United States Government Accountability Office

GAO

Report to Congressional Committees

April 2013

NASA

Assessments of Selected Large-Scale Projects

GAO

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GAO-13-276SP

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Highlights

Highlights of GAO-13-276SP, a report to congressional committees

April 2013

NASA

Assessments of Selected Large-Scale Projects

Why GAO Did This Study

This is GAO's fifth annual assessment of NASA's major projects. This report provides a snapshot of how well NASA is planning and executing its major acquisitions. Due to persistent cost and schedule growth associated with its major projects, this area is on GAO's high risk list. GAO previously reported that NASA has taken steps to address its acquisition management issues and was making progress toward improving the cost and schedule performance of its major projects.

This report provides observations about the cost and schedule performance of NASA's major projects, identifies factors that have contributed to this condition, and highlights challenges to NASA's management of the portfolio. To conduct this review, GAO assessed data on 18 current projects with an estimated life-cycle cost of over $250 million, including data on projects' cost, schedule, technology maturity, design stability, and contracts; analyzed monthly project status reports; and interviewed NASA and contractor officials.

What GAO Recommends

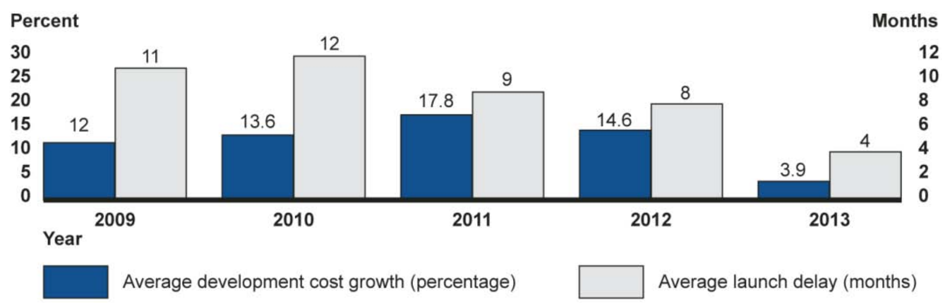
GAO is not making recommendations in this report, but is highlighting several challenges for NASA's attention, including managing competing priorities and improving cost and schedule estimating practices. GAO has made prior recommendations aimed at improving oversight, including improving the use of earned value management, implementing design stability best practices, and providing transparency into costs. NASA agreed with GAO's assessment of its progress and remaining challenges and stressed its commitment to sustaining progress.

View GAO-13-276SP. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The performance of the National Aeronautics and Space Administration's (NASA) portfolio of major projects has improved in the areas of cost and schedule growth since GAO's first assessment in 2009. Average development cost growth and schedule delay for the current portfolio have decreased to about a third of their 2009 levels.

Average Development Cost and Schedule Growth of Selected Major NASA Projects in the Implementation Phase, Excluding JWST



Source: GAO analysis of NASA data.

These figures exclude the cost and schedule growth of the James Webb Space Telescope (JWST), NASA's most expensive science project, in part because of its disproportionate effect on the portfolio average. Including the JWST in the calculation would increase the 2013 portfolio's average development cost growth from 3.9 percent to 46.4 percent and would double the average launch delay, from 4 to 8 months and obscure the progress the rest of the portfolio has made toward maintaining cost and schedule baselines. Of the 12 projects in implementation, 9 reported no development cost growth and or launch schedule delay in the past year, but 2 of these are currently facing cost and/or schedule pressures. Three projects reported development cost growth or a launch delay, but for two projects the impetus was outside of the project's direct control.

A number of factors appear to contribute to NASA's improved performance. For example, in prior reviews, a majority of projects exceeded their cost and schedule baselines. Most of these projects, however, have launched and are no longer affecting the portfolio. Consistent with prior recommendations, projects have also demonstrated some gains toward meeting best practices criteria for technology maturity and design stability. GAO has reported that conformity with these practices decreases cost and schedule risk. For example, 62 percent of the projects met technology maturity criteria this year as compared to 29 percent in 2010. Current projects also appear to be incorporating less technology risk, as the number of critical technologies per project has decreased from 4.7 in 2009 to 2.3 in 2013. NASA has also implemented new management practices that have likely contributed to improved performance, in part by increasing oversight.

Continued leadership attention will be needed to ensure that good practices are maintained in the face of several challenges including: (1) managing competing priorities within the context of constrained budgets, (2) estimating costs associated with several large-scale projects, (3) improving overall cost and schedule estimation, and (4) using consistent and proven design stability metrics.

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Abbreviations

AFB	Air Force Base
AFS	Air Force Station
ATLAS	Advanced Topographic Laser Altimeter System
CDR	critical design review
DCI	data collection instrument
EFT	exploration flight test
EMTGO	ExoMars Trace Gas Orbiter
ESA	European Space Agency
EVM	earned value management
GLAST	Gamma-ray Large Area Space Telescope
GPM	Global Precipitation Measurement (mission)
GRAIL	Gravity Recovery and Interior Laboratory
HEPS	High Efficiency Power Supply
ICESat-2	Ice, Cloud, and Land Elevation Satellite-2
ISIM	Integrated Science Instrument Module
JAXA	Japan Aerospace Exploration Agency
JCL	Joint Cost and Schedule Confidence Level
JWST	James Webb Space Telescope
KDP	key decision point
LADEE	Lunar Atmosphere and Dust Environment Explorer
LDCM	Landsat Data Continuity Mission

LRO	Lunar Reconnaissance Orbiter
MagEIS	Magnetic Electron Ion Spectrometer
MAVEN	Mars Atmosphere and Volatile EvolutioN
MDR	mission definition review
MMS	Magnetospheric Multiscale
MPCV	Multi-Purpose Crew Vehicle
MSL	Mars Science Laboratory
NASA	National Aeronautics and Space Administration
NGIMS	Neutral Gas and Ion Mass Spectrometer
NPR	NASA Procedural Requirements
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
OCFO	Office of the Chief Financial Officer (NASA)
OCO	Orbiting Carbon Observatory
OSIRIS-REx	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
PDR	preliminary design review
QMS	Quadrupole Mass Spectrometer
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
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPP	Solar Probe Plus
TDRS	Tracking and Data Relay Satellite
TIRS	Thermal Infrared Sensor
TPS	Thermal Protection System
TRL	technology readiness level
USGS	U.S. Geological Survey
WISE	Wide-field Infrared Survey Explorer

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United States Government Accountability Office
Washington, DC 20548

April 17, 2013

Congressional Committees

This is GAO's fifth annual assessment of the National Aeronautics and Space Administration's (NASA) major projects. This report provides a snapshot of how well NASA is planning and executing its major acquisitions—an area that has been on GAO's high risk list since 1990. Over the past 5 years, our review has covered a range of projects, from highly complex and sophisticated space transportation vehicles, to robotic probes, to satellites equipped with advanced sensors to study the earth. During the last 2 years, NASA has launched eight projects, of which six have begun returning science results. For example, in June 2011, NASA launched the Aquarius project. The data returned from Aquarius made possible the first global map of the salinity of the ocean surface, which allows scientists to study how the ocean's salinity influences Earth's climate. The Gravity Recovery and Interior Laboratory (GRAIL), launched in September 2011, has created the most accurate gravity map of the Moon's surface, allowing scientists to learn about the Moon's internal structure and composition in unprecedented detail. NASA's latest Mars rover, Curiosity, successfully landed and has begun beaming back images and data to scientists, such as the first indication that a stream once flowed vigorously across Mars. Notably, NASA has launched two missions in the last 2 years—GRAIL and Juno—within their established cost and schedule commitments.

Despite these successes, the effects of the additional resources needed to support NASA's largest science project—the James Webb Space Telescope (JWST)—began to resonate as the project identified the need for an additional $1.4 billion from fiscal years 2012 through 2017. At the same time, NASA's portfolio of major projects has decreased in size. For example, while eight science projects launched in the past 2 years and transitioned into operations, only two have entered the portfolio in that same period. One of those two projects, the ExoMars Trace Gas Orbiter, was subsequently proposed for termination by NASA in 2012.

The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act of 2009 directed GAO to prepare project status reports on selected large-scale NASA programs, projects, or activities. This report responds to that mandate. Specifically, we (1) assess the performance of NASA's portfolio of major projects in terms of cost and schedule; (2) identify factors that have contributed to the portfolio's current performance; and (3) highlight remaining challenges to continued improvement. The report expands on the importance of providing decision makers with an independent, knowledge-based assessment of individual systems that identifies potential risks and allows them to take actions to put projects that are early in the development cycle in a better position to succeed. We are not making recommendations in this report, but 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 project costs.

Our approach included an examination of 18 major projects each with an estimated life-cycle cost of over $250 million. These projects were in either the formulation phase or the implementation phase of the project life cycle. In the formulation phase, the project defines requirements—(i.e., what the project is being designed to do)—matures technology, establishes a schedule, estimates costs, and produces a plan for implementation. In the implementation phase, the project carries out these plans, performing final design and fabrication as well as testing components and system assembly, integrating these components and testing how they work together, and launching the project. This phase also includes the period from a project's launch through mission closeout.

In order to assess the performance of NASA projects in terms of cost and schedule, we compared the projects' baseline cost and schedule data with cost and schedule data that was current as of February 2013 for projects in implementation during our review, or 12 of the 18 major projects.[1] The remaining 6 projects were in formulation and NASA provided preliminary cost and schedule estimates for 5 of the 6. We reviewed and compared the 12 projects' current cost and schedule data to previously established cost and schedule baselines as applicable. We assessed the projects' cost and schedule and characterized growth as significant if it exceeded the thresholds that trigger cost or schedule

[1]The Space Network Ground Segment Sustainment (SGSS) project entered the implementation phase in April 2013, after our review of projects had concluded. This project is not included in our analyses of projects in implementation, however, the project's baseline cost and schedule is reported in the two page assessment.

growth reporting to certain congressional committees under the law.[2] To identify factors that contributed to the portfolios' current performance, we identified the number of technologies and lines of software code each project was developing, reviewed historical data on past projects and compared it to current project performance, and compared projects' technology maturity and design stability against established criteria for knowledge-based acquisitions and other GAO work on system acquisitions.[3] To identify remaining challenges to continued improvement, we principally relied on outstanding issues identified in our prior work on NASA, such as earned value management implementation issues and cost and schedule growth on NASA's most technologically advanced and costly projects. We examined how NASA is managing its large and complex missions within the current budget environment, and assessed the extent to which NASA has implemented GAO's prior recommendation that the agency develop a consistent set of proven metrics to assess design stability. In addition, we assessed the schedules for three major projects against best practices.[4] As a result of our interviews with project officials and analysis of information provided by the projects, we identified other challenges—launch, contractor management, parts, development partner, test and integration, workforce, and funding—that can affect project outcomes and are reported on the two-page 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 clarifying data discrepancies and corroborating NASA-generated data with other sources where applicable. We determined that the data were reliable enough for our purposes. 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, which were incorporated as appropriate. Appendix I contains detailed information on our scope and methodology.

[2]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).

[3]GAO, *Best Practices: Using a Knowledge-Based Approach to Improve Weapon Acquisition*, GAO-04-386SP (Washington, D.C.: Jan. 2004).

[4]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-12-120G (Washington, D.C.: May 30, 2012).

We conducted this performance audit from March 2012 to April 2013 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.

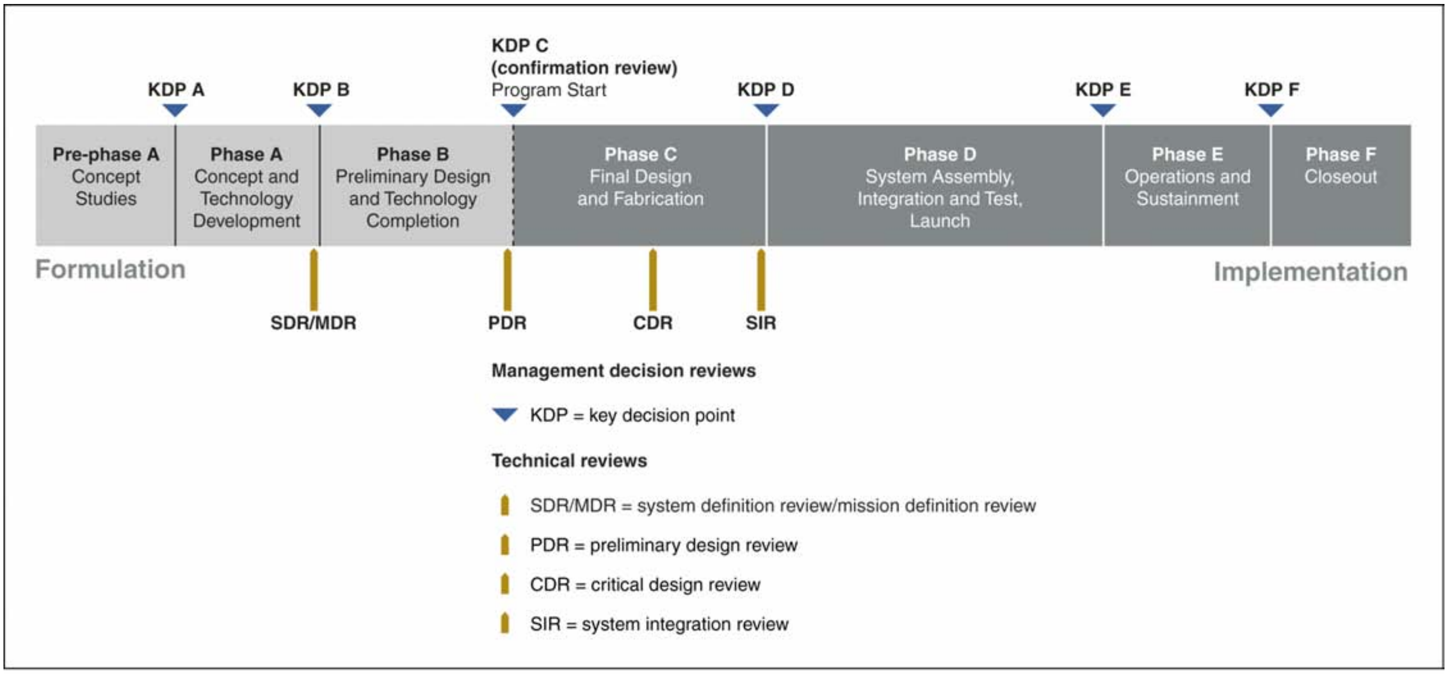
Background

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.[5] 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.

[5]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 time the projects develop and define requirements and the cost/schedule basis and design for implementation, including developing an acquisition strategy. During the end of the formulation phase, leading up to the preliminary design review (PDR), the project team completes its preliminary design and technology development.[6] *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 define the schedule and funding requirements for that work. The formulation agreement identifies new technologies and their planned development,

[6]According to NPR 7120.5E, Table 2-5 (Aug. 14, 2012), the PDR 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.

the use of heritage technologies, risk mitigation plans, and testing plans to ensure that technologies will work as intended in a relevant environment. The project also develops and maintains the status of a set of programmatic and technical leading indicators to ensure proper progress and management of the project or single-project program is achieved during the formulation phase. The formulation phase culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are confirmed and documented in the agency baseline commitment.[7] 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 (CDR), 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.[8] After CDR and just prior to beginning phase D, the project completes a system integration review (SIR) to evaluate the readiness of the project and associated supporting infrastructure to begin system assembly, integration and test.[9] 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.

[7]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).

[8]According to NPR 7120.5E, Table 2-5 (Aug. 14, 2012), the CDR evaluates the integrity of the project design and its ability to meet mission requirements, with appropriate margins and acceptable risk, within defined project constraints, including available resources. It determines if the design is appropriately mature to continue with the final design and fabrication phase.

[9]The SIR evaluates the readiness of the project and associated supporting infrastructure to begin system assembly, integration, and test. SIR evaluates whether the remaining project development can be completed within available resources and determines if the project is sufficiently mature to begin phase D, where test and integration activities occur. NPR 7120.5E, Table 2-5 (Aug.14, 2012).

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 its 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 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—6 projects in formulation and 12 projects in implementation. Three of the 12 projects in implementation—Radiation Belt Storm Probes (RBSP), Tracking and Data Relay Satellite Replenishment (TDRS K), and Landsat Data Continuity Mission (LDCM)—successfully launched during 2012 and 2013. The year after a project launches, we no longer include a two-page 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 table 1 for a list of the projects we reviewed in this year's assessment, and appendix II for a list of projects that we have reviewed from 2009 to 2013.

Table 1: 18 Selected Major NASA Projects Reviewed in GAO's 2013 Annual Assessment

Projects in formulation	ExoMars Trace Gas Orbiter (EMTGO)[a]
	Orion Multi-Purpose Crew Vehicle (MPCV)
	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx)
	Solar Probe Plus (SPP)
	Space Launch System (SLS)
	Space Network Ground Segment Sustainment (SGSS)[b]
Projects in implementation	Global Precipitation Measurement (GPM) Mission
	Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)
	James Webb Space Telescope (JWST)
	Landsat Data Continuity Mission (LDCM)[c]
	Lunar Atmosphere and Dust Environment Explorer (LADEE)
	Magnetospheric Multiscale (MMS)
	Mars Atmosphere and Volatile EvolutioN (MAVEN)
	Orbiting Carbon Observatory 2 (OCO-2)
	Radiation Belt Storm Probes (RBSP)[c]
	Soil Moisture Active and Passive (SMAP)
	Stratospheric Observatory for Infrared Astronomy (SOFIA)
	Tracking and Data Relay Satellite (TDRS) Replenishment K[c] and L[d]

Source: GAO analysis of NASA data.

[a]In February 2012, NASA proposed canceling the EMTGO project as part of its fiscal year 2013 budget request.

[b]SGSS entered the implementation phase in April 2013, after our review of projects had concluded. This project is not included in our analyses of projects in implementation, however, the project's baseline cost and schedule is reported in the two page assessment.

[c]NASA projects that launched during our review.

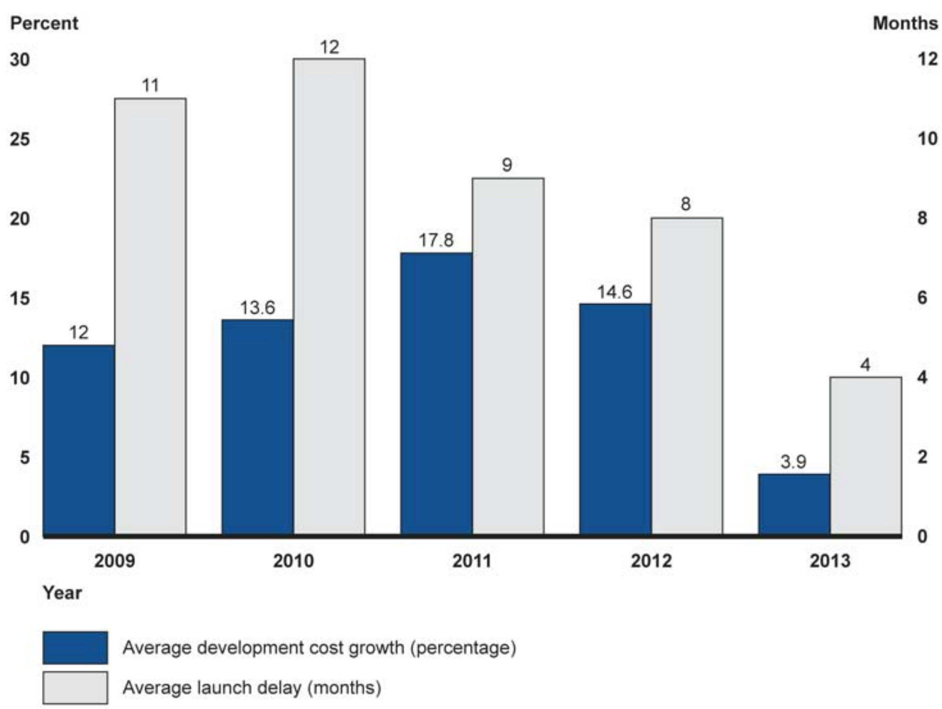
[d]TDRS Replenishment includes TDRS-K and TDRS-L. These satellites will launch separately, but are counted as only one mission.

