon 9 launch vehicle that will utilize a more powerful engine and a triple-redundant avionics system. SpaceX completed its human certification plan review in May 2013 and is making progress towards its critical design review that is scheduled for April 2014.

MILESTONE TIMELINE

10/13	11/13	02/14	04/14	05/14
System safety review	Flight review	Delta Ground Systems PDR	Integrated CDR	Dragon Primary Structure Qualification

Project Office Comments

The Commercial Crew program provided technical comments to a draft of this assessment, which were incorporated as appropriate. The program stated that it is building on the success of NASA's commercial cargo partnerships to achieve a certified crew transportation capability by 2017 and investing in three companies to promote competition and innovation. In parallel, the program stated that early certification products including verification plans and hazard reports are being developed and matured. The program also noted that the request for proposal for the Commercial Crew Transportation Capabilities contract has been released. Officials stated that funding at the requested level will ensure that the next phase of the program will be awarded before the end of 2014 which will keep the program on track to deliver a certified system by 2017 and re-establish a United States capability to transport crew to and from the International Space Station.

Agency Comments and Our Evaluation

We provided a draft of this report to NASA for its review and comment. In its written response, NASA generally agreed with our findings and stated that it remains dedicated to continuous improvement of its acquisition management processes and performance, and will continue to identify and address the challenges that lead to cost and schedule growth on its major projects.

In commenting on how current information is incorporated to track the cost and schedule progress of its major projects, the agency indicated that when a project is rebaselined there are often significant changes to its scope. As a result, the agency asserts that it is important and more accurate to track metrics that reflect progress against the new baseline and current scope. However, GAO also uses these metrics to support our assessment of whether sufficient progress has been made in the area of acquisition management to warrant removal from GAO's High Risk List. While we agree that holding projects accountable on an ongoing basis to new baselines that reflect the current scope of work is appropriate, GAO's assessment of NASA's progress in improving its acquisition management practices over time would be rendered useless if every time a project is rebaselined the metrics were reset to reflect new project baselines. We will continue to work with NASA to ensure a shared understanding of how NASA measures progress in relation to its high risk metrics.

NASA's written comments are reprinted in appendix VI. NASA also provided technical comments. We carefully considered and incorporated those changes that were supported by evidence consistent with GAO standards and our role as an independent auditor of executive agencies.

We are sending copies of the report to NASA's administrator and interested congressional committees. In addition, the report will be available at no charge on GAO's website at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix VII.

Cristina T. Chaplain
Director
Acquisition and Sourcing Management

List of Committees

The Honorable Barbara A. Mikulski
Chairwoman
The Honorable Richard C. Shelby
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Bill Nelson
Chairman
The Honorable Ted Cruz
Ranking Member
Subcommittee on Science and Space
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Frank R. Wolf
Chairman
The Honorable Chaka Fattah
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Steven Palazzo
Chairman
The Honorable Donna F. Edwards
Ranking Member
Subcommittee on Space
Committee on Science, Space, and Technology
House of Representatives

Appendix I: Objectives, Scope, and Methodology

Our objectives were to discuss broader trends and challenges faced by the agency in its management of acquisitions and to report on the status and challenges faced by 18 National Aeronautics and Space Administration (NASA) major projects and the Commercial Crew program with life-cycle costs of $250 million or more. Specifically, we assessed (1) the current status of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies (3) efforts NASA has taken to improve the design stability of its projects, and (4) any remaining challenges to NASA's management of the portfolio.

To respond to these objectives, we collected and analyzed data from May 2013 to April 2014 as well as data from prior reviews. We developed a standardized data collection instrument (DCI) that was completed by each project office. Through the DCI, we gathered and assessed data on each project's technology and design maturity, parts issues, and development partners. We developed other DCIs that were completed by NASA's Office of the Chief Financial Officer (OCFO) and Office of Procurement that gathered data on each project's cost performance, current and projected development activities (including the project's schedule and manifested/committed launch readiness dates), and contracts information.[1] NASA updated these data collection instruments in February 2014. NASA's Office of the Chief Engineer provided data on software-related metrics for selected projects. We evaluated projects' monthly or quarterly status reports and other project documentation. We also conducted interviews with officials from 14 of the 18 projects in our sample, officials from the Commercial Crew program, as well as with NASA headquarters and contractor officials to identify and understand projects' progress to date and any risks. For the Commercial Crew program, we reviewed Space Act Agreement values for each of the three funded partners, as well as both partner and NASA generated information and partner milestone performance and schedules and NASA information

[1]The manifested launch date is the launch date which the project is working toward, and when a launch vehicle is available to launch the project. This date is only a goal launch date for the project, not a commitment that they will launch on this date. The committed launch readiness date is determined through a launch readiness review that verifies that the launch system and spacecraft/payload s are ready for launch. For the fixed-price contracts discussed in this report, the initial contract values plus contract modifications issued to equitably adjust the contract costs equal the current contract values. For the cost-reimbursement contracts, the current contract value can be greater than the initial contract value when the government is required to reimburse the contractor for increased costs associated with performance.

on program risks and partner performance.[2] The Commercial Crew program differs from other NASA's other major projects in that NASA's approach to the program included having contractors provide significant financial investment in the development of their transportation systems. NASA's intent is to encourage private sector innovation by having commercial partners maintain ownership of the space vehicles and systems they develop, while NASA would receive the ancillary benefits of being able to eventually use the emerging commercial products to procure safe, reliable transportation services to the space station at a reasonable price. We reviewed the data and performed various checks to determine that the data were reliable for the purposes of this report. Where we discovered discrepancies, we clarified the data accordingly with agency and project officials.