Observations on NASA's Portfolio of Major Projects

When Excluding JWST, Portfolio Development Cost and Schedule Growth Have Significantly Improved Since Our Initial Review in 2009

In 2009, the major NASA projects in our review that were in the implementation phase had an average development cost growth of 12 percent and an average launch delay of 11 months. In the current portfolio of major projects, excluding JWST, the average development cost growth and launch delay of projects in implementation has decreased to a third of 2009 levels. As seen in figure 2 below, the portfolio of projects currently in implementation—excluding JWST—has an average development cost growth of 3.9 percent and an average launch delay of 4 months.

Figure 2: Average Development Cost and Schedule Growth of Selected Major NASA Projects in the Implementation Phase, Excluding JWST



Source: GAO analysis of NASA data.

Note: The calculations do not include the cost or schedule growth experienced by the JWST project.

For the purposes of this analysis we excluded JWST cost and schedule growth from the calculations for the portfolios because including them would mask the progress that the rest of the portfolio has made toward maintaining cost and schedule. Of those projects in implementation, JWST makes up 51 percent of the total development costs and including it in the portfolio calculation would increase the 2013 average development cost growth of projects in implementation by nearly a factor of 12, from 3.9 percent to 46.4 percent. It would also double the average launch delay from 4 months to 8 months. Nonetheless, while identifying progress within the portfolio is important, as a result of JWST's cost growth NASA will likely have less flexibility to address issues on other projects, should they arise. In addition, cost growth associated with projects over the past 5 years of our review has also limited the agency's flexibility to manage its entire portfolio and implement additional projects to achieve its mission. For example, while NASA has only had to find $119 million over the past year due to project cost growth, the agency has had to find $5.2 billion over the last 5 years—a 24 percent cost increase for projects in implementation—due to project cost growth.

Most Projects in the Portfolio Have Not Reported Cost and Schedule Growth in the Last Year, but a Few Projects Are Experiencing Cost and/or Schedule Pressure

NASA has had success in the last 2 years in launching missions on cost or on schedule. For example, the RBSP project is the third mission in the last 2 years that has launched on cost, building on the prior year's launches of the GRAIL and Juno missions that both launched within their cost and schedule baseline estimates.

Of the 12 projects in implementation, 9 reported no development cost growth and no launch schedule delay in the last year. Of those projects that have not reported cost and schedule growth in the last year, some have been replanned, baselined, or rebaselined within the last 2 years and in one instance cut capabilities.[10] Specifically, the Global Precipitation Measurement (GPM) project reduced development costs in its fiscal year 2012 replan by eliminating an instrument from the development plan that project officials stated will impact the science data returned by the

[10] A rebaseline is when cost, resources, and/or schedule commitments are revised. NASA projects are rebaselined when their estimated development cost exceeds NASA's baseline commitment development cost by 30 percent or more and Congress has reauthorized the project; events external to NASA make a rebaseline appropriate; or a NASA Associate Administrator determines that the project's scope changed from the approved project baseline.

mission. See table 2 below for more details on projects' development cost and schedule growth reported this year and against their baselines.

Table 2: Development Cost and Schedule Growth of Selected Major NASA Projects Currently in the Implementation Phase

Dollars in millions

Project	Cumulative development cost growth	Percentage cost growth	Development growth reported in last year	Cumulative launch delay (months)	Launch delay reported in last year (months)
GPM[a]	-$45.3	-8.2%	-$9.4	11	0
ICESat-2[b]	0.0	0.0	0.0	0	0
LADEE	7.9	4.7	0.3	0	0
LDCM[c]	-6.2	-1.1	0.0	-4	-4
MAVEN	-15.5	-2.7	-15.5	0	0
MMS	-0.1	0.0	0.0	0	0
OCO-2[d]	122.8	49.3	122.8	24	24
RBSP[e]	-23.6	-4.4	-20.6	4	0
SMAP[f]	0.0	0.0	0.0	0	0
SOFIA	208.9	22.7	0.0	12	0
TDRS Replenishment[g]	-24.8	-11.8	1.0	2	2
Portfolio excluding JWST					
Average	**$20.4**	**3.9%**	**$7.1**	**4**	**2**
Portfolio including JWST					
JWST[h]	$3,616.8	140.1%	$0.0	52	0
Average	**$320.1**	**46.4%**	**$6.6**	**8**	**2**

Source: GAO analysis of NASA data.

Note: Shading indicates projects that exceeded the cost or schedule thresholds that trigger reporting to certain House and Senate committees under the law.

[a]GPM's development cost decreased largely because one instrument was removed from the project.

[b]ICESat-2 entered Implementation and was baselined in December 2012.

[c]NASA reported that LDCM's development costs were reduced because of progress in delivering an instrument and integrating it with the spacecraft and in completing environmental testing on another instrument.

[d]OCO-2's development costs have increased largely because the project set a new baseline due to a change in launch vehicle.

[e]The life-cycle cost for RBSP has not changed. The reduction in development costs were offset by an increase in operation costs.

[f]SMAP established its initial cost and schedule baseline in 2012.

[g]NASA's development costs for TDRS Replenishment decreased for several reasons, including greater than expected contributions from one of NASA's partners and the inadvertent inclusion of costs for another TDRS satellite. Although TDRS Replenishment experienced a launch delay for both TDRS-K and TDRS-L, we only report the longer delay for TDRS-L.

[h]JWST was rebaselined in 2011.

Only three projects in the portfolio reported development cost growth or launch schedule delay in the last year, but impetus for the growth or delay, or both, was outside of two projects' direct control. For example, the Orbiting Carbon Observatory (OCO)-2 project reported the bulk of its development cost growth and schedule delay for the last year—$122.8 million and 24 months—was due to a change in launch vehicle late in the development cycle after two successive NASA science mission launch failures on OCO-2's planned launch vehicle. In addition, NASA has delayed the launch of the Tracking and Data Relay Satellite (TDRS) Replenishment project's TDRS-L satellite by 2 months due to other government mission launch schedules.

Two projects—although reporting little or no cost and schedule growth in the last year—are currently facing cost or schedule pressures. For example, the Lunar Atmosphere and Dust Environment Explorer (LADEE) project had spent more than three-quarters of its reserve funding prior to entering its test and integration phase and, according to officials, faces a potential launch schedule conflict with an Air Force mission that could delay its planned launch date. The test and integration phase is when issues generally arise that require additional money and time to address. The Magnetospheric Multiscale (MMS) project entered its test and integration phase in October 2012 and had already used more than 85 percent of its reserve funding as of December 2012. A significant portion of the reserve funding was used to pay for the costs associated with moving the project's thermal vacuum testing to the Naval Research Laboratory because of conflicts with other NASA projects.

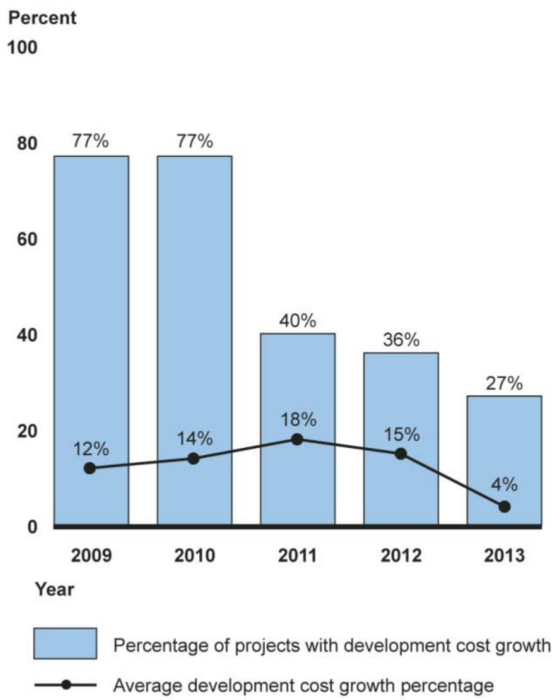
Contributing Factors to the Portfolio's Current Performance

Most of the Projects That Exceeded Their Cost and Schedule Baselines Are No Longer in the Portfolio

In the first 2 years of our review, 2009 and 2010, a majority of the projects in the portfolio exceeded their cost and schedule baselines; however, most of these projects have launched and therefore are no longer being accounted for in our cost growth and schedule delay calculations. For example, three projects that were removed from the portfolio in the last year—Aquarius, Mars Science Laboratory (MSL), and the National Polar-orbiting Operational Environmental Satellite System Preparatory

Project[11]—accounted for a combined development cost growth of more than $1 billion and 91 months of launch delays. Even including the cost increase of the OCO-2 project's launch vehicle change and subsequent launch delay, the removal of three costly projects from the portfolio lowered the average development cost growth from 15 percent in 2012 to 4 percent in 2013. As shown in figure 3 below, when projects with development cost growth and launch delays exit the portfolio, and when newer projects are maintaining their cost and schedule baselines, the portfolio's average development cost growth drops significantly.

Figure 3: Selected Major NASA Projects with Development Cost Growth and the Portfolio Average Development Cost Growth, 2009-2013



Source: GAO analysis of NASA data.

Note: The calculations do not include the cost growth experienced by the JWST project.

[11]Following this mission's launch, NASA renamed it the Suomi-National Polar-orbiting Partnership.

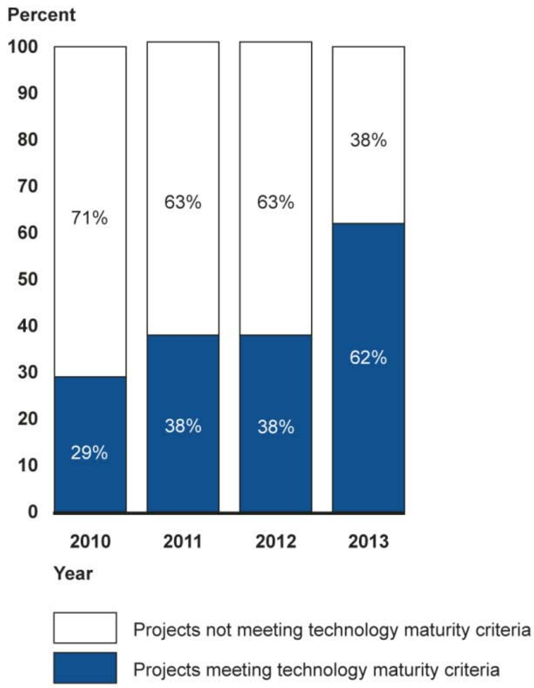
Major Projects Show Overall Improvement Meeting Technology Maturity Criteria, but Generally Plan to Develop Fewer New Technologies and Less New Software

In addition to observed improvements in cost and schedule performance this year, projects also demonstrated some gains in meeting best practices criteria for technology maturity. Nearly two-thirds of the projects in our current review meet best practice standards for technology maturity, showing a marked improvement from recent years. 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.[12] NASA's systems engineering policy also states that by the preliminary design review, a TRL of 6 is desirable prior to integrating a new technology in a project.[13] Demonstrating that technologies 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 by preliminary design review often experience subsequent technical problems. Specifically, 13 of the 18 projects in the current portfolio have completed their preliminary design review and of the 13, 8—approximately 62 percent—have met best-practice standards for technology maturity. These results mark a significant improvement from prior years. For example, only 29 percent of projects assessed in 2010 met the criterion. See figure 4 for an analysis of the projects that we reviewed in the past 4 years that held their preliminary design review and the percentage of those projects that proceeded into implementation with immature technologies.

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

[13]NASA Procedural Requirements 7123.1A, NASA *Systems Engineering Processes and Requirements with Change 1,* Appendix G, paragraph G.19b (Mar. 26, 2007).

Figure 4: Percentage of Selected Major NASA Projects Meeting and Not Meeting Technology Maturity Criteria at Preliminary Design Review

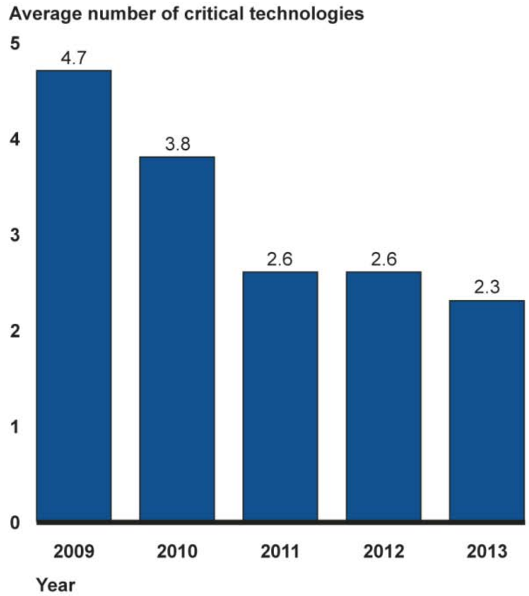


Source: GAO analysis of NASA data.

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

While NASA has made improvements in its technology development efforts, it appears that recent projects are taking on less technology risk than their predecessors by incorporating fewer new critical technologies into their design. As a result, we have also seen a decline over time in the number of critical technologies that projects we reviewed plan to develop. Specifically, we found that the average number of critical technologies reported per project has declined from 4.7 in our first review in 2009 to 2.3 in 2013. Significantly, the reduced averages in 2012 and 2013 include the JWST, which reported 10 critical technologies, substantially more than most other projects assessed. Without JWST included the average number of critical technologies declines to 1.67. See figure 5.

Figure 5: Average Number of Critical Technologies Reported for Selected Major NASA Projects Reviewed from 2009 to 2013



Source: GAO analysis of NASA data.

In addition to the hardware being developed by NASA projects, projects also require the development of computer software to perform critical mission functions, thus the amount of new mission-critical software developed by a project provides another indication of that project's technical complexity.[14] We received data from NASA projects concerning their development of new mission-critical software, and in most cases this information was consistent with the low number of critical technologies that projects planned to develop. Most projects in implementation have undertaken low amounts of new software development and have incorporated a lower number of critical technologies, which indicates a less-complex, lower-risk development effort. Specifically, six of nine projects in this year's portfolio that have completed a preliminary design

[14]For purposes of this analysis, we use the term "mission-critical software" to refer to software included under NASA software classes A or B. NASA defines Class A software as, among other things, ground and flight software systems needed to perform a primary mission objective of human space flight, and which directly interacts with human space flight systems. NASA defines Class B software as, among other things, software that must perform reliably to accomplish primary mission objectives or major function(s) in Non-Human Space Rated Systems.

review reported that less than 10 percent of the project's mission-critical software resulted from new software development, and all but one of these six projects reported one or no critical technologies. In contrast to this trend toward fewer critical technologies per project, the JWST project—one of NASA's most advanced science projects—reported 10 critical technologies and 60 percent of mission-critical software resulting from new development efforts. See table 3.

Table 3: Percent of New Mission Critical Software and Critical Technologies Reported by Selected NASA Major Projects

NASA Project	Reported percent of new source lines of code for mission-critical software	Reported number of critical technologies
James Webb Space Telescope (JWST)	60%	10
Magnetospheric Multiscale (MMS)	46	2
Lunar Atmosphere and Dust Environment Explorer (LADEE)	29	1
Landsat Data Continuity Mission (LDCM)	8	3
Soil Moisture Active and Passive (SMAP)	5	1
Global Precipitation Measurement (GPM)	5	1
Mars Atmosphere and Volatile EvolutioN (MAVEN)	4	1
Tracking and Data Relay Satellite Replenishment (TDRS)	4	1
Orbiting Carbon Observatory 2 (OCO-2)	0	0

Source: GAO analysis of NASA data.

Both GAO and NASA have reported that reusing software can benefit projects by reducing development time, costs, and testing. In one instance, we observed that one project reused software developed by another NASA project in order to recover from a delay in software development. While this decision demonstrated managers' resourcefulness in addressing a project challenge by making efficient use of resources and by reducing risk, the feasibility of adapting code from another project in this way does tend to illustrate similar degrees of lower technical complexity among recent projects, which could contribute to improved cost and schedule performance. Since the LDCM, OCO-2, and

TDRS Replenishment projects each are deploying spacecraft with similar missions to their predecessors, we would expect relatively high levels of software reuse and relatively low amounts of new software development in comparison to other major projects.

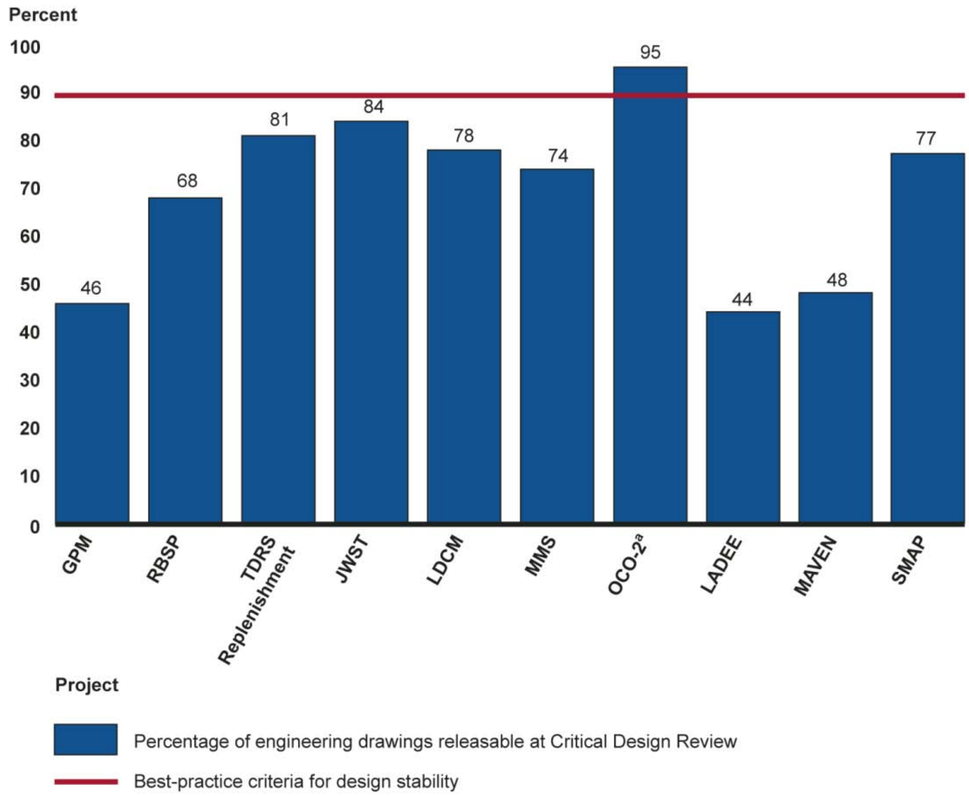
Most Projects Did Not Meet the Design Stability Best Practices, but Progress Has Been Made

Nine of the 10 projects in this year's portfolio that held a critical design review did not meet the best practice criteria of having at least 90 percent of engineering drawings in a releasable state at the time of the review. However, six of these nine projects reported between 67 and 90 percent of drawings releasable at the time of the review.[15] See figure 6. Our work on product development best practices shows 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.[16] Guidance in NASA's *Systems Engineering Handbook* mirrors this metric. Because the critical design review is the time in a project's life cycle when the integrity of the project design and its ability to meet mission requirements are assessed, it is important that a project's design is stable enough to warrant continuation with design and fabrication. A stable design allows projects to "freeze" the design and minimize changes prior to beginning the fabrication of hardware. It also helps to avoid re-engineering and rework efforts due to design changes that can be costly to the project in terms of time and funding.

[15]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."

[16]Appendix IV contains detailed information about the project attributes highlighted by knowledge-based metrics at each stage of systems development.

Figure 6: Percentage of Engineering Drawings Releasable at CDR for Selected Major NASA Projects

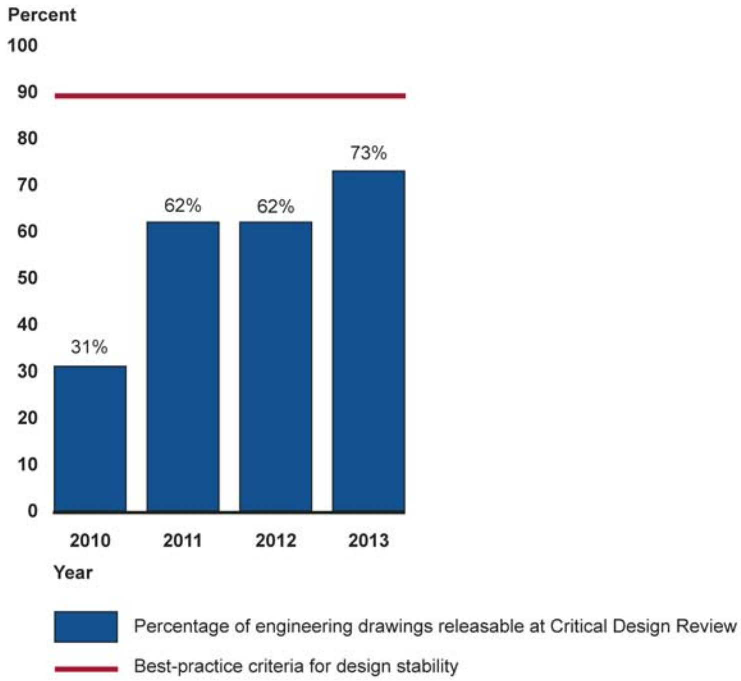


Source: GAO analysis of NASA data.

[a]The OCO-2 project is a rebuild of a prior design that launched and therefore a majority of its drawings were releasable.

While most of the projects in our review did not attain the 90 percent criteria, many of the recent projects have considerably higher percentages of drawings releasable at the critical design review than we reported in prior reviews. Specifically, the 10 projects in this year's portfolio that completed their critical design reviews averaged 73 percent of engineering drawings releasable at the time of that review, while projects at the same stage of development averaged 31 percent in 2010. See figure 7.

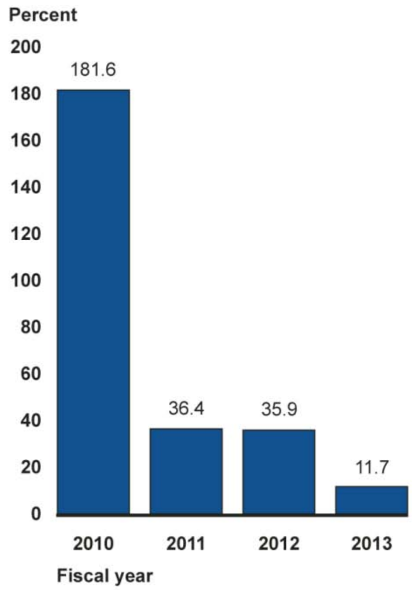
Figure 7: Percentage of Releasable Drawings for Selected Projects Reviewed That Held a Critical Design Review



Source: GAO analysis of NASA data.

An additional indicator of an unstable design is the degree to which the expected number of design drawings for a project increases after the critical design review. We continue to see a positive trend in this regard. As projects we reviewed improved their efforts to reach design stability by their CDR, they have also reported significantly improved performance in controlling increases in engineering drawings following critical design review. Specifically, nine projects assessed in our fiscal year 2010 study reported an average of a 181.6 percent increase in engineering drawings after CDR. The analogous figure has fallen to 11.7 percent for the 10 projects in this year's report that have completed CDR. See figure 8.

Figure 8: Average Percentage of Drawing Growth after CDR For Selected Projects from Fiscal Years 2010 through 2013



Source: GAO analysis of NASA data.

Six of these 10 projects report post-CDR growth less than or equal to 4 percent. Most of these projects held their critical design reviews 1 to 3 years ago, providing some time over which growth in the number of drawings might take place. The remaining 4 projects have had post-CDR growth in drawings exceeding 14 percent. Two of these projects—GPM and LADEE—had less than 50 percent of their engineering drawings releasable at CDR, and have reported post-CDR drawing growth of 14.4 and 65.2 percent, respectively.

Progress Made on the Management and Oversight of Major Projects

Over the past several years, NASA has made positive changes that have helped contribute to the improved performance of its projects. Among other things, we previously reported that NASA adopted a new policy to help project officials with management, cost and schedule estimating, and maintenance of adequate levels of reserves; established a management review process to enable NASA's senior management to more effectively monitor a project's performance, including cost, schedule, and cross-cutting technical and nontechnical issues; and have improved external oversight by increasing transparency into project costs. For example, NASA instituted the joint cost and schedule confidence level (JCL) process, which is expected to quantify potential risks and calculates cost, schedule, and reserve estimates based on all available data.[17] NASA also addressed one of our 2011 recommendations by beginning to provide more transparency into project costs in the early phases of development, such as life cycle cost estimate ranges for projects in formulation and information on prior year costs. This information should allow the Congress sufficient information to conduct oversight and ensure earlier accountability and should bring more attention to and focus on conducting early, reliable estimates of project costs.

Challenges Remain That Could Affect Continued Progress

The portfolio's improved cost and schedule performance is beginning to reflect changes that have increased oversight and brought more attention to disciplined project management. Continued leadership in this regard, however, will be necessary to ensure that such changes are sustained, especially as the agency deals with flat or decreasing budgets and the implementation of several large-scale, complex projects. In addition, by continuing to implement tools and metrics to monitor performance of projects, as we have recommended, NASA officials will better be able to ensure that progress will continue and that managers are equipped to oversee NASA's major projects and deliver positive results. Several challenges need to be addressed to ensure continued progress:

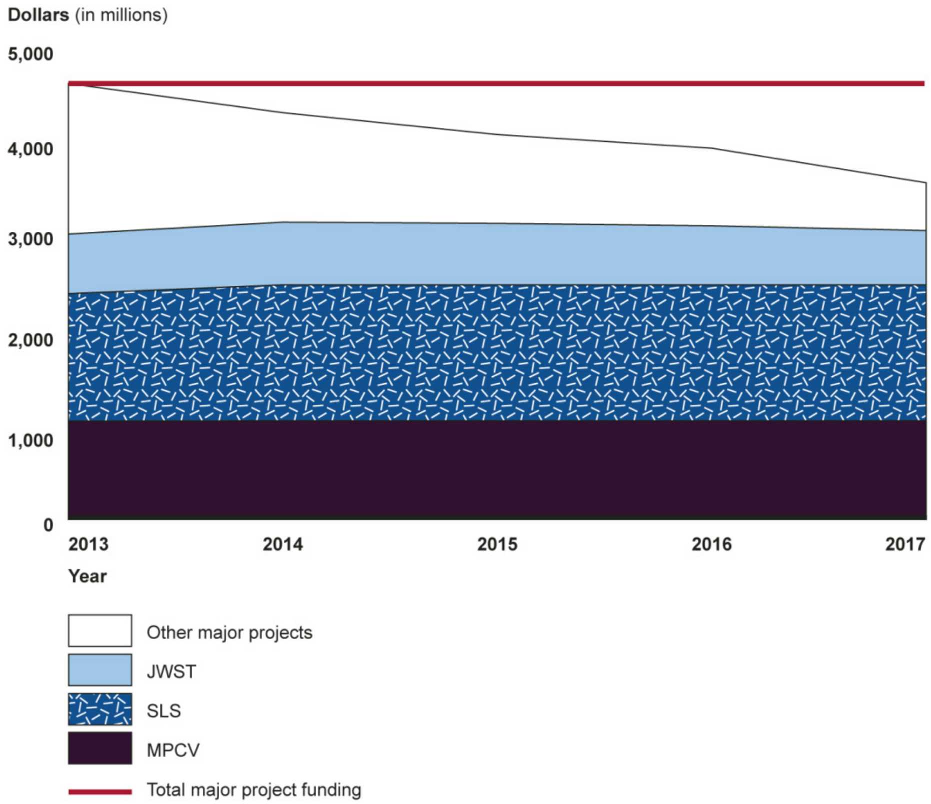
- **Managing competing priorities within the context of constrained budgets:** NASA's primary challenge in the next few years will be to complete a series of complex and expensive projects in the context of constrained budgets and sometimes competing priorities set by the Congress and the administration. This challenge will not be easily met if any of NASA's three flagship efforts—JWST, the Space Launch System (SLS), and the Orion Multi Purpose Crew Vehicle (MPCV)—experience large cost overruns as there is little flexibility in NASA's portfolio to address significant cost growth beyond canceling projects.

  Although cost and schedule growth can occur on any project, increases associated with its most costly and complex missions can have cascading effects on the rest of the portfolio. For example, recent JWST cost growth will have reverberating effects on the portfolio for years to come and required the agency to identify $1.4 billion in additional resources over

[17] The JCL is a probabilistic analysis that includes, among other things, all cost and schedule elements, incorporates and quantifies potential risks, assesses the impacts of cost and schedule to date, and addresses available annual resources to arrive at development cost and schedule estimates associated with various confidence levels.

fiscal years 2012 through 2017, according to Science Mission Directorate officials. NASA identified approximately half of this required funding from the four science divisions within the Science Mission Directorate account. The majority of the cuts were related to future high priority missions, missions in the operations and sustainment phase, and research and analysis. In essence, NASA has had to mortgage future high priority missions and research to address JWST's additional resource needs. Cost growth on SLS and MPCV would likely have similar effects. NASA initiated work on SLS and MPCV in November 2011 to replace the launch vehicle and crew capsule for the Constellation program, which was cancelled in February 2010. Together these three projects—JWST, SLS, and MPCV—are estimated to require approximately $3 billion a year through fiscal year 2017. Based on NASA's budget estimates for fiscal years 2012 and 2013, NASA expects to provide approximately $4.6 billion for its major projects. However, they are the types of costly and complex projects that NASA has struggled to complete within time and funding constraints over the past two decades. NASA cannot realistically expect to have significant additional funding available to cover any potential cost overruns on its major projects without negatively affecting its ability to begin new projects or its performance on existing projects. With a significant portion of this funding already committed to existing projects, NASA will have limited flexibility to address potential cost growth or begin new projects over the next 5 years. See figure 9.

Figure 9: Fiscal Year 2013 Budget Request for JWST, MPCV, SLS, and All Other Major NASA Projects, 2013 through 2017



Source: GAO analysis of NASA data.

Note: Budget data is from the fiscal year 2013 President's budget request. Total line indicates the 2013 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.

Should NASA experience significant cost growth on JWST, SLS, or MPCV, competing priorities set by the Congress and the administration will limit the agency's flexibility to make tradeoffs. On the one hand, the Congress has placed a priority on funding JWST, SLS and MPCV and Members of Congress have voiced concerns about the possibility of cuts or cancellations being made to other parts of NASA's portfolio such as projects focused on exploring Mars. On the other hand, other projects may be difficult to delay or cancel because they are providing critical capabilities to NASA and/or other government agencies. For instance, NASA's Space Network Ground Segment Sustainment project plans to develop and deliver a new ground system for NASA's Space Network—which provides essential communications and tracking services to NASA and non-NASA missions—because the existing ground system is based on 1980s technology and software and the systems are becoming obsolete and unsustainable.

Another project that would be difficult to cancel or delay is TDRS, as it is focused on replenishing a space-based network that provides 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. At the same time, the administration has placed a high priority on funding the Commercial Crew Program, which is fostering the development of spacecraft that can service the International Space Station, as there is no domestic means of doing so with the retirement of the space shuttle. This program has already seen delays in development activities and a major revision in its acquisition approach after NASA received less than anticipated funding from the Congress for fiscal years 2011 and 2012. Further cuts may prevent NASA from meeting its goals for servicing the space station with services provided by commercial companies.

An alternative to canceling specific programs in the face of significant cost growth within a large program is to cut or delay funding across many programs. But our work has consistently shown that this practice creates instabilities in programs that ultimately lead to more cost growth and delays and that it strengthens incentives to produce optimistic estimates. Both outcomes would likely erode NASA's progress in reducing acquisition risk.

- **Estimating costs associated with SLS and MPCV to ensure oversight and transparency:** Estimating the full life-cycle costs of SLS and MPCV projects will be critical to ensuring transparency into their cost and schedule and will enable effective oversight. At this point, however, NASA currently plans to estimate only the costs of portions of the SLS and MPCV projects, which is not a true life-cycle cost estimate. For example, the preliminary cost estimates of SLS only extend through the first non-crewed flight in 2017, plus 3 months of data analysis. This estimate does not include costs for the first crewed flight of the same vehicle type of the SLS in 2021, nor does it include costs associated with substantial development for future flights of other variants of the launch vehicle.[18] According to project officials, the cost of the first crewed flight will be tracked by the project. Similarly, the MPCV cost estimate extends only through the first crewed flight in 2021. MPCV officials told us that separate cost estimates will be completed for future flights of MPCV. Developing cost estimates in this manner will not allow NASA to provide a total life cycle cost for the SLS and MPCV projects. As a result, a true life cycle cost may never be established and oversight of the projects would be hampered because no one would be able to track the baseline cost and associated cost growth.

According to NASA officials, the agency is developing a tailored definition for SLS and MPCV life-cycle cost estimating since it is one of evolving capabilities on a continuum, not a traditional life cycle. Additionally, NASA officials stated that the full life-cycle costs of SLS and MPCV cannot be calculated because SLS and MPCV are really programs and not projects that have discrete start and endpoints. Thus, NASA is reporting the cost for attaining a certain level of capability and what it costs to fly each version of SLS and MPCV. In an era of declining budgets, a true life cycle cost estimate will inform decision makers about the long term affordability of these programs before making any long term investment decisions. Credible cost estimates also help assess the reasonableness of a contractor's proposals and program budgets, and can be used to determine how budget cuts may hinder a program's effectiveness.

While NASA indicated that they will provide transparency into the cost and schedule for various research and development segments, given the significant costs that will likely be associated with these projects and the impact that any overruns could have on the rest of the agency, we plan to review this issue further to ensure better cost oversight of the projects.

- **Implementing effective cost and schedule estimation practices across major NASA projects:** Our work as well as that of the National Research Council, NASA's Inspector General and NASA-commission studies have consistently pointed to long-term weaknesses in cost and schedule estimation at NASA, including a tendency to produce overly optimistic estimates, the lack of reliance on independent estimates, the lack of adherence to best practices, as well as insufficient resources and

[18] NASA plans to design a 70 metric ton SLS vehicle which will be capable of launching a crew capsule into low-Earth orbit. NASA plans to evolve this design and develop a vehicle capable of carrying 130 metric ton payloads to orbit.

qualified staff dedicated to cost estimating. Recently, for example, NASA's Inspector General found that "a culture of optimism and a can-do spirit permeate all levels of NASA, from senior management to front-line engineers. Although this optimistic organizational culture is essential for realizing groundbreaking scientific achievement, it can also lead to unrealistic projections about what can be achieved within approved budgets and timeframes. In addition, this culture has manifested itself in a tendency to view the success of projects primarily in technical rather than cost and schedule terms. More specifically, NASA's optimistic culture contributes to development of unrealistic plans and performance baselines that fail to account for all relevant risks." NASA's adoption of the JCL process is a positive step toward addressing these weaknesses and ensuring estimates are more realistic. But it still remains to be seen whether this process will be sustained long enough to overcome a cultural tendency to be optimistic and whether enough resources will be dedicated to producing estimates.

Further, one important part of estimating and monitoring costs for projects is the effective implementation of Earned Value Management. We reported in November 2012 that NASA's implementation of earned value management (EVM) across the projects in the current portfolio was inconsistent.[19] For example, we reported that:

- NASA has not yet fully implemented EVM for 10 of the projects we reviewed in the current portfolio,
- half of the 10 projects did not use an EVM system that had been certified as compliant with industry standards,[20] and

[19]GAO, *Earned Value Management Implementation across Major (NASA) Spaceflight Projects is Uneven*, GAO-13-22 (Washington, D.C.: Nov. 19, 2012). 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.

[20]When an EVM system is certified the agency has assurance that the implemented system can be considered to provide reliable and valid data from which to manage a project. Certification of an EVM system ensures that the implemented system was validated for compliance with American National Standards Institute/Electronic Industries Alliance (ANSI/EIA)-748 standard by independent and qualified staff. ANSI/EIA-748 is regarded as the national standard and an industry best practice for EVM systems. It describes 32 guidelines that a certified EVM system must meet in the areas of organization; planning, scheduling, and budgeting; accounting; analysis and management reports; and revisions and data maintenance.

- only 4 of the 10 projects had reviews to ensure that key data produced by the system was reliable, and only 3 projects were found to have reliable EVM data.

We found that cultural and other challenges impeded the effective use of EVM at NASA as the agency's culture has traditionally focused on managing science and engineering challenges and not on monitoring cost and schedule data, like an effective EVM system produces. We also found that NASA does not have the policies in place, or the workforce with the skills and experience, to analyze EVM data to ensure correct implementation of EVM so that NASA managers could rely on EVM as a tool to measure progress on projects. In addition, we reported that NASA's current policy does not require rigorous oversight of how projects are implementing EVM. We made several recommendations including that NASA establish a timeframe for when projects will be required to use the new EVM system, conduct an EVM skills gap assessment of its staff, and require projects to implement formal EVM oversight. In response, the agency plans to conduct a skills gap assessment, to augment its EVM training to address any identified gaps, and to develop an EVM change management plan to better embrace the implementation of EVM techniques throughout the agency. We plan to monitor the agency's progress in addressing these recommendations.