The information collected from each project office, Mission Directorate, and OCFO was summarized in a project assessment providing a project overview; key cost, contract, and schedule data; and a discussion of the challenges associated with the deviation from relevant indicators from best practice standards. The aggregate measures and averages calculated were analyzed for meaningful relationships, for example, relationship between cost growth and schedule slippage and knowledge maturity attained both at critical milestones and through the various stages of the project life cycle.

To assess the current status of NASA's portfolio of major projects, we reviewed current cost and schedule data, technology maturity, design stability, and other challenges affecting each of the projects. To determine the extent to which each project exceeded its cost and schedule baselines, we compared the current cost and schedule data reported by NASA in February 2014 to previously established project cost and schedule baselines to determine the extent to which each project

[2] Space Act agreements are transactions other than contracts, leases, and cooperative agreements. Congress granted NASA the authority to enter into these types of transactions in the National Aeronautics and Space Act of 1958 to give the agency greater flexibility in achieving its mission. Under a funded Space Act agreement, appropriated funds are transferred to a domestic partner, such as a private company or a university, to accomplish an agency mission. These agreements differ from FAR contracts in that they do not include requirements that generally apply to government contracts entered into under the authority of the FAR. Unfunded agreements accomplish the same goals but no appropriated funds are transferred. Under such agreements, the company can benefit from NASA's experience, guidance, and advice and NASA can gain insight into the company's system.

exceeded its baselines. We identified cost and/or schedule growth as significant where, in either case, a project's cost and/or its schedule exceeded the thresholds that trigger reporting to certain Senate and House committees.[3] We also compared the average development cost growth and average schedule delay since our initial assessment in 2009 to this year's average development cost growth and average schedule delay to determine whether NASA major projects had improved in adhering to cost and schedule baselines. All cost information is presented in nominal then-year dollars for consistency with budget data.[4] Current baseline costs are adjusted to reflect the cost accounting structure in NASA's fiscal year 2009 budget estimates. For the fiscal year 2009 budget request, NASA changed its accounting practices from full-cost accounting to reporting only direct costs at the project level.

To assess technology maturity, we asked project officials to provide the technology readiness levels of each of the project's critical and heritage technologies at various stages of project development—including the preliminary design review—and compared those levels against our technology maturity best practice to determine the extent to which the portfolio was meeting the criteria. Our work has shown that a technology readiness level of 6—demonstrating a technology as a fully integrated prototype in a relevant environment—by the preliminary design review is the level of maturity needed to minimize risks for space systems entering product development. Originally developed by NASA, technology readiness levels are measured on a scale of one to nine, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. See appendix IV for the definitions of technology readiness levels. We also compared this year's results against those in prior years to assess whether NASA was improving in this area. We did not assess technology maturity for those projects that had not yet reached the preliminary design review at the time of this assessment. We also collected information on the use of heritage technologies in the projects, including what heritage technologies were being used; what effort was needed to modify the form, fit, and

[3] NASA is required to report to certain committees in the House and Senate if the development cost of a program is likely to exceed the baseline estimate by 15 percent or more, or if a milestone is likely to be delayed by 6 months or more. 51 U.S.C. § 30104(e).

[4] Because of changes in NASA's accounting structure, its historical cost data are relatively inconsistent. As such, we used then-year dollars to report data consistent with the data NASA reported to us. Then year dollars include the effects of inflation and escalation.

function of the technology for use in the new system; whether the project encountered any problems in modifying the technology; and whether the project considered the heritage technology as a risk to the project.

To assess design stability, we asked project officials to provide the number of engineering drawings completed or projected for release by the preliminary and critical design reviews and as of our current assessment.[5] In most cases, we did not verify or validate the percentage of engineering drawings provided by the project office. However, we collected the project offices' rationale for cases where it appeared that only a small number of drawings were completed by the time of the design reviews or where the project office reported significant growth in the number of drawings released after the critical design review. In accordance with best practices, projects were assessed as having achieved design stability if at least 90 percent of projected drawings were releasable by the critical design review. We compared this year's results against those in prior years to assess whether NASA was improving in this area. We did not assess design stability for those projects that had not yet reached the critical design review at the time of this assessment. We also reviewed NASA's implementation of its technical performance metrics and how the projects were meeting those metrics in response to our prior recommendation that the agency develop a consistent set of proven metrics to assess design stability.[6] On February 14, 2013, we convened a meeting of experts, to discuss additional approaches for measuring design stability across a range of unique space acquisition projects. We contracted with the National Academy of Sciences to select and recruit a panel of experts with a range of in-depth experience in engineering and managing unique space acquisition projects. We analyzed the input provided by the experts and following the meeting distributed a questionnaire to each of the experts asking them to comment on the utility for measuring design stability of 12 metrics that were identified by the experts during the meeting. Based on their responses, we reviewed selected documentation from NASA's projects to

[5] In our calculation for the percentage of total number of drawings projected for release, we used the number of drawings released at the critical design review as a fraction of the total number of drawings projected, including where a growth in drawings occurred. So, the denominator in the calculation may have been larger than what was projected at the critical design review. We believe that this more accurately reflected the design stability of the project.