Along with earned value data, development of realistic, dynamic, and logic-driven schedules provide another critical input to estimating and monitoring project costs. We have previously reported that a reliable project schedule can enhance cost estimation by contributing to an understanding of the cost impact if a particular project does not finish on time. In an effort to continually assess NASA's progress in improving NASA's cost-estimating policies and external oversight of these policies, we selected three projects—GPM, MMS, and JWST—that planned significant amounts of implementation-phase work during 2012, and assessed these projects' schedules against best practices for project scheduling developed by GAO. We could not validate any of the three projects' schedules as reliable based on our methodology. While we cannot generalize the results of these analyses to NASA's scheduling practices across the entire portfolio of projects, the results do provide us with insights into areas that could require further investigation into all of NASA's major projects, given the critical importance of a reliable schedule to NASA's overall ability to estimate the time and funds necessary to complete its projects. Appendix V contains detailed information about the criteria for schedule analyses, and the performance of the GPM and MMS project schedules against the criteria. The appendix also includes findings with respect to the JWST project schedule, developed through work for another GAO report.[21]

- **Using consistent and proven design stability metrics:** Along with continued NASA leadership to manage projects through constrained budgets and continuous improvement of project offices' estimating capacities, further progress on delivering projects more consistently within cost and schedule baselines would benefit from NASA's full implementation of a consistent and proven set of design stability metrics. We have previously reported that NASA's acquisition policy does not specify a metric to measure a project's design stability at the critical design review. In 2010, the National Research Council found that the critical design review milestone for many NASA missions may be held prematurely—driven by schedule rather than driven by design maturity.[22] They added that most of the cost growth on NASA missions takes place after the critical design review even though the design of the mission's instruments and spacecraft should be frozen at the critical design review. In 2011, we recommended that NASA develop a common set of measurable and proven criteria to assess design stability and amend its systems engineering policy to that effect.[23] In response to this recommendation, NASA established three technical 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 project requests for action.[24] In 2012, NASA updated its program

[21]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).

[22]National Research Council, the National Academies. *Controlling Cost Growth of NASA Earth and Space Science Missions*, (Washington D.C. 2010).

[23]GAO, *Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects*, GAO-11-364R (Washington, D.C.: Mar. 3, 2011); GAO, *NASA: Issues Implementing the NASA Authorization Act of 2010*, GAO-11-216T (Washington, D.C.: Dec.1, 2010); GAO, *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).

[24]Mass is a measurement of how much matter is in an object. It is related to an object's weight and 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.

management and systems engineering policies to reflect these changes, and each project must now report on these metrics. Since that time, the projects in our portfolio have reported these metrics in their monthly updates to NASA leadership. In the future, officials told us that NASA also plans for these projects to incorporate design indicators applicable to their unique project, such as requirement and schedule trends, to ensure proper progress and management of the project is achieved during the formulation phase. These indicators will also be provided in the project's plan and will be shared with other projects.

GAO and NASA have different opinions about the importance of assessing the design stability of a project at the critical design review. Our metric seeks design stability at the critical design review as a means to determine the readiness of the project to proceed with fabrication. On the other hand, NASA prefers to use technical indicators that are focused on whether the design is maturing over time, not necessarily whether the design is stable or not at any given point. In addition, NASA officials have stated that given the unique nature of each of its projects, there are no one-size-fits-all indicators that can be applied across the board to assess design stability. GAO is working with experts from various sectors of the government and industry to assess additional criteria that can be applied to NASA and other complex, unique projects for assessing design stability.

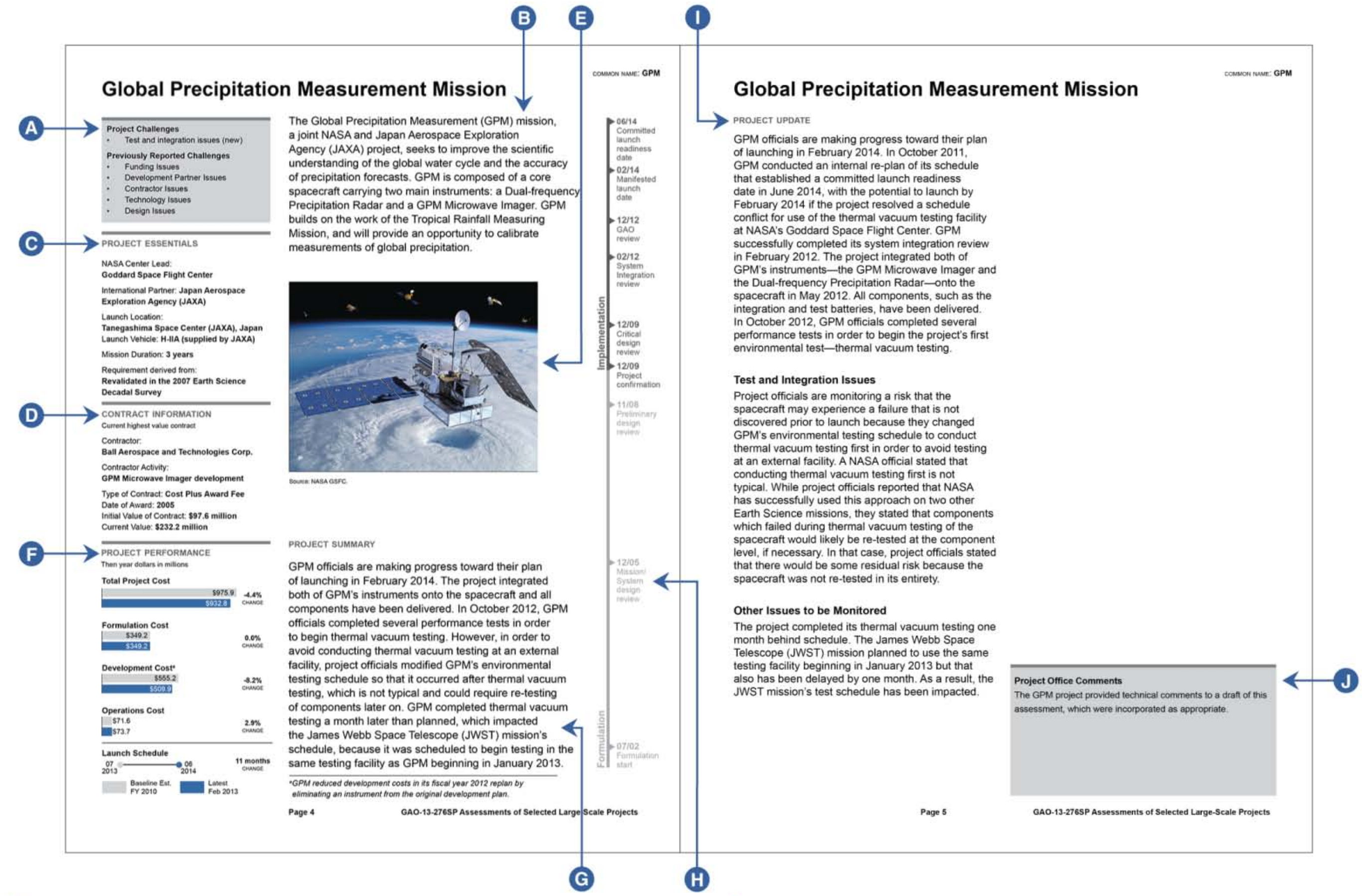
Project Assessments

The two-page assessments of the projects we reviewed provide a profile of each project and 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 a general description of the mission objectives for each project; a picture of the spacecraft, aircraft, or ground system; a schedule timeline identifying key dates for the project, including a manifested launch date if known and different than the project committed launch readiness date;[25] a table identifying programmatic and contract information; a table showing the current baseline year cost and schedule estimates and the February 2013 cost and schedule data; a table showing the challenges relevant to the project; and a project summary narrative. To maintain information on challenges the projects experience over their lifetimes, we continued to identify project challenges that were previously reported. 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. 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 corrections as appropriate and summarized the general comments below the project update.

See figure 10 for an illustration of the layout of each two-page assessment.

[25]The launch dates on the NASA launch manifest (or manifested launch date) are the desired launch dates as determined by the payload mission and approved by the NASA Flight Planning Board, and are not typically the same as the Agency Baseline Commitment schedule dates. According to NASA, a launch manifest is a dynamic schedule that is affected by real world operational activities conducted by NASA and multiple other entities. It reflects the results of a complex process that requires the coordination and cooperation by multiple users for the use of launch range and launch contractor assets. The launch dates shown on NASA's launch manifest are a mixture of "confirmed" range dates for missions launching within approximately 6 months, and contractual/planning dates for the missions beyond 6 months from launch. The launch manifest date is typically earlier than the Agency Baseline Commitment schedule date, which according to NASA allows for the operationally driven fluctuations to the launch schedule. The launch manifest is updated on a periodic basis throughout the year.

Figure 10: Illustration of a Project's Two-Page Summary



- **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.

COMMON NAME: **EMTGO**

ExoMars Trace Gas Orbiter

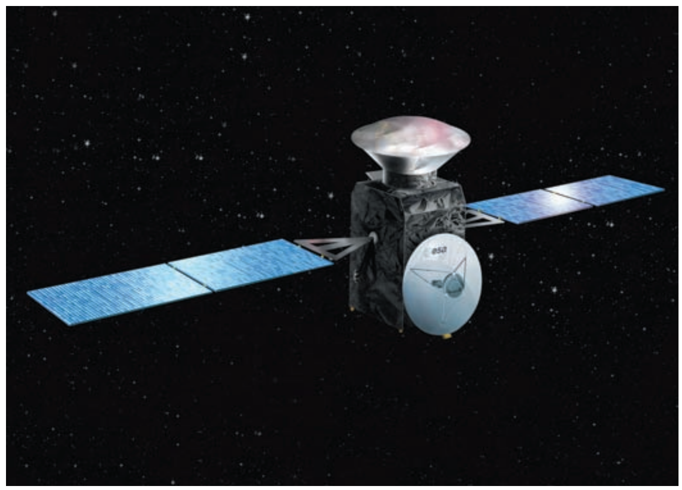
PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner:
European Space Agency

Requirement derived from:
2011 Planetary Decadal Survey

The ExoMars Trace Gas Orbiter (EMTGO) was planned to be the first of two joint missions that were to be developed by NASA and the European Space Agency (ESA) for launch in 2016 and 2018. EMTGO was envisioned to investigate trace gases on Mars that may be signatures of active biological and/or geographical processes. EMTGO instruments were designed to work across different bands of the electromagnetic spectrum, including infrared, visible, and ultraviolet light. EMTGO was to provide data relay services for future missions.



Source: NASA (artist depiction).

PROJECT SUMMARY

NASA's EMTGO project and planning for the NASA/ESA Mars 2018 mission concept was proposed for termination in NASA's fiscal year 2013 President's Budget Request. With NASA's departure from the project, ESA and the Russian Federal Space Agency—Roscosmos—are planning to continue development of the mission. NASA, however, is researching the feasibility of future missions to Mars in 2018 and beyond. NASA recently announced plans to build a new Mars rover that is planned to launch in 2020. According to project officials, NASA is continuing development of EMTGO's instrument designs through the preliminary design phase to reduce risk should future missions decide to use them.

Implementation

12/12 GAO review

02/12 Proposed for termination

Formulation

03/11 Formulation start

ExoMars Trace Gas Orbiter

PROJECT UPDATE

NASA's portion of the EMTGO project was proposed for termination in the fiscal year 2013 President's Budget Request. ESA decided to go forward with the project and has subsequently partnered with the Russian Federal Space Agency, Roscosmos, to do so. NASA's Mars Program Planning Group has identified options for future missions to Mars through the 2030s, including missions that could launch in 2018 and 2020. In December 2012, NASA announced plans to build a new Mars robotic science rover with an expected launch in 2020. The agency stated that the new rover will be based on NASA's latest Mars rover, Curiosity, which is currently on Mars.

In March 2012, NASA's Administrator stated that the fiscal environment had forced NASA's decision not to continue development of EMTGO with ESA. Specifically, the Mars Exploration budget—of which EMTGO is a part—was reduced in the fiscal year 2013 President's Budget Request by about $353 million for fiscal years 2013 through 2016, or about 25 percent. NASA officials stated that the agency has redirected most of the fiscal year 2012 funding originally allocated to EMTGO to other priorities. At this point, however, Congress has not taken formal action to terminate the program.

According to project officials, the project developed a plan to mature the designs of the project's instruments as much as possible for use on future missions once the project was proposed for cancellation, but these instruments will not be used on the 2020 robotic science rover. Three of the project's four instruments have completed their preliminary design reviews. According to project officials, all technologies are mature and the project is working to ensure that the design drawings are complete and available so that other projects would be able to use them if needed. Project officials noted that the instruments designed for EMTGO may be used on future Earth, Mars, or other planetary missions and the risk in using them on future projects will be reduced because three of the four instruments have been developed through the preliminary design phase. For example, project officials stated that the Mars Atmosphere Trace Molecule Occultation Spectrometer—which is designed to detect molecules in the atmosphere and map their location—can be used to study almost any atmosphere. They also added that the ExoMars Climate Sounder—which is designed to track Martian wind and atmospheric dust—may be useful in planning landings for human exploration of Mars. In addition, the project intends to continue development of the Electra Relay Radio—which relays radio data between the orbiter and assets on the surface of Mars—for the ESA's ongoing ExoMars mission development. The Electra is also expected to support future assets on Mars.

Project Office Comments

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

Global Precipitation Measurement Mission

Project Challenges

- Test and integration issues (new)

Previously Reported Challenges

- Funding Issues
- Development Partner Issues
- Contractor Issues
- Technology Issues
- Design Issues

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:
Revalidated in the 2007 Earth Science Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor:
Ball Aerospace and Technologies Corp.

Contractor Activity:
GPM Microwave Imager development

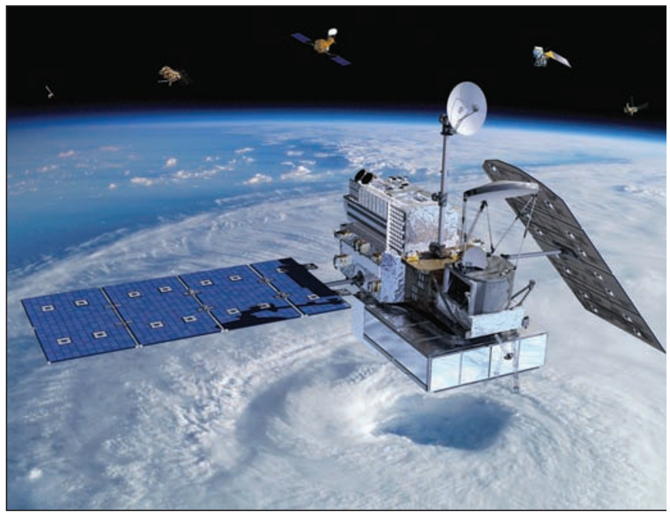
Type of Contract: **Cost Plus Award Fee**
Date of Award: **2005**
Initial Value of Contract: **$97.6 million**
Current Value: **$232.2 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline Est. FY 2010	Latest Feb 2013	Change
Total Project Cost	$975.9	$932.8	-4.4%
Formulation Cost	$349.2	$349.2	0.0%
Development Cost[a]	$555.2	$509.9	-8.2%
Operations Cost	$71.6	$73.7	2.9%
Launch Schedule	07 2013	06 2014	11 months

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: NASA GSFC.

PROJECT SUMMARY

GPM officials are making progress toward their plan of launching in February 2014. The project integrated both of GPM's instruments onto the spacecraft and all components have been delivered. In October 2012, GPM officials completed several performance tests in order to begin thermal vacuum testing. However, in order to avoid conducting thermal vacuum testing at an external facility, project officials modified GPM's environmental testing schedule so that it occurred after thermal vacuum testing, which is not typical and could require re-testing of components later on. GPM completed thermal vacuum testing a month later than planned, which impacted the James Webb Space Telescope (JWST) mission's schedule, because it was scheduled to begin testing in the same testing facility as GPM beginning in January 2013.

[a]*GPM reduced development costs in its fiscal year 2012 replan by eliminating an instrument from the original development plan.*

Implementation

- **06/14** Committed launch readiness date
- **02/14** Manifested launch date
- **12/12** GAO review
- **02/12** System Integration review
- **12/09** Critical design review
- **12/09** Project confirmation
- **11/08** Preliminary design review

Formulation

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

Global Precipitation Measurement Mission

PROJECT UPDATE

GPM officials are making progress toward their plan of launching in February 2014. In October 2011, GPM conducted an internal re-plan of its schedule that established a committed launch readiness date in June 2014, with the potential to launch by February 2014 if the project resolved a schedule conflict for use of the thermal vacuum testing facility at NASA's Goddard Space Flight Center. GPM successfully completed its system integration review in February 2012. The project integrated both of GPM's instruments—the GPM Microwave Imager and the Dual-frequency Precipitation Radar—onto the spacecraft in May 2012. All components, such as the integration and test batteries, have been delivered. In October 2012, GPM officials completed several performance tests in order to begin the project's first environmental test—thermal vacuum testing.

Test and Integration Issues

Project officials are monitoring a risk that the spacecraft may experience a failure that is not discovered prior to launch because they changed GPM's environmental testing schedule to conduct thermal vacuum testing first in order to avoid testing at an external facility. A NASA official stated that conducting thermal vacuum testing first is not typical. While project officials reported that NASA has successfully used this approach on two other Earth Science missions, they stated that components which failed during thermal vacuum testing of the spacecraft would likely be re-tested at the component level, if necessary. In that case, project officials stated that there would be some residual risk because the spacecraft was not re-tested in its entirety.

Other Issues to be Monitored

The project completed its thermal vacuum testing one month behind schedule. The James Webb Space Telescope (JWST) mission planned to use the same testing facility beginning in January 2013 but that also has been delayed by one month. As a result, the JWST mission's test schedule has been impacted.

Project Office Comments

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

Ice, Cloud, and Land Elevation Satellite-2

Project Challenges
- Launch Issues
- Funding Issues
- Workforce Issues (new)

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

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline Est. FY 2013	Latest Feb 2013	Change
Total Project Cost	$860.3	$860.3	0.0% CHANGE
Formulation Cost	$248.8	$248.8	0.0% CHANGE
Development Cost	$558.9	$558.9	0.0% CHANGE
Operations Cost[a]	$52.9	$52.9	0.0% CHANGE
Launch Schedule	05 2017	05 2017	0 months CHANGE

NASA's Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) is a follow-on mission to ICESat, tasked with measuring changes in polar ice-sheet mass with space-borne altimetry measurements to understand mechanisms that drive change and the impact of change on future 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: Trax International.

PROJECT SUMMARY

In February 2013, NASA selected the Delta II as the launch vehicle for ICESat-2. This is a change from project officials' original plan to launch the satellite on the same vehicle, or dual-manifest, with an Air Force mission. As a result of this change, planned costs for the project are $84 million more than the preliminary cost estimate range. Several ICESat-2 milestones, such as the project's preliminary design review, were delayed because of funding challenges. In addition, the cost of the Advanced Topographic Laser Altimeter System (ATLAS)—which, among other things, measures the topography of ice sheets—has increased due to workforce and funding challenges.

Implementation
- **05/17** Committed launch readiness date
- **07/16** Manifested launch date
- **06/15** System integration review
- **09/13** Critical design review
- **12/12** 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

Launch Issues

In February 2013, NASA selected the Delta II as the launch vehicle for ICESat-2. This is a change from project officials' original plan to launch the satellite on the same vehicle, or dual-manifest, with an Air Force mission, which would have lessened launch costs for the project. However, because the project must now launch separately, planned costs for the project are $84 million more than the preliminary cost estimate range we reported last year. In April 2012, the Air Force informed NASA that the planned dual-manifest launch was no longer a viable option because the Air Force mission's launch date slipped to 2020, beyond ICESat-2's preliminary launch schedule in 2016.

Funding/Workforce Issues

Several ICESat-2 milestones were delayed because of funding challenges. Specifically, project officials stated that the milestones were delayed because of a proposal to defer some of ICESat-2's funding for fiscal year 2013. For example, project officials delayed the mission's preliminary design review by about four months to October 2012, and allocated a significant portion of the project's fiscal year 2012 funding reserves to mitigate potential cost impacts caused by holding the review later than planned. Project officials stated that they delayed their manifested launch date by three months to July 2016 due to the proposed funding deferment.

The cost of the Advanced Topographic Laser Altimeter System (ATLAS)—which, among other things, measures the topography of ice sheets—has increased by about $30.2 million, or 13.4 percent, since December 2011 due to workforce and funding challenges. For example, slightly more than half of this increase occurred because the project incorporated recommendations from the instrument's preliminary design review that, according to project officials, caused the project to hire additional staff. Project officials stated that ICESat-2 hired staff to provide additional expertise in certain areas, such as integrated systems engineering.

The remaining amount of the ATLAS cost increase occurred because project officials delayed the instrument's schedule by three months due to the proposed deferment of some of ICESat-2's funding. Project officials stated that the schedule delay increased workforce costs because the project has to pay for personnel costs for three months longer than planned.

Project Office Comments

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

James Webb Space Telescope

Project Challenges
- Design Issues
- Technology Issues
- Test and Integration Issues (new)

Previously Reported Challenges
- Funding Issues
- Contractor Issues

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 Company**

Type of Contract: **Cost Plus Award Fee**
Date of Award: **2002**
Initial Value of Contract: **$824.8 million**
Current Value: **$2.12 billion[a]**

[a]NASA is currently in negotiation with the contractor and the expected value will likely exceed $3 billion.

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$4963.6
$8835.0
78% CHANGE

Formulation Cost
$1800.1
$1800.1
0.0% CHANGE

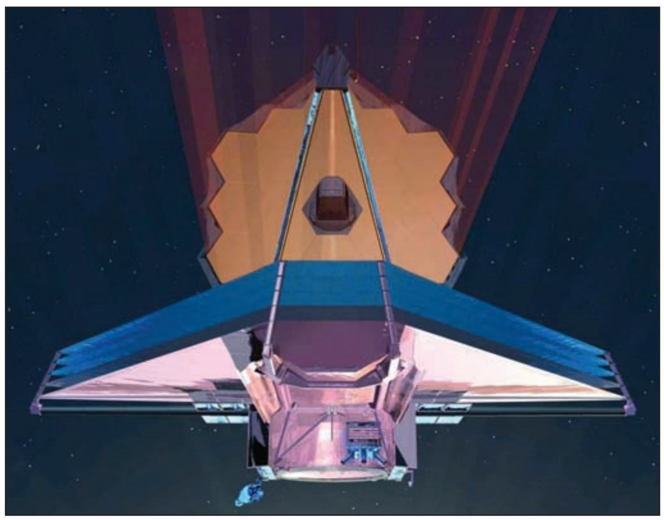
Development Cost
$2581.1
$6197.9
140.1% CHANGE

Operations Cost
$582.4
$837.0
43.7% CHANGE

Launch Schedule
06 2014 — 10 2018
52 months CHANGE

Baseline Est. FY 2009 | Latest Feb 2013

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: Northrop Grumman Aerospace Systems (artist depiction).

PROJECT SUMMARY

JWST is currently experiencing technical issues on the spacecraft and integrated science instrument module (ISIM) that have impacted the test schedule. For example, project and contractor officials are working to reduce spacecraft mass because it is currently over its allocation. In addition, only two instruments have been delivered for integration with ISIM and the other two instruments will be delivered at least 11 months late. NASA established a 66 percent confidence level for its revised baselines; however, we found that the process used to develop the revised cost estimate was not fully consistent with best practices. For example, the credibility of the estimate was lessened because a sensitivity analysis was not performed that would have identified key drivers of costs, such as workforce size.

Implementation
- **10/18** Committed launch readiness date
- **09/17** System integration review
- **12/12** GAO review
- **03/10** Critical design review
- **07/08** Project confirmation

Formulation
- **03/08** Preliminary design review
- **01/06** Mission/ System definition review
- **03/99** Formulation start

James Webb Space Telescope

PROJECT UPDATE

In December 2012, GAO issued an in-depth report on JWST and made several recommendations regarding the project's cost estimate and oversight approach. Below is a summary of key issues identified in that report.[b]

Design/Technology Issues

The project is currently experiencing issues with the expected mass of the spacecraft and technical issues on several instruments that are requiring a significant amount of time to address and have impacted instrument deliveries. For example, the spacecraft is currently over its mass allocation due to greater than expected increases in the estimated weight of the electrical wiring harnesses and other structures that make up the spacecraft. Project and contractor officials have focused on reducing spacecraft mass because it is the least mature subsystem and can more easily accommodate design changes that will be necessary to address the issue.

ISIM is experiencing technology and engineering challenges that resulted in the use of 18 of ISIM's 26 months of schedule reserve and the addition of a third test cycle to test replacement detectors in three instruments. Only two instruments were delivered on plan by September 2012. The other two instruments are estimated to be delivered at least 11 months late due to additional issues found during test and integration and workmanship issues. As a result, the test schedule for the ISIM has been delayed by 17 months. Another technical challenge associated with ISIM is the development of the cryo-cooler system that removes heat and cools one of the instrument detectors and heat shield.

Test and Integration Issues

Project officials reported that the JWST schedule has 14 months of funded reserve, which meets Goddard guidance for schedule reserve; however, only 7 of the 14 months will likely be available for the project's last three of five complex integration and test efforts. GAO's prior work shows that it is during integration and test where problems are commonly found and schedules tend to slip. Given that JWST has a challenging integration and test schedule, this could particularly be the case. Currently, NASA's plan for project oversight calls for one independent system integration review about 13 months before launch. While this is consistent with what NASA requires for its projects, this approach may not be sufficient for a project as complex as JWST and may be inadequate to ensure key technical and management issues are identified early enough to be addressed within the project's current schedule.

Other Issues to be Monitored

Despite NASA investing considerable time and resources replanning and establishing a 66 percent confidence level for its revised baselines, we found that the process used to develop the revised cost estimate was not fully consistent with cost estimating best practices. For example, the accuracy of the cost estimate, and therefore the confidence level assigned to the estimate, was lessened by the schedule used in the joint cost and schedule confidence level analysis because the schedule prevented us from, among other things, identifying the activities that were on the critical path—defined as time associated with activities that drive the overall schedule. The credibility of the estimate was lessened because project officials did not perform a sensitivity analysis that would have identified key drivers of costs, such as workforce size.

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, other than the delayed delivery of two instrument, the project completed all external milestones for fiscal year 2012. They added that meeting these milestones reflects performance in line with the rebaseline plan.

[b]*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)*

Landsat Data Continuity Mission

Recent / Continuing Project Challenges

- Design Issues
- Test and Integration Issues (new)

Previously Reported Challenges

- Funding Issues
- Development Partner Issues
- Technology Maturity

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner:
U.S. Geological Survey

Launch Location: **Vandenberg AFB, CA**
Launch Vehicle: **Atlas V**

Mission Duration:
5 years (10 years propellant)

Requirement derived from:
Continuation of Landsat data series, 1972

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital Sciences**

Contractor Activity: **Spacecraft development**

Type of Contract: **Firmed Fixed Price**

Date of Award: **April 2008**
Initial Value of Contract: **$119.0 million**
Current Value: **$193.7 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$941.7
$931.2
-1.1% CHANGE

Formulation Cost
$341.5
$341.4
0.0% CHANGE

Development Cost
$583.4
$577.2
-1.1% CHANGE

Operations Cost[a]
$16.8
$12.5
-25.6% CHANGE

Launch Schedule
06 2013 — 02 2013
-4 months CHANGE

Baseline Est. FY 2010 | Latest Feb 2013

The Landsat Data Continuity Mission (LDCM), a partnership between NASA and the U.S. Geological Survey (USGS), seeks to extend the ability to detect and quantify changes on the Earth's surface at a scale where natural and man-made causes of change can be differentiated. It is the successor mission to Landsat 7. The Landsat data series, begun in 1972, is the longest continuous record of changes in the Earth's surface as seen from space. Landsat data is a resource for people who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research.

Source: NASA-0011 0, Delivery Order 17 with Orbital Sciences Corporation.

PROJECT SUMMARY

LDCM successfully launched on Feburary 11, 2013. Prior to its launch, LDCM was facing schedule pressure, in part, because of a parts issue with the Thermal Infrared Sensor (TIRS) instrument and an anomaly with the spacecraft's electronics. These issues, as well as issues with the broader launch manifest, caused a delay to the LDCM manifested launch date by about two months to the end of the launch window in February 2013. Although LDCM's committed launch date was in June 2013, NASA was able to launch the project earlier.

Implementation

06/13 Committed launch date

02/11/13 Launch date

12/12 GAO review

09/11 System integration review

05/10 Critical design review

12/09 Project confirmation

Formulation

07/09 Preliminary design review

05/08 Mission/System design review

10/03 Formulation start

[a]In FY 2012, LDCM reported a decrease in operations because USGS agreed to bear additional cost for LDCM operations.

Landsat Data Continuity Mission

PROJECT UPDATE

LDCM successfully launched on February 11, 2013. Prior to its launch, LDCM was facing schedule pressure, in part, because of a parts issue with the Thermal Infrared Sensor (TIRS) instrument and an anomaly with the spacecraft's electronics. These issues, as well as issues with the broader launch manifest, caused project officials to delay their manifested launch date to the end of the launch window in February 2013. Although LDCM committed to a June 2013 launch date, NASA was able to launch the project earlier.

Design Issues

Project officials reported that a parts issue with the TIRS instrument—which measures the Earth's temperature—contributed to their decision to delay the earlier launch date they were working toward. Specifically, LDCM and contractor officials changed the design of a component on the TIRS instrument in order to eliminate a helium leak. Project officials repaired the component, which exhausted the project's remaining schedule reserve at that time. As a result, the project reported that LDCM would not be ready to launch on the earlier date—December 2012—project officials were working toward.

Test and Integration Issues

The spacecraft experienced an anomaly during installation of its flight battery in April 2012 that delayed environmental testing and damaged electronics components. Project and contractor officials determined that the anomaly may have been caused by an electrical current from a battery cable that damaged the spacecraft. Project officials delayed LDCM's environmental testing schedule by about two months in order to evaluate which components were damaged and replace them. Project officials recovered from the anomaly with the spacecraft's electronics by, among other things, pushing back the launch date they were working toward and implementing a 7-day work week.

Project Office Comments

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

Lunar Atmosphere and Dust Environment Explorer

Recent / Continuing Project Challenges

- Test and Integration Issues (new)
- Launch Issues

Previously Reported Challenges

- Technology Issues
- Design Issues

PROJECT ESSENTIALS

NASA Center Lead:
Ames Research Center

Partners: **None**

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

Mission Duration: **180 days**

Requirement derived from:
The Scientific Context for the Exploration of the Moon (National Research Council, 2007) and Visions and Voyages for Planetary Science (2013-2022)

CONTRACT INFORMATION

Current highest value contract

Contractor: **Space Systems Loral**

Major Contractor: **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**

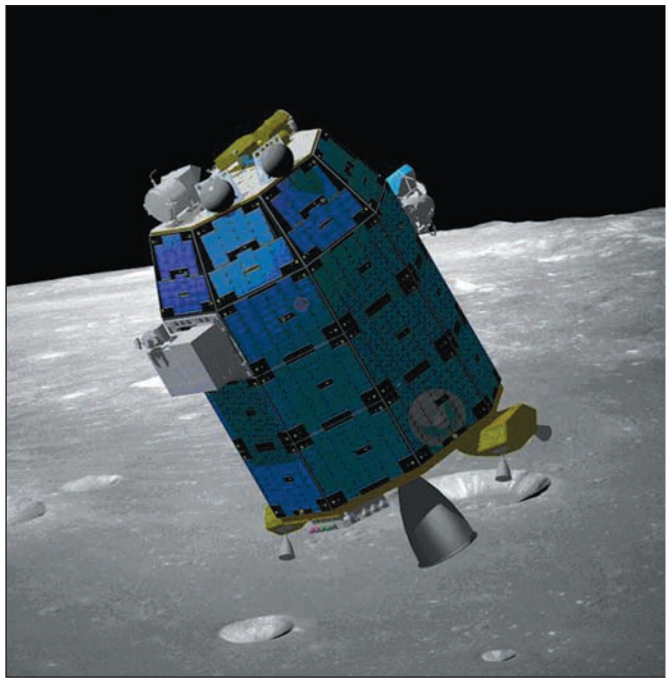
PROJECT PERFORMANCE

Then year dollars in millions

	Baseline Est. FY 2010	Latest Feb 2013	Change
Total Project Cost[a]	$262.9	$262.9	0.0% CHANGE
Formulation Cost	$79.5	$79.5	0.0% CHANGE
Development Cost[b]	$168.2	$176.1	4.7% CHANGE
Operations Cost[b]	$15.2	$7.3	-52.0% CHANGE
Launch Schedule	11 2013	11 2013	0 months CHANGE

Baseline Est. FY 2010 — Latest Feb 2013

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 Office (artist depiction).

PROJECT SUMMARY

The LADEE project is under both cost and schedule pressure to meet its baseline commitments. The project expended three-quarters of its reserve funds prior to entering the test and integration phase, leaving little margin for any potential issues that may arise in the future. The project has experienced schedule pressure because two of the project's instruments have had failures or workmanship issues during vibration testing. As a result, the project is left with little schedule reserve and has slipped its manifested launch date by 3 months from May to August 2013. LADEE must launch before mid-October 2013 to meet science requirements or the mission will be delayed until at least April 2014.

[a]This estimate does not include the Lunar Laser Communications Demonstration which is being funded by the Human Exploration and Operations Mission Directorate at a cost of approximately $65 million.

[b]In FY 2012, NASA shifted $7.9 million from the operations phase to the development phase.

Implementation

- **11/13** Committed launch readiness date
- **08/13** Manifested launch date
- **12/12** GAO review
- **08/12** System integration review
- **05/11** Critical design review

Formulation

- **08/10** Project confirmation
- **07/10** Preliminary design review
- **07/09** Mission/ System design review
- **02/09** Formulation start

Lunar Atmosphere and Dust Environment Explorer

PROJECT UPDATE

LADEE is under both cost and schedule pressure to meet its baseline commitments. The project has experienced delays developing its instruments and has expended three-quarters of its reserve funds prior to entering the test and integration phase. The reduced amount of reserve funds leaves the project with little margin for any potential issues that may arise during its test and integration phase. The project originally did not pass its system integration review—which evaluates the readiness of the system to begin integration activities—but it passed its follow-up review held in August 2012.

Test and Integration Issues

In May 2012, the project experienced vibration test failures in its Neutral Mass Spectrometer—which is designed to detect various elements and molecules in the lunar atmosphere and dust. As a result, the instrument had little schedule margin remaining. Project officials stated that some of the instrument's internal wiring connections were causing electrical shorts and officials had to reopen the instrument to fix the issue and then reseal and requalify it. Additional funds were necessary to pay for the repairs and the instrument was delivered in October 2012—5 months later than planned—and installed on the spacecraft.

The development of the Lunar Laser Communications Demonstration—a communications demonstrator being developed by NASA's Human Exploration and Operations Mission Directorate—is behind schedule due to damage and workmanship issues and has little schedule margin. Project officials stated that a fiber optic line was damaged in transport to the testing facility. Once testing began, the project also discovered workmanship issues with the demonstrator's modem. In total, officials expected delivery of the instrument to be 4 to 6 weeks behind schedule. They stated that LADEE will launch without it should the instrument be unable to meet its scheduled delivery date. In November 2012, the project reported that one of the three flight components of the Lunar Laser Communications Demonstration was delivered and is integrated onto the spacecraft.

Launch Issues

The project has experienced schedule pressure due to development delays and slipped the launch date it was working toward by three months from May to August 2013. According to NASA officials, this delay has created a potential launch schedule conflict because the U.S. Air Force has requested the same launch pad for one of its missions, also in August 2013. However, the Air Force mission does not have a confirmed launch date and the launch services provider is working on several possible courses of action to de-conflict the Air Force and the LADEE launch dates. In addition, while LADEE's committed launch readiness date is November 2013, project officials have stated that it cannot launch later than mid-October 2013 due to the start of the lunar eclipse season. If delayed beyond mid-October, the project would not be able to launch until at least April 2014 after the lunar eclipse season.

Project Office Comments

The LADEE project provided technical comments to a draft of this assessment, which were incorporated as appropriate. NASA officials also commented that in October 2012, LADEE developed a plan to potentially accommodate a Lunar Laser Communications Demonstration late delivery. A risk assessment and determination will be made in January 2013.

Magnetospheric Multiscale

Project Challenges

- Test and Integration Issues (new)
- Parts Issues
- Contractor Issues

Previously Reported Challenges

- Design Issues
- Development Partner Issues
- Funding Issues
- Technology Issues

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: **2003 Solar and Space Physics Decadal Survey**

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: **$225 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$1082.7
$1082.6
0.0% CHANGE

Formulation Cost
$173.0
$172.9
0.0% CHANGE

Development Cost
$857.4
$857.3
0.0% CHANGE

Operations Cost
$52.3
$52.4
0.0% CHANGE

Launch Schedule
03 2015 — 03 2015
0 months CHANGE

Baseline Est. FY 2009 | Latest Feb 2013

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 pyramid 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: NASA GSFC Project Office.

PROJECT SUMMARY

The MMS project is working toward a manifested launch date of October 2014 and should soon complete final integration of the first spacecraft. The project had to shift locations for spacecraft thermal vacuum testing because of test schedule conflicts with other projects, which required it to use about $33 million in reserve funds. Two instruments have experienced technical issues or parts failures that consumed cost reserves and resulted in slips to their integration and test delivery dates. After schedule slips driven by parts failures, the contractor overseeing development of all MMS instruments overran its cost plan and project officials asked the contractor to propose a new budget with cost reductions. An independent review board found that the project's reserve funding was adequate, but could be threatened by possible future problems.

Implementation

03/15 Committed launch readiness date
10/14 Manifested launch date
12/12 GAO review
08/12 System integration review
08/10 Critical design review
06/09 Project confirmation

Formulation

05/09 Preliminary design review
09/07 Mission/System definition review
05/02 Formulation start

Magnetospheric Multiscale

PROJECT UPDATE

The MMS project is working toward a manifested launch date of October 2014, which is 5 months earlier than the project's March 2015 committed launch readiness date. In August 2012, the project held its System Integration Review, which evaluates the project's readiness to begin assembly, integration, and test activities. Integration of each of the four spacecraft is at various stages of completion.

Test & Integration/Parts Issues

The MMS project was directed to use the Naval Research Laboratory's facility for thermal vacuum testing of the fully integrated spacecraft rather than the one at Goddard Space Flight Center. This move was necessary because of test schedule conflicts with other NASA projects. The move delayed the project's planned launch date from August to October 2014 and required the project to use about $33 million of its reserve funding. Project officials told us that they will incur costs to build transport and testing equipment and to have project staff at both locations.