[6] GAO-11-364R.

identify whether projects were currently tracking and reporting the most useful metrics as identified by the experts.

To identify any remaining challenges to continued improvement, we reviewed outstanding issues identified in our prior work on NASA, such as cost and schedule growth on one of NASA's most technologically advanced and costly projects and assessed NASA's efforts to make progress on these issues. To understand how NASA is managing large and complex missions within the current budget environment, we examined NASA's budget documentation. To understand budget uncertainty at NASA we obtained and analyzed agency documents and interviewed agency officials to understand the impact of the government shutdown and fiscal year 2013 sequestration and the ability of NASA and projects to execute their current plans under such funding constraints. To assess NASA's approach for continuing to improve its acquisition management practices and project oversight, we reviewed NASA's metrics for measuring acquisition management and supporting data. We also reviewed project documentation and held interviews with projects that had moved into implementation but were still experiencing issues with resources and known risks. To assess NASA implementation of the joint cost and schedule confidence level (JCL) process, we analyzed a number of projects in our review that had developed JCLs, spoke with projects about the development of their JCL, and interviewed project officials on the guidance they had provided to projects on formulating their JCLs. We also reviewed JCLs for projects that had established them at the key decision point C (KDP-C). To assess NASA's efforts to create reliable cost estimates, we reviewed eight project's life cycle cost estimates provided by NASA and compared them to the project's committed baselines to determine whether the baseline cost fell within the estimate, or by what percentage it fell above or below the estimate.

Our work was performed primarily at NASA headquarters in Washington, D.C. In addition, we visited Goddard Space Flight Center in Greenbelt, Maryland; the Jet Propulsion Laboratory in Pasadena, California; Kennedy Space Center, Florida; Marshall Space Flight Center in Huntsville, Alabama; and contractor facilities in Canoga Park, California and Promontory, Utah to discuss individual projects.

Project Profile Information on Each Individual Project Assessment

This year, we developed project assessments for the 18 projects in the portfolio with an estimated life cycle cost greater than $250 million. We also assessed the Commercial Crew program which has a life cycle cost greater than $250 million and recently entered a phase which include development activities. For each project assessment we included a description of each project's objectives, information concerning the NASA center, major contractor, or other partner involved in the project, the project's cost and schedule performance, a schedule timeline identifying key project dates, and a brief narrative describing the current status of the project. As applicable, we included a detailed discussion of project challenges for selected projects. For LADEE, SOFIA, and TDRS we produced one-page assessments. For LADEE and SOFIA, both projects were nearing the end of development work and preparing for their launch or full operation capability, respectively, and did not warrant a more detailed discussion. For TDRS, the project was in storage from April 2013 through October 2013 prior to its launch and did not warrant a more detailed discussion. For the three page assessment of the Commercial Crew program, we additionally included discussions of each of the three funded partners' current status and milestone timelines.

Project cost and schedule performance is outlined according to cost and schedule changes in the various stages of the project life cycle. To assess the cost and schedule changes of each project, we obtained data directly from NASA's OCFO through our data collection instrument.

The project's timeline is based on acquisition cycle time, which is defined as the number of months between the project's start, or formulation start, and projected or actual launch date.[7] Formulation start generally refers to the initiation of a project; NASA refers to a project's start as KDP-A, or the beginning of the formulation phase. The preliminary design review typically occurs toward the end of the formulation phase, followed by a review at KDP-C, known as project confirmation, which allows the project to move into the implementation phase. The critical design review is generally held during the latter half of the final design and fabrication phase of implementation and demonstrates that the maturity of the design is appropriate to support continuing with the final design and fabrication phase. The manifested launch date is the launch date which the project is working toward, and when a launch vehicle is available to launch the project. This date is only a goal launch date for the project, not a commitment that they will launch on this date. The committed launch readiness date is determined through a launch readiness review that

[7]Some projects reported that their spacecraft would be ready for launch sooner than the date that the launch authority could provide actual launch services. In these cases, we used the actual launch date for our analysis rather than the date that the project reported readiness.

verifies that the launch system and spacecraft/payloads are ready for launch. The implementation phase includes the operations of the mission and concludes with project disposal.