Two instruments have experienced parts failures that required the project to use cost reserves and resulted in slips to the two instruments' respective integration and test delivery dates. The Electron Drift Instrument—which measures magnetic and electric fields—had a part failure that delayed its delivery for integration. The project has replanned its integration schedule to allow this instrument to be one of the last items integrated on the spacecraft. Two types of sensors in the Fast Plasma Investigation instrument—which measure ions and electrons in plasma—have had parts issues that required rework and additional testing. These issues delayed the sensors' delivery for instrument integration and testing by 4 months.

Contractor Issues

The contractor responsible for managing instrument development has experienced cost overruns following cost and schedule issues with several instruments, and project officials required the contractor to prepare a new budget proposing cost reductions in several areas. The project has set aside reserve funding to account for the cost overruns and the possibility that the planned cost savings might not be realized.

Other Issues to be Monitored

An independent review board found that the project's reserve funding was adequate, but could be threatened by possible future problems. The project has used or set aside at least 80 percent of this funding and has just recently begun the test and integration phase where cost and schedule growth is typically realized.

Project Office Comments

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

Mars Atmosphere and Volatile EvolutioN

Project Challenges

- Parts Issues
- Workforce Issues (new)

Previously Reported Challenges

- Launch Issues
- Design Issues

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: **21 months of operations, including a 10 month cruise**

Requirement derived from:
2003 Planetary Exploration Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft development**

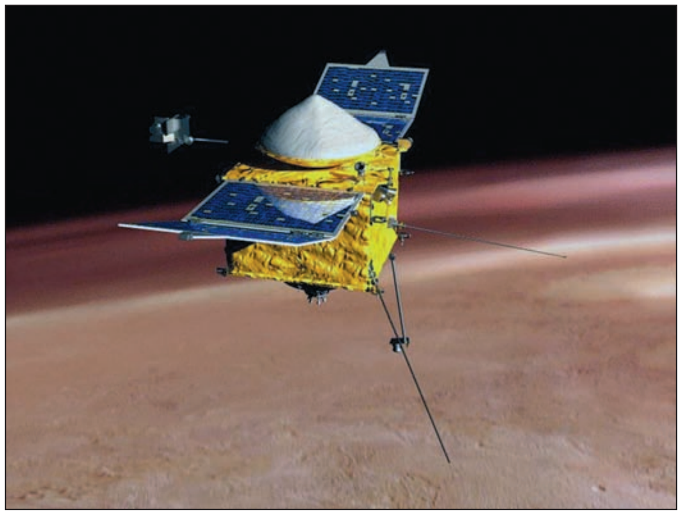
Type of Contract: **Cost Plus Award Fee**
Date of Award: **April 2009**
Initial Value of Contract: **$237 million**
Current Value: **$250.3 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline Est. FY 2011	Latest Feb 2013	Change
Total Project Cost	$671.2	$671.2	0.0%
Formulation Cost	$63.9	$63.9	0.0%
Development Cost[a]	$567.2	$551.7	-2.7%
Operations Cost	$40.1	$55.7	38.9%
Launch Schedule	11 2013	11 2013	0 months

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



Source: NASA GSFC MAVEN Project Office (artist depiction).

PROJECT SUMMARY

MAVEN remains on target to meet its cost and schedule commitments with adequate cost and schedule reserves. The project, however, has experienced several issues with the development of the Neutral Gas and Ion Mass Spectrometer (NGIMS). In particular, the instrument's main component has lagged against NGIMS milestones. These issues have nearly exhausted the instrument's schedule reserve. Despite these issues, the project office has taken steps to regain schedule reserve on the NGIMS instrument. NASA officials have reported adequate cost reserves to compensate for these delays.

[a]*Development costs were reduced because the negotiated price of the launch vehicle decreased. The majority of these funds were rephased to operations.*

Implementation
- **11/13** Committed launch readiness date
- **12/12** GAO review
- **06/12** System integration review
- **07/11** Critical design review
- **10/10** Project confirmation

Formulation
- **07/10** Preliminary design review
- **09/08** Formulation start

Mars Atmosphere and Volatile EvolutioN

PROJECT UPDATE

The MAVEN project formally began Phase D in September 2012 following a successful KDP D review. The project remains on target to meet its baseline commitments with adequate cost and schedule reserves. At the confirmation review, NASA managers set the project's cost and schedule baselines at a higher confidence level than required by NASA policy, which is intended to increase the likelihood of launching within cost and on schedule. NASA officials told us that meeting the November 2013 committed launch readiness date allows MAVEN to reach Mars during a period in the 11-year cycle of solar-radiation activity essential to obtaining science returns critical for mission success.

Parts/Workforce Issues

The project has experienced several issues with the development of the Neutral Gas and Ion Mass Spectrometer (NGIMS). In particular, the instrument's main component, the Quadrupole Mass Spectrometer (QMS) has lagged against NGIMS milestones which could impact the NGIMS test and integration schedule. As of June 2012, the project had nearly consumed the instrument's schedule reserve to address delays on QMS. These delays resulted from several factors. For example, the project discovered a gas leak into the QMS and also received parts for the QMS that were manufactured below specifications. Some delays stemmed from the project's redirection of assembly staff. The project also had to use NGIMS schedule reserves because of resource sharing on other projects' instruments, such as the Lunar Atmosphere and Dust Environment Explorer's Neutral Mass Spectrometer, and when the project also augmented NGIMS's test approach based on lessons learned from failures late in testing on a similar instrument.

The project office has taken steps to regain schedule reserve on the NGIMS instrument, including working longer days and weekends. The project's current plans include delivering the NGIMS instrument in late February 2013. Officials also reported that the project office has coordinated with the integration and test contractor to develop plans to accommodate late delivery of NGIMS into integration and testing activities so they are not disrupted. In June 2012, NASA officials reported that MAVEN holds adequate cost reserves to compensate for NGIMS-related delays.

Issue Update

We reported last year that project officials were concerned with the high probability of failure of the High-Efficiency Power Supply (HEPS) card. Since our last report, the project has resolved the HEPS card's previously-identified workmanship issues. However, a power-supply error during post-rework testing required the project to remove the HEPS card and replace its fuses. The flight model HEPS card has been integrated into the power and drive unit in which it will fly, and is undergoing final testing.

Project Office Comments

The MAVEN project provided technical comments to a draft of this assessment, which were incorporated as appropriate. MAVEN officials reported that MAVEN continues to meet cost and schedule commitments with adequate reserves. All spacecraft critical path elements have been delivered for assembly, test, launch and operations to start, and testing has begun.

COMMON NAME: **OCO-2**

Orbiting Carbon Observatory 2

Project Challenges

- Launch Issues
- Funding Issues
- Parts Issues

Previously Reported Challenges

- Design Issues

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 Fixed Fee/ Incentive Fee**
Date of Award: **May 2010**
Initial Value of Contract: **$48 Million**
Current Value: **$53.6 Million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$349.9
$467.7
33.7% CHANGE

Formulation Cost
$60.9
$60.9
0.0% CHANGE

Development Cost
$249.0
$371.8
49.3% CHANGE

Operations Cost
$40.0
$35.0
-12.5% CHANGE

Launch Schedule
02 2013
02 2015
24 months CHANGE

Baseline Est. FY 2010
Latest Feb 2013

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 the 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

In 2013, NASA rebaselined OCO-2's cost and schedule because of a change in its launch vehicle from Orbital's Taurus XL to the United Launch Alliance's Delta II following the failure of the Taurus XL launch vehicle on two prior NASA missions. According to project officials, the change of launch vehicle is the primary reason for an estimated $118 million cost increase and a projected 24-month launch delay. Due to this delay, the project plans to store the observatory for a period of time after completing approximately half of planned integration and test activities. The project is concerned about losing key personnel during that time. The project has decided to replace the existing reaction wheel assemblies due to unexplained in-flight anomalies on similar units flown on commercial satellites.

02/15 Committed launch readiness date

12/12 GAO review

05/12 System integration review

Implementation

09/10 Project confirmation

08/10 Critical design review

Formulation

03/10 Formulation start

Orbiting Carbon Observatory 2

PROJECT UPDATE

Launch Issues

In July 2012, a new launch vehicle, the Delta II, was selected for OCO-2 given two failures of its original launch vehicle, the Taurus XL. As a result, NASA officials stated that the original analysis of the thermal, loads, vibration, and integration characteristics—which are different between a Taurus XL and a Delta II—must be reworked in order to ensure that the launch vehicle meets observatory constraints. NASA officials stated that the Delta II launch vehicle will be configured to meet the requirements of the OCO-2 observatory, rather than OCO-2 being configured for the launch vehicle.

Funding Issues

Due to the launch vehicle change and related delay, the project rebaselined its cost and schedule. NASA reported that OCO-2 had experienced a $118 million life cycle cost estimate increase and a 24-month launch delay. As required by law, NASA reported to certain House and Senate Committees that the OCO-2 project had exceeded both its development cost and schedule baselines. According to officials, the project is also planning to store the observatory for a period of time and reduce project staff during this period to control costs. This has led the project to carry a risk that some key engineering personnel at the Jet Propulsion Laboratory will be required to stop working on the project due to lack of funds and may not be available when the project restarts at a later date. The project may incur schedule delays if it loses key personnel and has to train new staff or, according to officials, it may incur cost increases if it has to retain staff during the observatory storage period. NASA is working to temporarily place key personnel on other projects with the understanding that they will return following observatory storage.

Parts Issues

NASA officials stated that a constellation of commercial telecommunication satellites utilizing reaction wheel assemblies—rotating wheels used to point and stabilize the spacecraft—with a similar design to those on OCO-2 have experienced a number of in-flight anomalies that are, as of yet, unexplained. After review, the project decided to replace the existing assemblies with units of a different design, however procurement and replacement of the assemblies may impact the project's revised launch readiness date.

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

Project Challenges

- Development Partner Issues (new)

PROJECT ESSENTIALS

NASA Center Lead: **Goddard Space Flight Center**

International Partner: **Canadian Space Agency**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **TBD**
Mission Duration: **7 years**

Requirement derived from: **Mid-decade update to the 2003 Planetary Science Decadal Survey**

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: **$26 million**
Current Value: **$44 million**

PROJECT PERFORMANCE

Then year dollars in millions

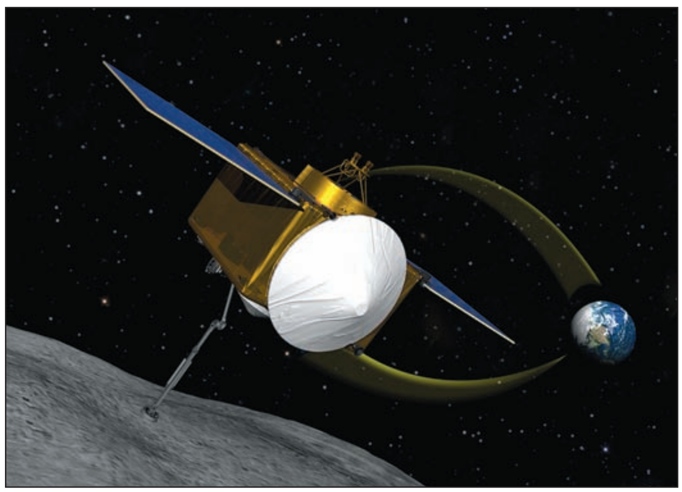
Preliminary estimate of Project Life Cycle Cost*

Latest: **Feb 2013** **$1,085 - $1,210**

**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 **09/2016**

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

OSIRIS-REx officials are working toward the project's scheduled preliminary design review in March 2013 and developing instruments that fulfill the mission's science requirements. However, project officials stated that they are closely monitoring issues that could impact the project's schedule because missing the launch window could delay the launch by five years due to the orbit of the project's destination. For example, project officials are monitoring a potential delay in development of the partner-provided laser altimeter instrument, which could cause the instrument to be removed from the mission. Project officials are also monitoring a risk that potential undiscovered defects could affect the reliability of a critical technology that is used during sample collection.

Implementation

09/16 Projected launch date

02/15 System integration review

04/14 Critical design review

05/13 Project confirmation

Formulation

03/13 Preliminary design review

12/12 GAO review

05/12 Mission/ System design review

05/11 Formulation start

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

PROJECT UPDATE

The OSIRIS-REx mission entered Phase B—the preliminary design and technology completion phase of formulation—in December 2011 with a preliminary life cycle cost estimate of $1.085 to $1.210 billion. OSIRIS-REx successfully completed its mission definition review in May 2012, and project officials scheduled its preliminary design review for March 2013.

Officials are developing five instruments that fulfill the project's planned science requirements. Project officials stated that the mission's primary objective is to return samples from the asteroid to Earth. Therefore, they explained that four of the five instruments could be removed from the mission if necessary because they are not needed for sample return. According to NASA officials, the mission's science requirements will not be finalized until the project is confirmed.

Development Partner Issues

Project officials are monitoring a potential nine-and-a-half month delay in development of the project's mapping and ranging instrument—the OSIRIS-REx Laser Altimeter—provided by the Canadian Space Agency. Specifically, the Canadian Space Agency received authority to spend development funds on the altimeter later than planned, which contributed to delays in the instrument's schedule. Project officials reported that the altimeter's schedule remains a significant challenge, and the Canadian Space Agency is evaluating de-scope options for reducing the instrument's development schedule.

Other Issues to be Monitored

Project officials stated that missing the launch window or backup opportunity in 2017 could result in a five year launch delay due to the orbit of the project's destination. According to project officials, the mission must launch by September 2016 in order to use the Earth's gravity to assist the spacecraft with intercepting the asteroid. They added that the mission could launch in 2017 if necessary, but the spacecraft would have to carry more fuel for maneuvering in space. After 2017, the mission would not be able to launch again until 2022, when the Earth and the asteroid orbit phasing returns to a favorable alignment.

Project officials are also monitoring a risk with the maturity of the mission's Light Detection Ranging technology, which is critical for collecting the sample. They stated that this technology was not designed for a long mission and has only flown to the International Space Station; whereas OSIRIS-REx requires the sensor to operate during asteroid operations, which complete approximately 4.5 years after launch. Project officials are studying navigation techniques that would provide redundancy and reduce the criticality of the light detection and ranging technology.

Project Office Comments

The OSIRIS-REx project provided technical comments to a draft of this assessment, which were incorporated as appropriate. In general, the OSIRIS-Rex project agrees with the GAO findings. NASA officials added that the only issue currently being tracked is the ability of the international partner to deliver the laser altimeter on schedule. Project officials also said that there are a number of risks that are being closely watched to ensure that critical hardware is delivered on schedule.

Orion Multi-Purpose Crew Vehicle

Project Challenges
- Funding Issues
- Design Issues

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

CONTRACT INFORMATION

Current highest value contract

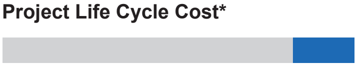
Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft Development**
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: **February 2013** **$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**

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

Source: Lockheed Martin Space Systems Company.

PROJECT SUMMARY

The MPCV program is developing and building hardware for its first exploration flight test (EFT-1), but has encountered development challenges which could threaten its September 2014 test date. In order to manage vehicle development within the constraints of the current budget, the project has deferred development and testing of critical components. For example, the project shifted the ascent abort test two years later than originally proposed, because of budget constraints through the first non-crewed launch. MPCV's current design exceeds the allowed mass for the first crewed flight tests on the Space Launch System. Project officials are studying a risk that the spacecraft's heatshield may crack during reentry into the Earth's atmosphere, and these analyses have impacted production of the heatshield for EFT-1.

Implementation
- **08/2021** First crewed launch date
- **12/2017** First non-crewed launch date
- **01/15 - 04/15** Critical design review
- **09/14** Project confirmation

Formulation
- **04/14** Preliminary design review
- **12/12** GAO review
- **02/12** Orion MPCV 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

The project has experienced delays in building and delivering hardware for its first exploration flight test (EFT-1) which could threaten the launch currently scheduled for September 2014. EFT-1 will test numerous separation events, the thermal protection system, and the parachutes, all of which protect the crew during flight, reentry, and landing events. Development challenges coupled with an aggressive schedule have led the project to miss more internal milestones than anticipated for this test event. The project is currently working to develop a mitigation plan in order to meet their planned September 2014 test date. In addition, NASA is in discussion with the European Space Agency regarding an agreement for development of the service module.

Funding issues

According to NASA officials, vehicle development that cannot be managed within the constraints of the current budget will either cause the project to accept additional risk, defer capabilities to later flights, or delay the first crewed launch date. For example, in order to stay within current budget constraints, the project has deferred development and testing of the launch abort system, which is needed to carry the crew away from the launch vehicle in case of a failed launch. By shifting the ascent abort test to two years later than originally planned, the project has shortened the length of time between the ascent abort test and the first crewed flight which decreases the amount of time the project has to address any issues that may be discovered during the ascent abort test.

Design Issues

The current projected mass of the spacecraft for the first crewed flight test exceeds the recommended mass by over 5,000 pounds. Project officials have deferred mass reduction activities for the first non-crewed flight to the first crewed flight. The project plans to use EFT-1 component testing and flight test results, among other analyses, in order to further refine the spacecraft's design to meet mass requirements.

Project officials are tracking a risk that the thermal protection system could crack due to the thermal expansion stress loads of the heatshield prior to reentering the Earth's atmosphere, which could threaten the safety of the crew and success of the mission. This cracking property was known prior to selection of the heatshield material, but project officials have been conducting stress analyses on the heatshield, among other studies, to understand the magnitude of the cracking. These analyses have delayed production of the heatshield for EFT-1.The heatshield was deemed mature during its critical design in May 2012, and project officials expect its capability to be fully demonstrated in EFT-1.

Other Issues to be Monitored

Development of MPCV continues under a contract awarded in August 2006 for development of the Orion vehicle under the Constellation Program. This contract is currently valued at $6.2 billion. Project officials told us they are working to modify the contract to reflect budgetary, technical and schedule changes of the reformulated program consistent with Congressional direction.

Project Office Comments

The MPCV project provided technical comments to a draft of this assessment, which were incorporated as appropriate. NASA officials also commented that while MPCV continues to make progress on the first production spacecraft to fly on EFT-1 in 2014, the project is reformulating to the objectives and constraints of the revised human space exploration policy.

Radiation Belt Storm Probes

Project Challenges
- Parts Issues
- Test and Integration Issues (new)

Previously Reported Challenges
- Design Issues
- Contractor Issues

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **National Reconnaissance Office**

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

Mission Duration: **2 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: **Spacecraft Development & Operations**

Type of Contract: **Cost Plus Fixed Fee**
Date of Award: **2006**
Initial Value of Contract: **$435.5 million**
Current Value: **$504.4 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline Est. FY 2009	Latest Feb 2013	Change
Total Project Cost	$685.8	$686.0	0.0%
Formulation Cost	$88.2	$88.2	0.0%
Development Cost[a]	$533.9	$510.3	-4.4%
Operations Cost[a]	$63.7	$87.5	37.4%
Launch Schedule	05 2012	08 2012	3 months

The Radiation Belt Storm Probes (RBSP) mission is planned to explore the Sun's influence on the Earth and near-Earth space by studying the planet's radiation belts at various scales of space and time. The two spacecraft are expected to measure the particles, magnetic and electric fields, and waves that fill geospace and provide new knowledge on the dynamics and extremes of the radiation belts. Understanding the radiation belt environment has practical applications in the areas of spacecraft system design, mission planning, spacecraft operations, and astronaut safety.

Source: © 2010 The Johns Hopkins University/Applied Physics Laboratory (artist depiction).