Project Challenges Discussion on Each Individual Project Assessment

To assess the project challenges for each project, we submitted a DCI to each project office. In the DCI, we requested information on the maturity of critical and heritage technologies, number of releasable design drawings at project milestones, software development information, project contractors with related contract values and award fees, and project partnerships. We also held interviews with representatives from 14 of the projects and the Commercial Crew program to discuss the information on the DCI. Four projects—SOFIA, LADEE, TDRS, and MAVEN— provided written responses. These discussions led to identification of further challenges faced by NASA projects. We then reviewed project documentation—such as the project plans, schedules, risk assessments, and major project review documentation—to corroborate any testimonial evidence we received in the interviews. A challenge was identified for a project if project performance had been or could be affected by the issue. For this year's report, we identified the following challenges across the projects we reviewed: launch, contractor management, integration of existing hardware, parts, development partners, funding, workforce, design, technology, and test and integration. These challenges do not represent an exhaustive or exclusive list. They are subject to change and evolve as we continue this annual assessment in future years. The challenges, indicated as "issues" in each project assessment, are based on our definitions and assessments, not that of NASA.

To supplement our analysis, we relied on our work over past years examining acquisition issues across multiple agencies. These reports cover such issues as contracting, program management, acquisition policy, and cost estimating. We also have an extensive body of work related to challenges NASA has faced with specific system acquisitions, financial management, and cost estimating. This work provided the context and basis for large parts of the general observations we made about the projects we reviewed.

Data Limitations

NASA provided updated cost and schedule data in February 2014 for projects in implementation, or 14 of the 18 projects in our review. In March 2014, one project – SPP – was confirmed and entered into implementation at which time NASA provided cost and schedule data to us. NASA provided preliminary estimated life-cycle cost ranges and associated schedules for four of the projects that had not yet entered implementation, which are generally established at KDP-B.[8] For the Commercial Crew program, NASA provided Space Act Agreement values for each of the partners. NASA formally establishes cost and schedule baselines, committing itself to cost and schedule targets for a project with a specific and aligned set of planned mission objectives, at key decision point C, which follows a preliminary design review. KDP-C reflects the life-cycle point where NASA approves a project to leave the formulation phase and enter into the implementation phase. NASA explained that preliminary estimates are generated for internal planning and fiscal year budgeting purposes at KDP-B, which occurs midstream in the formulation phase, and hence, are not considered a formal commitment by the agency on cost and schedule for the mission deliverables.

We conducted this performance audit from May 2013 to April 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

[8] These missions include Gravity Recovery and Climate Experiment Follow On (GRACE-FO), Orion Multi-Purpose Crew Vehicle (Orion), Solar Probe Plus (SPP) and Surface Water and Ocean Topography (SWOT).

Appendix II: Selected Major NASA Projects Reviewed in GAO's Annual Assessments

We have reviewed 38 major National Aeronautics and Space Administration (NASA) projects or programs since our initial review in 2009. See table 2 below for a list of projects included in our assessments from 2009 to 2014 and whether each project was in formulation or implementation at the time of our review.

Table 2: Selected Major NASA Projects and Programs Reviewed in GAO's Annual Assessments

	2009	2010	2011	2012	2013	2014
Projects in formulation	Ares I	Ares I	Ares I[c]	EMTGO	EMTGO[c]	Orion[d]
	GPM	GPM	ICESat-2	ICESat-2	Orion MPCV[d]	SLS
	JWST	LDCM	Orion[c]	Orion MPCV[d]	OSIRIS-REx	SWOT
	LDCM	Orion	SMAP	SLS	SPP	
	Orion		SPP	SMAP	SLS	
				SPP	SGSS	
Projects in implementation	Aquarius	Aquarius	Aquarius	Aquarius[a]	GPM	GPM[a]
	Dawn[a]	Glory	Glory[b]	GPM	ICESat-2	GRACE-FO
	GLAST[a]	GRAIL	GPM	GRAIL[a]	JWST	ICESAT-2
	Glory	Herschel[a]	GRAIL	Juno[a]	LADEE	InSight
	Herschel	Juno	Juno	JWST	LDCM[a]	JWST
	Kepler	JWST	JWST	LADEE	MAVEN	LADEE[a]
	LRO	Kepler[a]	LADEE	LDCM	MMS	MMS
	MSL	LRO[a]	LDCM	MAVEN	OCO-2	MAVEN[a]
	NPP	MMS	MAVEN	MMS	RBSP[a]	OCO-2
	OCO[b]	MSL	MMS	MSL[a]	SMAP	OSIRIS-REx
	SDO	NPP	MSL	NPP[a]	SOFIA	SMAP
	SOFIA	RBSP	NPP	OCO-2	TDRS Replenishment[a]	SPP
	WISE	SDO[a]	OCO-2	RBSP		SGSS
		SOFIA	RBSP	SOFIA		SOFIA
		WISE[a]	SOFIA	TDRS Replenishment		TDRS Replenishment[a]
			TDRS Replenishment			
Commercial Crew						CST-100 (Boeing)
						DreamChaser (SierraNevada)
						DragonRider (Space-X)

Source: GAO analysis of NASA data.