PROJECT SUMMARY

RBSP successfully launched on August 30, 2012 within its planned cost and schedule baselines. However, in July 2011 NASA rebaselined RBSP's launch date to a date 3 months later because of changes to the launch manifest caused by other missions. Several instruments had to be de-integrated from the spacecraft or had their integration delayed, then underwent rework in order to address challenges identified during integration and test. According to project officials, after launch RBSP will be completing 60 days of on-orbit acceptance activities, such as commissioning instruments. The project began returning science data in October 2012.

Timeline

Implementation
- **12/12** GAO review
- **08/30/2012** Launch date
- **10/10** System integration review
- **12/09** Critical design review
- **12/08** Project confirmation

Formulation
- **10/08** Preliminary design review
- **10/07** Mission/ System design review
- **09/06** Formulation start

[a]Funds remaining in development after launch were rephased to operations.

Radiation Belt Storm Probes

PROJECT UPDATE

RBSP successfully launched on August 30, 2012 within its planned cost and schedule baselines. However, in July 2011 NASA rebaselined RBSP's committed launch date to a date three months later because of changes to the launch manifest caused by other missions, including some from the Department of Defense. According to project officials, after completing 60 days of on-orbit acceptance activities, such as commissioning instruments, the project began returning science data on October 30, 2012.

Parts/Test and Integration Issues

The project had to rework several instruments in order to address challenges identified during integration and test. For example, one of the mission's six Magnetic Electron Ion Spectrometers (MagEIS) failed during thermal vacuum testing. Project officials removed the failed instrument and one other MagEIS instrument from one spacecraft, and delayed delivery of two other MagEIS instruments for associated rework on all MagEIS instruments. After spacecraft-level vibration testing, the outstanding MagEIS units were delivered to the spacecraft. In addition, after completing spacecraft environmental testing, the project removed the Helium-Oxygen Proton-Electron instruments and power and communications components from both spacecraft for rework. Project officials reported retesting both instruments prior to re-integrating these instruments on both spacecraft prior to launch.

Project Office Comments

The RBSP project provided technical comments to a draft of this assessment, which were incorporated as appropriate. NASA officials added that the slip in the launch date from August 15, 2012 to August 30, 2012 was due to launch vehicle availablity and unfavorable weather conditions that were outside of the project's control. The project completed the commissioning phase and transitioned into operations on October 30, 2012 within cost.

Soil Moisture Active and Passive

Project Challenges
- Launch Issues
- Design Issues (new)

Previously Reported Challenges
- Funding Issues
- Technology Issues

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

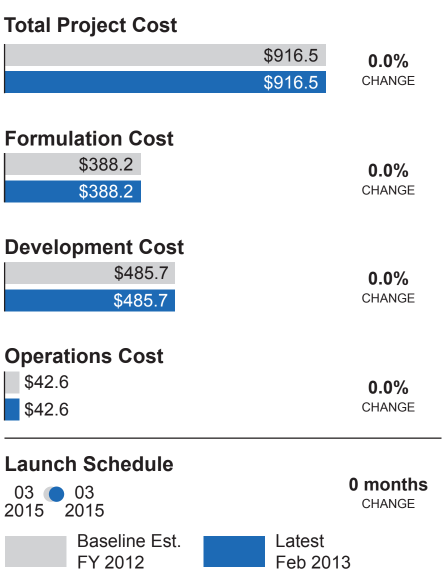
Contractor: **Northrop Grumman Aerospace Systems**

Contractor Activity: **Reflector Boom Assembly development**

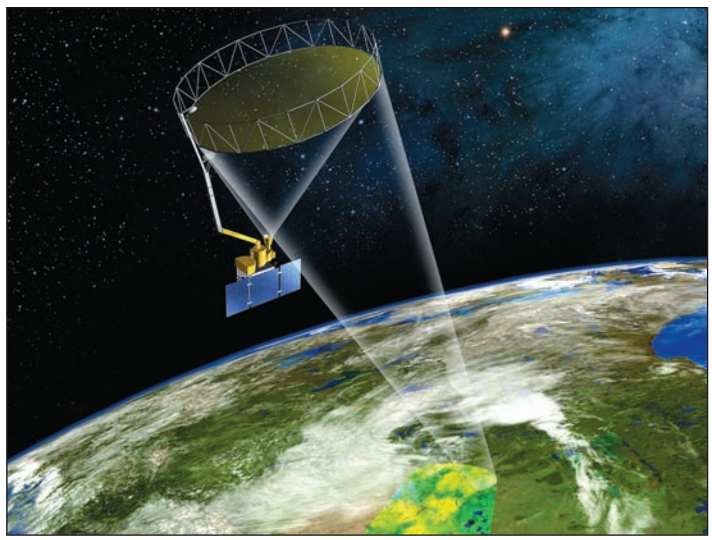
Type of Contract: **Cost Plus Fixed Fee**
Date of Award: **June 2009**
Initial Value of Contract: **$18.56 million**
Current Value: **$35.0 million**

PROJECT PERFORMANCE

Then year dollars in millions



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, improve weather, flood, and drought forecasts, and climate changes.



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

PROJECT SUMMARY

In July 2012, NASA selected a launch vehicle for SMAP. This decision took place 16 months later than the project originally requested. The project postponed key reviews but continued development work to remain on schedule. SMAP was able to continue development by keeping members of its review board aware of progress with spacecraft design and by modifying its launch vehicle adapter. Project officials are working to complete the analysis necessary to understand how the spacecraft and launch vehicle will interact. The project has implemented plans to address concerns with instrument components that were identified during developmental shock tests near the end of the design phase.

Soil Moisture Active and Passive

PROJECT UPDATE

The SMAP project successfully held its confirmation review in May 2012 and its critical design review in July 2012. At the confirmation review, NASA approved a March 2015 committed launch date, though the project continues to work toward a launch in October 2014. In July 2012, NASA selected the Delta II as the SMAP project's launch vehicle.

Launch Issues

NASA selected SMAP's launch vehicle 16 months later than the project originally requested to accommodate the selection process for a new vehicle. The preliminary design review is the time in the development lifecycle when project officials prefer to have a launch vehicle identified due to its importance to the design of the spacecraft. In order to accommodate the delayed launch vehicle selection, the project postponed its preliminary design review, project confirmation, and critical design review by several months, but the preliminary design review and confirmation were still held prior to the selection of a launch vehicle. NASA officials have previously stated that changing a launch vehicle after a project's preliminary design review can delay design or lead to a fundamental change to the mission design, resulting in potential cost and schedule growth. As a result, NASA authorized the project to take steps to continue development as planned and maintain its schedule to the extent possible. For example, the project mitigated some of the risk associated with late selection of the launch vehicle by modifying its launch vehicle adapter design so that the spacecraft could be mated to any of the launch vehicles that were under consideration.

Project officials stated that while no significant issues or concerns remain following the project's critical design review, important analyses need to be completed. Specifically, the project is working with the launch vehicle provider to ensure that the analysis of how the spacecraft and launch vehicle interact will be completed on schedule so that there is time to address any issues that might arise.

Design Issues

The project is working to resolve an issue with the deployment mechanism for the reflector boom assembly—which is part of the instrument antenna and is used by the radar and the radiometer. Specifically, the structural loads analysis indicated that mechanical loads on specific parts may exceed acceptable limits for those parts. The project is making design changes to address this issue and currently estimates a one month delivery delay for the boom assembly.

The project is also working to address a risk to the radiometer—designed to provide data to measure soil moisture by detecting radiant energy emitted from the Earth—and to the control electronics as initial development tests on the engineering model of the instrument showed that shock levels could be above their heritage levels. To mitigate this risk, the project reduced the shock levels transmitted to these components by modifying the design and using shock-absorbing materials to reduce shock levels on the electronics and radiometer assemblies.

Project Office Comments

The SMAP project provided technical comments to a draft of this assessment, which were incorporated as appropriate. NASA officials also commented that the design issues identified are typical of those encountered near the end of a design phase where developmental hardware testing and maturing analyses reveal a small number of isolated design issues with a few components. They added that finding such issues at the end of the design phase helps to avoid the downstream risk of discovering a design issue while testing the actual flight hardware. These issues were discovered before the project's critical design review, they were reported to the Standing Review Board at the critical design review, which determined that the project's approach for addressing the issues was sound.

Solar Probe Plus

Recent / Continuing Project Challenges

- Launch Issues
- Technology Issues (new)
- Design Issues (new)

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: **$232.9 million**

PROJECT PERFORMANCE

Then year dollars in millions

Preliminary estimate of Project Life Cycle Cost*

Latest: **Feb 2013** **$1,233 - $1,439**

** 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 **07/2018**

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 SPP project has begun designing the project to launch on an Atlas V, but a launch vehicle has not been selected by NASA. If the Atlas V is selected, it will need to be modified and a modified solid rocket motor upper stage will need to be added in order to obtain enough energy to reach SPP's orbit. The SPP project will not rate the solid rocket motor as mature until after the project's critical design review. SPP also faces challenges with the development of a heat shield and high intensity solar arrays.

Implementation

- **07/18** Projected launch date
- **06/16** System integration review
- **03/15** Critical design review
- **03/14** Project confirmation

Formulation

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

Solar Probe Plus

PROJECT UPDATE

Launch Issues
The SPP project has begun designing the project to launch on an Atlas V, but a launch vehicle has not been selected. If the Atlas V is selected, it will need to be modified in order to reach SPP's orbit. As a result, the project is developing a new solid rocket upper stage in order to achieve enough energy to reach the mission's trajectory around the Sun.

Technology Issues
The SPP project will not rate the upper stage's solid rocket motor as mature—meaning that it has been demonstrated as a fully integrated prototype in a relevant environment—until after the project's critical design review. The solid rocket motor relies on existing technologies, but the technologies have not been integrated together before and therefore need to be tested together to assess performance.

Design Issues
SPP faces challenges with two other technologies—the spacecraft's sun shield and the system used to cool its solar arrays. For example, the project has begun development of a Thermal Protection System (TPS)—a carbon-foam filled sun shield and connecting structure—which will protect SPP's instruments from the Sun's heat. The project has identified a risk that the physical loads exerted during launch on the sun shield could exceed the TPS design margins and require a redesign. The project is considering an alternate TPS design to mitigate this risk and is conducting an analysis to further understand the TPS performance under the expected loads.

Project officials are also focused on the development of two sets of solar arrays—essentially solar power generators—and have concerns that the cells within the arrays may provide insufficient power to the spacecraft or place unsustainable thermal demands on SPP's solar array cooling system. In order to mitigate the risk, the project has fabricated SPP's solar cell assemblies using alternative techniques and is currently testing their performance.

The project will not be able to test a full scale probe under conditions like those in the near-Sun environment. To address this risk to the extent possible, the project demonstrated the functionality of a 1/6 scale cooling system and is currently validating subsystem design performance in conditions like those in the near-Sun environment using engineering models.

Issue to be Monitored
The project has reported that NASA did not structure its current budget to align with its development and execution needs. As a result, the project may have had to cut short future development and test activities, which raised the technical risk level of the project. To address this risk, in July 2012, NASA's Science Mission Directorate realigned its FY2014 budget allocation to mitigate the risk, and plans on addressing the other budget needs in the future.

Project Office Comments
The SPP project provided technical comments to a draft of this assessment, which were incorporated as appropriate. NASA officials stated that the project remains on track for its preliminary design review in January 2014 and on track for a July 2018 launch.

Space Launch System

Project Challenges

- Design Issues
- Funding Issues

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: **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 Cost through first non-crewed launch*

Latest: **February 2013** **$7.65 – $8.59 BILLION**

**This estimate is preliminary through the first non-crewed launch in December 2017, 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: **2017**
First crewed launch: **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 Multi-Purpose Crew Vehicle and service the International Space Station if necessary. The vehicle is being designed with an initial lift capacity of 70 metric tons to low-Earth orbit and evolvable to 130 metric tons. The initial 70 metric ton capability will include a core stage and two five-segment boosters. The 130 metric ton capability will include a core stage, an upper stage powered by a J-2X engine, and advanced boosters.

Source: SLS Project Office (artist depiction).

PROJECT SUMMARY

In November 2012, the SLS project produced a preliminary cost estimate range as part of the project's system requirements and definition review, but this estimate does not include costs of launch vehicles beyond the first non-crewed launch in 2017. While the project is utilizing heritage hardware to control cost, modifications to the hardware will be required in order to meet SLS objectives. As a result of budget constraints, the project has focused practically all of its current resources on development of the 70 metric ton launch vehicle needed for the first non-crewed and crewed launch dates, and has deferred some work on future versions of SLS.

Implementation

- **2021** First crewed launch date
- **2017** First non-crewed launch date
- **01/15 - 03/15** Critical design review
- **10/13 - 12/13** Project confirmation

Formulation

- **07/13 - 09/13** Preliminary design review
- **12/12** GAO review
- **07/12** Mission/System design review
- **11/11** Formulation start

Space Launch System

PROJECT UPDATE

In November 2012, NASA produced a preliminary estimate of $7.65 to $8.59 billion for the 70 metric ton version of SLS. This is not a life cycle cost estimate, however, because it only covers the first non-crewed launch date in December 2017, plus three months of data analysis. This estimate does not include costs for the first crewed flight of the same vehicle type of the SLS in 2021, nor does it include costs associated with substantial development for future flights of other variants of the launch vehicle. NASA officials stated that the full life-cycle cost of SLS cannot be calculated because SLS is really a program and not a project that has a discrete start and endpoint. Thus, NASA is thinking in terms of what the cost is for attaining a certain level of capability, and what it costs to fly each version of SLS.

Design Issues

Project officials are still assessing whether existing, or heritage hardware, can meet performance requirements without modifications. For example, project officials will not know if the shuttle-era RS-25 engines as currently designed can meet SLS's performance requirements without significant modifications until the engine preliminary design review. In addition, the controllers for the RS-25 engines—designed over 30 years ago to monitor and control the engines and perform diagnostics on other components—will need to be redesigned to address parts obsolescence issues.

The project is working with NASA officials to determine what human safety requirements will be required for SLS and whether the existing SLS design will meet those requirements. For example, the project is currently evaluting options for a propulsion stage that is designed to provide additional power to push the Multi-Purpose Crew Vehicle spacecraft into deep space. The project is also concluding a study on whether an existing propulsion stage could meet human rating and performance requirements, or would require additional design modifications.

Funding Issues

In order to stay within its short-term funding projections, the project has deferred work on the 130 metric ton vehicle. For example, the project has deferred work on the upper stage—which will store liquid hydrogen and liquid oxygen needed to feed the rocket's engines—for the 130 metric ton vehicle. The project also reported that developing the core stage for the 70 metric ton vehicle in parallel with the core stage of the 130 metric ton vehicle would be preferable in order to ensure optimum core stage design and full evaluation of integration issues between the two stages, and would be more cost effective. However, due to budget constraints this is not possible. As a result, once development of the 130 metric ton vehicle begins, modifications may be needed.

Other Issues to be Monitored

Project officials told us that development of SLS components continue under modified undefinitized contracts awarded under the Constellation program's Ares project. Project officials reported that the SLS work conducted under these contracts remains within the scope of the Ares prime contracts, however the contracts need to be modified to be in line with the design requirements and flight objectives of the SLS project. As of November 2012, the project plans to definitize all SLS contracts by the fourth quarter of fiscal year 2013.

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

- Funding Issues (new)
- Contractor Issues (new)
- Technology Issues (new)

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

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: **$644.0 million**[a]

[a] *This represents the full cost of the General Dynamics contract that NASA is managing, however the cost is shared with commercial users of the NASA Space Network.*

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$493.9
$493.9
0.0% CHANGE

Formulation Cost
$125.8
$125.8
0.0% CHANGE

Development Cost
$368.1
$368.1
0.0% CHANGE

Operations Cost[b]
$0
$0
0.0% CHANGE

Launch Schedule
06 2017 — 06 2017
0 months CHANGE

Baseline Est. FY 2013 | Latest Apr 2013

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 the systems 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.

PROJECT SUMMARY

NASA officials reported that SGSS delayed entering the implementation phase until April 2013 due to the unknown impacts of current and future funding constraints on the project's scope. Although SGSS officials reported that all of the project's technologies are mature, a management review board determined that two of the project's heritage technologies that need to be adapted for use in the SGSS system were not at an appropriate level of maturity at the project's preliminary design review. Project officials are also monitoring several risks related to software development and the deployment and transition of the new system that could significantly affect the project's cost and schedule.

[b] *The SGSS project does not have an operations phase. The NASA Space Network program will assume delivery of the SGSS products and continue the operations phase. Additional costs for the system will be shared with commercial users of the NASA Space Network.*

Implementation

- **06/2017** Final acceptance review
- **08/13** Critical design review
- **04/13** Project confirmation

Formulation

- **12/12** GAO review
- **09/12** Preliminary design review
- **12/11** Mission/system design review
- **11/11** Formulation start

Space Network Ground Segment Sustainment

PROJECT UPDATE

Funding Issues

SGSS entered the implementation phase in April 2013. NASA officials reported that NASA delayed entering the implementation phase by several months due to the unknown impacts of current and future funding constraints on the project's scope.

Contractor Issues

SGSS officials are monitoring a risk that staffing levels and costs could increase, and the project's schedule could be delayed because a sub-contractor estimated that it could develop software at an unrealistic rate. SGSS and contractor officials estimate that this risk could delay the project's schedule by 3-to-9 months, and about 22 percent of the project's reserve funding could be needed to mitigate this risk. SGSS officials requested progress metrics so that they could monitor the sub-contractor's performance, but project officials reported that they have not yet received the metrics.

Technology Issues

Although SGSS officials reported that all of the project's technologies are mature, a management review board determined that two of the project's heritage technologies that need to be adapted for use in the SGSS system were not at an appropriate level of maturity at the project's preliminary design review. According to SGSS officials, the management review board determined that the technologies were not mature because they have not been demonstrated in an operational environment, which is consistent with our best practices work on technology maturity. According to SGSS officials, both technologies will be tested at one or more of the Space Network's ground terminals beginning in 2014. Until then, they stated that SGSS and contractor officials will continue developing and testing prototypes of both technologies. Project officials said they are not concerned about the maturity of the technologies and do not anticipate needing to use backup technologies because prototypes of both technologies have performed well in laboratory environments.

Other Issues to be Monitored

Project officials estimate that potential risks during the scheduled deployment of and transition to the new system in 2014 could delay the schedule and require utilization of a quarter of the project's reserve funding. For example, the SGSS project is tracking a risk that there is inadequate time for verification and validation testing at the ground terminals, such as demonstrating control of a tracking and data relay satellite, because, among other things, the schedule and planned staffing levels are aggressive. Project officials stated that this risk contributed to a projection that SGSS's schedule could increase by 9 months.

Project Office Comments

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

Stratospheric Observatory for Infrared Astronomy

Recent / Continuing Project Challenges
- Design Issues

Previously Reported Challenges
- Funding Issues

PROJECT ESSENTIALS

NASA Center Lead:
Dryden Flight Research Center

International Partner:
German Aerospace Center

Aircraft: **Modified 747SP**

Sortie Location:
Dryden Aircraft Operations Center, CA

Mission Duration: **20 years of science flights**

Requirement derived from:
Astronomy and Astrophysics Committee, National Research Council, 1991

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: **$581 Million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$2954.4
$3002.9
1.6% CHANGE

Formulation Cost
$35.0
$35.0
0.0% CHANGE

Development Cost
$919.5
$1128.4
22.7% CHANGE

Operations Cost
$2000.0
$1839.5
-8.0% CHANGE

Launch Schedule
12 2013 — 12 2014
12 months CHANGE

Baseline Est. FY 2007 | Latest Feb 2013

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 for the observatory are being developed to allow a range of scientific measurement to be taken by SOFIA.