[a]NASA projects that have launched.

[b]NASA projects that have launched but failed to reach orbit.

[c]NASA projects that were cancelled before entering implementation.

[d]In 2014, NASA adopted Orion as the common name for Orion MPCV; the project did not change. This Orion project stems from the original Orion project that was cancelled in June 2011 when the Constellation program was cancelled after facing significant technical and funding issues. During the closeout process for the Constellation program, NASA identified elements of the Ares I and Orion projects that would be transitioned for use on the new Space Launch System and Orion MPCV programs.

Appendix III: Selected Major NASA Projects Reviewed in GAO's 2014 Annual Assessment

The content of figure 2 is presented below in a noninteractive format.

PROJECTS IN FORMULATION

Project: Orion Multi-Purpose Crew Vehicle (Orion)
Launch Readiness Date: August 2021
Project Summary: Orion is being developed to enable astronauts to explore deep space and to transport crew to the International Space Station as a backup capability if necessary.
Preliminary Estimate of Project Life-Cycle Cost: $8.53 – 10.29 billion

Project: Space Launch System (SLS)
Launch Readiness Date: December 2017
Project Summary: SLS, a human heavy-lift launch vehicle, is being developed to launch NASA's Orion Multi-Purpose Crew Vehicle and enable deep-space exploration by humans.
Preliminary Estimate of Project Life-Cycle Cost: $7.65 - $8.59 billion

Project: Surface Water and Ocean Topography (SWOT)
Launch Readiness Date: October 2020
Project Summary: SWOT is a joint project between NASA and the French Space Agency that will collect measurements of the world's oceans and freshwater bodies to develop a global survey which will make it possible to estimate water discharge into rivers more accurately, and help improve flood and weather prediction.
Preliminary Estimate of Project Life-Cycle Cost: $642-$752 million

PROJECTS IN IMPLEMENTATION

Project: Global Precipitation Measurement Mission (GPM)
Launch Date: February 27, 2014
Project Summary: The GPM mission is a joint project between NASA and the Japan Aerospace Exploration Agency that seeks to improve the scientific understanding of the global water cycle and the accuracy of precipitation forecasts.
Latest Estimate of Total Project Cost: $928.1 million

Project: Gravity Recovery and Climate Experiment Follow On (GRACE-FO)
Launch Readiness Date: February 2018
Project Summary: GRACE-FO is a joint effort with the German Research Center for Geosciences (GFZ) that will provide global high-resolution models of Earth's gravity field, which will provide increased insight into water movement on and beneath the Earth's surface over a 5-year mission period.

Latest Estimate of Total Project Cost: $431.9 million

Project: Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)
Launch Readiness Date: May 2017 (under review)
Project Summary: ICESat-2, a follow-on mission to ICESat, will measure changes in polar ice-sheet mass in order to better understand mechanisms that drive changes in ice thickness and the impact of change on global sea level.
Latest Estimate of Total Project Cost: $860.3 million (under review)

Project: Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight)
Launch Readiness Date: March 2016
Project Summary: InSight is a Mars lander intended to help NASA understand the formation and evolution of terrestrial planets, and determine the present level of tectonic activity and meteorite impact rate on Mars.
Latest Estimate of Total Project Cost: $675.1 million

Project: James Webb Space Telescope (JWST)
Launch Readiness Date: October 2018
Project Summary: JWST is designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, the formation of stars and planetary systems, and characteristics of planetary systems.
Latest Estimate of Total Project Cost: $8.83 billion

Project: Lunar Atmosphere and Dust Environment Explorer (LADEE)
Launch Date: September 6, 2013
Project Summary: The LADEE mission will assess the global density, composition, and time variability of the lunar atmosphere.
Latest Estimate of Total Project Cost: $281.5 million

Project: Magnetospheric Multiscale (MMS)
Launch Readiness Date: March 2015
Project Summary: MMS is planned to use the Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection. The data will help predict space weather in support of terrestrial and space exploration activities.
Latest Estimate of Total Project Cost: $1.08 billion

Project: Mars Atmosphere and Volatile EvolutioN (MAVEN)
Launch Date: November 18, 2013

Project Summary: MAVEN is a robotic orbiter intended to deliver comprehensive answers to long-standing questions regarding the loss of Mars' atmosphere, climate history, liquid water, and habitability.
Latest Estimate of Total Project Cost: $636.5 million

Project: Orbiting Carbon Observatory 2 (OCO-2)
Launch Readiness Date: February 2015
Project Summary: OCO-2 is planned to make precise, time-dependent global measurements of atmospheric carbon dioxide and is expected to enhance understanding of the carbon cycle which should improve predictions of future atmospheric carbon dioxide increases and their potential impact on the climate.
Latest Estimate of Total Project Cost: $467.5 million

Project: Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx)
Launch Readiness Date: October 2016
Project Summary: OSIRIS-REx will travel to a near-Earth asteroid and use a robotic arm to retrieve samples to help further understanding of our solar system's formation and how life began. If successful, OSIRIS-REx will be the first U.S. mission to return samples from an asteroid to Earth.
Latest Estimate of Total Project Cost: $1.06 billion

Project: Soil Moisture Active and Passive (SMAP)
Launch Readiness Date: March 2015
Project Summary: The SMAP mission is designed to provide soil moisture measurements and its freeze/thaw state that will improve understanding of regional and global water cycles and climate changes, and improve the accuracy of weather, flood, and drought forecasts.
Latest Estimate of Total Project Cost: $914.6 million

Project: Solar Probe Plus (SPP)
Launch Readiness Date: August 2018
Project Summary: SPP is designed to explore the Sun's outer atmosphere to further the science of heliophysics by shedding light on the origin and evolution of solar wind and why the Sun's outer atmosphere is so much hotter than the visible surface.
Latest Estimate of Total Project Cost: $1.55 billion

Project: Space Network Ground Segment Sustainment (SGSS)
Completion Date: June 2017 (under review)
Project Summary: SGSS plans to develop and deliver a new ground system that will enable the Space Network—which provides essential

communications and tracking services to NASA and non-NASA missions—to continue safe, reliable, and cost efficient operations for the next several decades.
Latest Estimate of Total Project Cost: $493.9 million (under review)

Project: Stratospheric Observatory for Infrared Astronomy (SOFIA)
Full Operational Capability: April 2014
Project Summary: SOFIA is a joint project between NASA and the German Aerospace Center to install a 2.5 meter telescope in a specially modified Boeing 747SP aircraft to study many different kinds of astronomical objects and phenomena, for example planets, comets, and asteroids in our solar system.
Latest Estimate of Total Project Cost: $2.99 billion

Project: Tracking and Data Relay Satellite K/L (TDRS)
Launch Date: January 23, 2014 (TDRS L)
Project Summary: The TDRS System provides mission services for near-Earth user satellites and orbiting vehicles. TDRS L will contribute to the existing satellite network by providing continuous high-bandwidth digital voice, video, and mission payload data relay services to Earth-orbiting spacecraft.
Latest Estimate of Total Project Cost: $426.5 million

Commercial Crew Program

Project: CST-100 (Boeing)
Project Summary: CCP is a multi-phase effort to stimulate private-sector interest in providing commercial space transportation capabilities. Boeing's CST-100 spacecraft is being designed to include a crew as well as a cargo configuration and to be reusable for up to 10 missions.
Space Act Agreement Total: $480.0 million

Project: Dream Chaser (Sierra Nevada)
Project Summary: CCP is a multi-phase effort to stimulate private-sector interest in providing commercial space transportation capabilities. Sierra Nevada plans that its Dream Chaser spacecraft should be able to transport five crew to and from low earth orbit and will be capable of autonomous flight if needed.
Space Act Agreement Total: $227.5 million

Project: DragonRider (SpaceX)
Project Summary: CCP is a multi-phase effort to stimulate private-sector interest in providing commercial space transportation capabilities. The cargo version of the Dragon capsule has already carried cargo to the

International Space Station and is being modified to launch crew aboard a Falcon 9 rocket.
Space Act Agreement Total: $460.0 million

Appendix IV: Technology Readiness Levels

Technology readiness level	Description	Hardware	Demonstration environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis).	None.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis).	None.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytical studies and demonstration of nonscale individual components (pieces of subsystem).	Lab.
4. Component and/or breadboard. Validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of ad-hoc hardware in a laboratory.	Low fidelity breadboard. Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include high-fidelity laboratory integration of components.	High-fidelity breadboard. Functionally equivalent but not necessarily form and/or fit (size, weight, materials, etc). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated realistic environment.	Prototype. Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.

Technology readiness level	Description	Hardware	Demonstration environment
7. System prototype demonstration in a realistic environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in a realistic environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit, and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative realistic environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight qualified hardware	Developmental Test and Evaluation (DT&E) in the actual system application
9. Actual system "flight-proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug-fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Operational Test and Evaluation (OT&E) in operational mission conditions

Source: GAO analysis of NASA data.

Appendix V: Elements of a Sound Business Case

The development and execution of a knowledge-based business case for the National Aeronautics and Space Administration's (NASA) projects can provide early recognition of challenges, allow managers to take corrective action, and place needed and justifiable projects in a better position to succeed. Our studies of best practice organizations show the risks inherent in NASA's work can be mitigated by developing a solid, executable business case before committing resources to a new product's development.[1] In its simplest form, a knowledge-based business case is evidence that (1) the customer's needs are valid and can best be met with the chosen concept and that (2) the chosen concept can be developed and produced within existing resources—that is, proven technologies, design knowledge, adequate funding, adequate time, and adequate workforce to deliver the product when needed. A program should not be approved to go forward into product development unless a sound business case can be made. If the business case measures up, the organization commits to the development of the product, including making the financial investment. The building of knowledge consists of information that should be gathered at these three critical points over the course of a program:

- When a project begins development, the customer's needs should match the developer's available resources—mature technologies, time, and funding. An indication of this match is the demonstrated maturity of the technologies required to meet customer needs—referred to as critical technologies. If the project is relying on heritage—or pre-existing—technology, that technology must be in the appropriate form, fit, and function to address the customer's needs within available resources. The project will generally enter development after completing the preliminary design review, at which time a business case should be in hand.

- Then, about midway through the project's development, its design should be stable and demonstrate it is capable of meeting

[1]GAO, *Defense Acquisitions: Key Decisions to Be Made on Future Combat System*, GAO-07-376 (Washington, D.C.: Mar. 15, 2007); *Defense Acquisitions: Improved Business Case Key for Future Combat System's Success*, GAO-06-564T (Washington, D.C.: Apr. 4, 2006); *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes*, GAO-06-218 (Washington, D.C.: Dec. 21, 2005); and *NASA's Space Vision: Business Case for Prometheus 1 Needed to Ensure Requirements Match Available Resources*, GAO-05-242 (Washington, D.C.: Feb. 28, 2005).

performance requirements. The critical design review takes place at that point in time because it generally signifies when the program is ready to start building production-representative prototypes. If project development continues without design stability, costly re-designs to address changes to project requirements and unforeseen challenges can occur.

- Finally, by the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets and have demonstrated its reliability, and the design must demonstrate that it performs as needed through realistic system-level testing. Lack of testing increases the possibility that project managers will not have information that could help avoid costly system failures in late stages of development or during system operations.

Appendix VI: Comments from the National Aeronautics and Space Administration

National Aeronautics and Space Administration
Office of the Administrator
Washington, DC 20546-0001

APR 8 2014

Ms. Cristina Chaplain
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to comment on the Government Accountability Office (GAO) draft report entitled "Assessments of Selected Large-Scale Projects" (GAO-14-338SP). NASA remains dedicated to continuous improvement of its acquisition management processes and performance and will continue to work with GAO to identify and address any challenges that may lead to cost and schedule growth of our projects.

The GAO's Congressionally-mandated annual assessment is a good opportunity for NASA to receive an independent perspective on its performance in acquisition of major programs and projects. While we are not always fully in agreement, we appreciate the GAO's insights and the opportunity for open dialogue. NASA values the continued constructive communications between NASA and the GAO on this effort and appreciates the ongoing work by the GAO assessment team. We would also like to thank the GAO for considering and incorporating many technical corrections provided by the projects' subject matter experts as part of the audit. Inclusion of these comments is important to present an accurate and balanced view of the projects' technical status.

NASA is pleased that the GAO has recognized NASA's achievements over the past year, including the successful launch of four projects in 2013 and early 2014. Lunar Atmosphere and Dust Explorer (LADEE) was launched from Wallops Flight Facility, VA on September 6, 2013. After being successfully inserted into lunar orbit, LADEE conducted science operations to gather detailed information about the structure and composition of the thin lunar atmosphere and determine whether dust is being lofted into the lunar sky, as well as demonstrated very high-rate laser communications. LADEE is expected to impact the Moon by April 24, 2014, taking science data through its decent. Mars Atmosphere and Volatile EvolutioN (MAVEN) was launched on November 18, 2013, and the initial checkouts of all payloads on the spacecraft were completed in February 2014, with everything performing as expected. The spacecraft will enter orbit around Mars in September 2014. The second of NASA's three next-generation Tracking and Data Relay Satellites (TDRS), TDRS-L, launched on January 23, 2014, and is currently undergoing on-orbit checkout activities. TDRS-L bolsters our network of satellites that provides essential communications to support space exploration and improves the overall health and longevity of this system. Global Precipitation Measurement (GPM), a joint Earth-observing mission between NASA and the Japan Aerospace Exploration Agency (JAXA), was launched February 27, 2014, and is undergoing checkout activities and internal calibrations in preparation for full operations. As the GAO noted, both MAVEN and GPM were launched on schedule and within budget. TDRS-L was completed within budget and delivered early; however, the launch was delayed one month due to launch site availability. LADEE experienced cost growth but was launched on schedule.

The draft report identifies three challenges that could affect NASA's continued progress including: (1) managing competing priorities within the context of constrained budgets; (2) budget uncertainty; and (3) NASA's acquisition management. The first two are closely related, and the GAO's report rightly observes that any large cost overruns that might occur in NASA's three largest missions—James Webb Space Telescope (JWST), Space Launch System (SLS), and Orion—would make it challenging for NASA to manage its portfolio of projects. We further agree with the GAO's assessment that budget uncertainty complicates NASA's planning efforts given the complex multiyear planning that is required to successfully execute spaceflight projects. To the extent possible, NASA's budget planning process tries to account for these external factors and look for flexibilities to minimize impact to our programs and projects. As described by the GAO, NASA has implemented numerous changes to policy and practice. These changes are part of NASA's continuous improvement effort to improve acquisition management and are targeted at reducing cost and schedule growth within NASA's spaceflight projects.

NASA agrees that we cannot sustain large cost growth or schedule overruns on Orion and SLS, and the Agency has learned from the issues associated with JWST. Since the rebaseline of JWST in 2011, the project has consistently remained within its cost and schedule 2011 baseline. The project continues to make excellent progress meeting critical milestones, including successfully completing the spacecraft critical design review (CDR) in January 2014. Orion and SLS are also making excellent progress as both proceed toward confirmation this year.

NASA has a long-standing designation as a GAO High Risk area, and the GAO has previously identified weaknesses in NASA's cost and schedule estimating practices. In response to the High Risk designation, NASA created a High Risk Corrective Action Plan in 2007 and in 2008, established Success and Supporting Measures in support of the Corrective Action Plan. To date, six of the seven initiatives NASA identified are complete and operational, with additional work remaining in the area of cost performance. The current methodology employed to assess whether the major development projects are achieving the anticipated cost and schedule performance is detailed in the GAO's draft report. These metrics were established to help assess whether projects are on track to meet their Major Program Annual Report (MPAR) baselines, as approved by NASA and Congress.

NASA missions are technically challenging and typically achieve new capabilities for the first time, and the development of those missions is high risk by their nature with inherent uncertainties. Through the planning and review processes that have been put in place, NASA seeks to identify and characterize those risks and uncertainties to inform our decision making process, but there remains room for improvement. NASA acknowledges that Ice, Cloud, and land Elevation Satellite (ICESat-2) and Space Network Ground Sustainment (SGSS) experienced performance issues shortly after confirmation. The review process identified the risks that led to these issues, but underestimated the likelihood and impact of those risks as part of the analysis. NASA is committed to continuous improvement and evolving our management practices to better forecast and address items early and to ensure that when there are issues we take appropriate action. Given the complexity and uniqueness of our major projects, we are continually challenged and faced with issues that we have not encountered before, which makes it even more important to NASA to ensure we get the basics right in our standard business practices like risk management and our acquisition approach. We understand that there is still work to be done and look forward to continuing a dialog with the GAO to achieve this end.

As part of NASA's continuous improvement in cost estimating policies and processes, NASA instituted a Joint Cost and Schedule Confidence Level (JCL) Policy in 2009 (NASA Procedural Directive 1000.5) to increase the likelihood of project success at the specified funding level. In 2010, this policy was further expanded and clarified to require projects arriving at Key Decision Point (KDP)-B to produce probabilistic estimates of project life-cycle cost and schedule, consistent with GAO's 2011 recommendation. In order to manage resources, the policy directed projects to develop high and low cost and schedule estimates as the basis for their budgets until the Agency Baseline Commitment is established at KDP-C. As the GAO observes, projects are not always confirmed at a cost and schedule within the early estimates. Given the unique characteristics of all NASA projects, the Formulation Phase is the time for projects to understand and evolve the different technical elements and requirements so that the Agency can make a realistic cost and schedule commitment at the time of confirmation. Cost and schedule estimates may change as a result of this iterative process as more is known about the project.

NASA Procedural Requirements (NPR) 7120.5E currently stipulates specific circumstances under which a project will need to be rebaselined and a new JCL developed to support a new cost and schedule commitment. These requirements have evolved over time, so not all of the projects in this year's report were rebaselined at a time when this policy was in place, including the Stratospheric Observatory for Infrared Astronomy (SOFIA) and JWST. When a project is rebaselined, there are often significant changes to the scope of the mission. It is therefore important to track performance against the new baseline since it is a more accurate reflection of the project. An internal assessment is also done to show how the new baseline relates to the original baseline and to track any changes.

NASA is committed to working with the GAO to address any questions. We appreciate the ongoing opportunity to comment on the assessments and will continue to work with the GAO to ensure that comments are submitted and appropriately reflected in final reports. If you have any questions or require additional information, please contact Ellen Gertsen at (202) 358-0812.

Sincerely,

Robert Lightfoot
Associate Administrator

Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

Cristina Chaplain, (202) 512-4841 or chaplainc@gao.gov

Staff Acknowledgments

In addition to the contact named above, Shelby S. Oakley, Assistant Director; Jessica M. Berkholtz; Laura Greifner; Ramzi N. Nemo; Kenneth E. Patton; Carrie Rogers; Sylvia Schatz; Daniel Singleton; Roxanna T. Sun; Kristin Van Wychen; and Holly Williams made key contributions to this report.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through GAO's website (http://www.gao.gov). Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. To have GAO e-mail you a list of newly posted products, go to http://www.gao.gov and select "E-mail Updates."

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, http://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on Facebook, Flickr, Twitter, and YouTube. Subscribe to our RSS Feeds or E-mail Updates. Listen to our Podcasts. Visit GAO on the web at www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact:

Website: http://www.gao.gov/fraudnet/fraudnet.htm
E-mail: fraudnet@gao.gov
Automated answering system: (800) 424-5454 or (202) 512-7470

Congressional Relations

Katherine Siggerud, Managing Director, siggerudk@gao.gov, (202) 512-4400, U.S. Government Accountability Office, 441 G Street NW, Room 7125, Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149
Washington, DC 20548