Source: NASA.

PROJECT SUMMARY

SOFIA has spent most of calendar year 2012 performing maintenance, upgrades, and repairs on the aircraft and preparing for the start of a new round of science flights. The changes include software updates, avionics upgrades, and electrical rewiring as well as repairs to the back side of the observatory's primary mirror. However, the project has experienced delays while performing these changes, which has delayed the resumption of science flights. Despite these delays, officials indicate that the SOFIA is on track to meet full operational capability in late 2013.

12/14 Full operational capability

12/12 GAO review

12/10 Initial operational capability

08/00 Critical design review

Implementation

11/95 Project confirmation

Formulation

10/91 Formulation start

Stratospheric Observatory for Infrared Astronomy

PROJECT UPDATE

Although the project's life cycle cost has increased since it was baselined, the project has experienced limited development cost growth since the project was replanned in 2010. In the replan, the project shifted—from 8 to 4—the number of instruments required to demonstrate full operational capability and the project remains ahead of schedule to achieve full operational capability. Additionally, the project has reduced—from 8 to7—the number of first generation science instruments that will eventually fly on SOFIA. In December 2011, the project entered a planned "downtime" period to perform maintenance, upgrades, and repairs on the aircraft. During this downtime period, the project experienced delays related to software development, avionics and wiring upgrades, and primary mirror repairs. The start of the downtime period was also delayed, in part, due to an extension of the previous science flight segment. The project plans to resume science flights in April 2013, 5 months later than previously planned.

Design Issues

The critical design review for the project's Mission Control and Communication System—a hardware and software system used, in part, to control the observatory and the telescope assembly, and ensure correct positioning of the telescope and cavity door—was delayed and its software delivery occurred later than planned. NASA officials told us that anomalies were discovered and addressed during software testing and the current version contains all of the required functionality for observatory verification and validation in October 2012.

The project has also had to upgrade the aircraft's avionics and electrical wiring, which has taken longer than originally planned. According to officials, the project is updating the aircraft's avionics from the 1970s to current technology. Technical issues have persisted during the upgrade process and are causing delays. The project has addressed issues with an element of the avionics, necessary for both the validation and verification and science flights, and successfully completed a series of test flights in January 2013. In addition, the aircraft required some electrical rewiring due to undersized wiring that had to be replaced with a larger gauge wire in order to avoid unacceptable voltage drops. The new electrical wiring was designed and fabricated in-house and is complex—it has over 10,000 connection points—and as a result has contributed to the project's schedule delays.

Issue Update

We previously reported that damage occurred on the project's primary mirror because of unequal thermal expansion of aluminum wire mount tabs that led to chipping of the back side of the primary mirror's glass. To address this issue, the project successfully removed many of these tabs and repaired the chips. The mirror's manufacturer inspected the repairs and determined that the issue was addressed.

Project Office Comments

The SOFIA project office provided technical comments to a draft of this assessment, which were incorporated as appropriate. Project officials reported that the project has completed a significant amount of aircraft system upgrades and an avionics modernization effort that will allow it to meet airspace requirements. Further, they stated that the project continues to hold healthy margin against its Full Operational Capability milestone and plans to complete commissioning of 4 instruments by the end of calendar year 2013 to meet an early full operational capability.

Tracking and Data Relay Satellite Replenishment

Recent / Continuing Project Challenges
- Test and Integration Issues (new)
- Contractor Issues
- Launch Issues

Previously Reported Challenges
- Technology Issues
- Parts Issues

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: **Boeing Satellite Systems**

Contractor Activity: **Spacecraft development**

Type of Contract: **Fixed Price Incentive Fee**
Date of Award: **December 2007**
Initial Value of Contract: **$1.38 billion**[a]
Current Value: **$1.41 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

Total Project Cost
$451.3
$426.5
-5.5% CHANGE

Formulation Cost
$241.9
$241.9
0.0% CHANGE

Development Cost[a]
$209.4
$184.6
-11.8% CHANGE

Operations Cost
$0.0
$0.0
0.0% CHANGE

Launch Schedule
K: 12 2012 → 01 2013 — **1 month** CHANGE
L: 12 2013 → 02 2014 — **2 months** CHANGE

Baseline Est. FY 2010 | Latest Feb 2013

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 successfully launched on January 30, 2013, one month after its committed launch date, due to an engine issue on the satellite's own launch vehicle and problems a similar propulsion system experienced during a recent Air Force launch. Project officials rescheduled TDRS L's launch readiness date to February 2014, 2 months later than its committed launch date, because of other missions' launch schedule needs.

[a]In fiscal year 2012, NASA removed funding for future versions of TDRS.

Implementation
- **02/14** Committed launch date (TDRS L)
- **01/30/13** Launch date (TDRS K)
- **12/12** GAO review
- **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

Tracking and Data Relay Satellite Replenishment

PROJECT UPDATE

Launch Issues

TDRS K: TDRS K successfully launched on January 30, 2013, one month after its committed launch date. This launch was delayed, however, due to launch vehicle concerns. In September 2012, the project reported the failure of a steering component in the first-stage engine aboard the Atlas V launch vehicle provided for TDRS K. The project also noted that such a failure could result in loss of control during launch and subsequent loss of the mission. The launch-vehicle provider implemented additional shifts to remove and replace the first-stage engine assembly and is investigating the root cause of the failure. However, NASA did not have the results of the launch vehicle provider's investigation of this failure by TDRS-K's launch date.

In addition, in November 2012, the project reported the possibility of a slip in TDRS K's December 2012 launch date following a power shortfall during an October 2012 Department of the Air Force launch. The Air Force launch employed the same upper-stage engine used in the Atlas V launch vehicle that launched TDRS K. Early in December 2012, the Atlas V contractor, United Launch Alliance, cleared the propulsion systems for the next manifested launch. However, NASA had already slipped TDRS K's launch date to January 2013.

TDRS L: Project officials have rescheduled TDRS L's launch date to February 2014, 2 months later than its original committed launch readiness date. NASA officials told us that they made this change because of other missions' launch schedule needs. Officials also indicated they hoped to make adjustments to TDRS L based on TDRS K's on-orbit commissioning experience, and preferred to separate the K and L launches by at least 9 months. Since the project schedule currently indicates that Boeing will complete TDRS L in March 2013, NASA will incur some cost to store the satellite between its completion and launch.

Contractor/Test and Integration Issues

The project's prime contractor—Boeing—experienced problems with spacecraft test and integration that impacted its schedule. For example, in December 2011, an electrical anomaly during thermal vacuum testing damaged electronic components in one of TDRS K's power-distribution units. In order to maintain schedule, the project began working 7 days a week to replace damaged parts with rebuilt components, and conducted an additional round of environmental testing on these rebuilt components. TDRS L also experienced schedule delays due to this issue. The project also reported losing 9 days of schedule reserve in February 2012 as a result of delays encountered during integration of the satellite's flight antenna.

Project Office Comments

The TDRS project provided technical comments to a draft of this assessment, which were incorporated as appropriate. The TDRS-L spacecraft has progressed through integration and test, and has successfully completed the spacecraft thermal vacuum test program. The spacecraft has several months of margin to the early 2014 launch date.

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.

NASA agreed with us that its initiatives to mitigate acquisition management risk have helped contribute to the improved performance of its projects. NASA also agreed with our observations that any large cost overruns that occur on large complex projects, such as the James Webb Space Telescope, the Space Launch System, or the Orion Multi-Purpose Crew Vehicle, would complicate the management of NASA's entire major-project portfolio. NASA further observed that an uncertain and unstable funding environment could drive cost increases on such projects through less-than-optimal phasing of current and future work. Given the current fiscal environment, our findings underscore the importance of NASA remaining committed to its initiatives to reduce acquisition risk, especially with regard to management of its larger and more complex missions. Doing so will help NASA continue the improvements it has made to reduce cost and schedule growth in its portfolio and improve its ability to successfully manage the fiscal uncertainty that is likely to continue for many years.

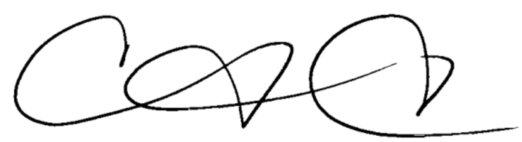
In its response, NASA also noted its commitment to advance implementation and improve the use of the joint cost and schedule confidence level (JCL) process and its intention to implement probabilistic analyses of project cost and schedule for those projects transitioning into the last phase of formulation. The agency 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. Completion of the JCL implementation handbook, which was expected to be completed in 2012, could help projects institute more consistent practices. We encourage NASA to prioritize completion of the JCL handbook as part of efforts to advance implementation of the JCL process. Extending the preparation of these analyses, as NASA indicated in its response that it plans to do, into the last phase (Phase B) of formulation cycle could allow for earlier identification and mitigation of risks for the projects.

In its response, NASA noted that it has identified many technical indicators to assess a project's design stability and maturity over time, and projects have begun to consistently track their progress against these indicators. NASA's approach includes developing and implementing a set of indicators based on the project’s unique complexity and mission objectives. We are encouraged by the attention and focus that NASA has placed on instituting metrics to assess design stability. We plan to review how the tailored use of the newly-developed indicators by NASA’s projects yields a common set of measurable and proven metrics to assess design stability and how this information will be used by agency decision makers. To assist in our ability to assess NASA’s progress in this regard, we recently convened a panel of experts to discuss measuring design stability in NASA projects. We expect that the results of these discussions will enhance our ability to assess projects in the future. We remain committed to further discussions with NASA in this area.

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.

Should you or your staff have any questions on matters discussed in 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 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 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 with life-cycle costs of $250 million or more. Specifically, we (1) assessed the performance of NASA's portfolio of major projects in terms of cost and schedule, (2) identified factors that have contributed to the portfolio's current performance, and (3) highlighted remaining challenges to continued improvement.

To respond to these objectives, we collected and analyzed data from a variety of sources. 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 provided several updates to these data collection instruments. NASA's Office of the Chief Engineer provided data on software-related metrics for selected projects. We also analyzed data and documentation from three NASA major projects on the extent to which these projects were meeting GAO scheduling best practices.[2] We evaluated projects' monthly or quarterly status reports and other project documentation and conducted interviews with project, NASA headquarters, and contractor officials to identify projects' progress to date and any risks. We did not validate the data provided by the project or other NASA offices, but reviewed the data and performed various checks to determine that the data were reliable enough for our purposes. Where we discovered discrepancies, we clarified the data accordingly. We determined that the data were sufficiently reliable for our purposes.

[1]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.

[2]GAO-12-120G.

The information collected from each project office, Mission Directorate, and OCFO was summarized in a two-page report format 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 factors contributing to the cost and schedule performance 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 2013 to previously established project cost and schedule baselines to determine the extent to which each project 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. We also compared the average development cost growth and average schedule delay since our initial assessment to this year's report 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.[3] 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 identify factors that contributed to the portfolio's current performance, we identified the number of technologies and lines of software code each project was developing, reviewed historical data on past projects and compared it to current project performance, and compared projects' technology maturity and design stability against established criteria for knowledge-based acquisitions and other GAO work on system

[3]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.

acquisitions.[4] We also analyzed data and documentation from three NASA major projects to determine the extent to which these projects were meeting GAO scheduling best practices.[5] See appendix V for more information on GAO's assessment of schedule for the three major projects.

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 III 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 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. We also worked with NASA's Office of the Chief Engineer to develop a data collection instrument to collect three metrics on software-related data for selected projects, which include data on the software requirements, software size, and current Computer Software Configuration Items/major systems currently under development.

To assess design stability, we asked project officials to provide the percentage of engineering drawings completed or projected for

[4]GAO-04-386SP.

[5]GAO-12-120G.

completion by the preliminary and critical design reviews and as of our current assessment.[6] 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 they had at least 90 percent of projected drawings 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. In addition, although some projects used other methods to assess design stability, such as computer and engineering models and analyses, we did not assess the effectiveness of these other methods.

To identify remaining challenges to continued improvement, we principally relied on 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 earned value management implementation issues. We examined how NASA is managing large and complex missions within the current budget environment, and the extent to which NASA has implemented GAO's prior recommendation that the agency develop a consistent set of proven metrics to assess design stability.[7]

Our work was performed primarily at NASA headquarters in Washington, D.C. In addition, we visited NASA's Ames Research Center at Moffett Field in California; Dryden Flight Research Center at Edwards Air Force Base in California; Goddard Space Flight Center in Greenbelt, Maryland; the Jet Propulsion Laboratory in Pasadena, California; Johnson Space

[6]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.

[7]GAO-11-364R.

Center in Houston, Texas; Kennedy Space Center, Florida; and Marshall Space Flight Center in Huntsville, Alabama, to discuss individual projects.

NASA's Integrated Budget and Performance Documents

To supplement our analysis, we relied on GAO's work over past years examining acquisition issues across multiple agencies. These reports cover such issues as contracting, program management, acquisition policy, and cost estimating. GAO also has 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. Additionally, the discussions with the individual NASA projects helped us identify further challenges faced by the projects. Together, the past work and additional discussions contributed to our development of a short list of challenges discussed for each two-page project assessment. The challenges we identified and discussed do not represent an exhaustive or exclusive list. They are subject to change and evolution as GAO continues this annual assessment in future years. The challenges, indicated as "issues" in each two-page assessment, are based on our definitions and assessments, not those of NASA.

Project Profile Information on Each Individual Two-Page Assessment

We summarized our assessments of each individual project or program in two components—a project profile and a detailed discussion of project challenges. This section of the two-page assessment includes 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.

Project performance is depicted 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/OCFO through our data collection instrument and from NASA's Integrated Budget and Performance documents.

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.[8] Formulation start generally refers to the initiation of a project; NASA refers to a project's start as key decision point 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 key decision point 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 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 Two-Page 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 17 of the projects to discuss the information on the DCI. One project, RSBP, provided written responses. These discussions led to identification of further challenges faced by NASA projects. The challenges we identified were largely apparent in the projects that had entered the implementation phase; however, there were instances where these challenges were identified in projects in the formulation phase. We then reviewed pertinent 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 would be affected by the issue. For this year's report, we identified the following

[8] 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.

challenges across the projects we reviewed: launch, contractor management, parts, development partners, funding, workforce, and test and integration.

The individual project offices were given an opportunity to comment on and provide technical clarifications to the two-page assessments prior to their inclusion in the final product. We incorporated these comments as appropriate and where sufficient supporting documentation was provided.

Data Limitations

NASA provided updated cost and schedule data in February 2013 for projects in implementation, or 12 of the 18 projects in our review. 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 key decision point B (KDP-B).[9] We did not receive cost estimates or ranges for one project— ExoMars Trace Gas Orbiter—since this project had not yet reached KDP-B, the point in the acquisition life cycle where a preliminary life-cycle cost estimate would normally be developed. One project, the Space Network Ground Segment Sustainment system entered the implementation phase in April 2013, after our review of projects had concluded. This project is not included in our analyses of projects in implementation; however, the project's baseline cost and schedule is reported in the two page assessment. 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 (KDP-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. NASA officials stated that because of changes that occur to a project's scope and technologies between KDP-B and KDP-C, estimates of project cost and schedule can change significantly heading toward KDP-C.

[9]These missions include Ice, Cloud, and Land Elevation Satellite-2, Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer, Solar Probe Plus, and Space Launch System.

We conducted this performance audit from March 2012 to April 2013 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.

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

We have reviewed 34 major National Aeronautics and Space Administration (NASA) projects since our initial review in 2009. See table 4 below for a list of projects included in our assessments from 2009 to 2013 and whether each project was in formulation or implementation at the time of our review.

Table 4: Selected Major NASA Projects and Programs Reviewed in GAO's Annual Assessments.

	2009	2010	2011	2012	2013
Projects in formulation	Ares I	Ares I	Ares I[c]	EMTGO[d]	EMTGO[d]
	GPM	GPM	ICESat-2	ICESat-2	Orion MPCV
	JWST	LDCM	Orion[c]	Orion MPCV	OSIRIS-REx
	LDCM	Orion	SMAP	SLS	SPP
	Orion		SPP	SMAP	SLS
				SPP	SGSS[e]
Projects in implementation	Aquarius	Aquarius	Aquarius	Aquarius[a]	GPM
	Dawn[a]	Glory	Glory[b]	GPM	ICESat-2
	GLAST[a]	GRAIL	GPM	GRAIL[a]	JWST
	Glory	Herschel[a]	GRAIL	Juno[a]	LADEE
	Herschel	Juno	Juno	JWST	LDCM[a]
	Kepler	JWST	JWST	LADEE	MAVEN
	LRO	Kepler[a]	LADEE	LDCM	MMS
	MSL	LRO[a]	LDCM	MAVEN	OCO-2
	NPP	MMS	MAVEN	MMS	RBSP[a]
	OCO[b]	MSL	MMS	MSL[a]	SMAP
	SDO	NPP	MSL	NPP[a]	SOFIA
	SOFIA	RBSP	NPP	OCO-2	TDRS Replenishment[a]
	WISE	SDO[a]	OCO-2	RBSP	
		SOFIA	RBSP	SOFIA	
		WISE[a]	SOFIA	TDRS Replenishment	
			TDRS Replenishment		

Source: GAO analysis of NASA data.

[a]NASA projects that launched during the review year.

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

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

[d]In February 2012, NASA proposed canceling the EMTGO project as part of its fiscal year 2013 budget request.

[e]SGSS entered the implementation phase in April 2013, after our review of projects had concluded.

Appendix III: 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 IV: 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 V: Best-Practices Analysis of Schedules from Three NASA Projects

We have previously reported that a reliable project schedule can enhance cost estimation by contributing to an understanding of the cost impact if a particular project does not finish on time. In an effort to continually assess the National Aeronautics and Space Administration's (NASA) progress in improving its cost-estimating policies and external oversight of these policies, we selected three projects—Global Precipitation Measurement (GPM), Magnetospheric Multiscale (MMS), and James Webb Space Telescope (JWST)—that planned significant amounts of implementation-phase work during the audit year, and assessed these projects' schedules against best practices for project scheduling developed by GAO. We cannot generalize the results of these analyses to NASA's scheduling practices across the entire portfolio of projects, but the results do provide us with insights into areas that could require further investigation in all of NASA's major projects, given the critical importance of a reliable schedule to NASA's overall ability to estimate the time and funds necessary to complete its projects.

The methodology for analysis of project scheduling was developed by GAO in consultation with experts from government and industry and assesses a given schedule's reliability based on a combination of four characteristics—whether the estimate is comprehensive, well-constructed, credible, and controlled. A schedule's achievement of each of these four characteristics results from the degree to which the schedule embodies two or more best practices.[1] To qualify as reliable, a schedule should substantially or fully meet all four of these characteristics. Neither the GPM nor MMS schedules fully met any of these four characteristics. See tables 5 and 6.

[1] GAO-12-120G.

Table 5: Summary Assessment of GPM Schedule Estimate Compared to Best Practices

Characteristic	Overall assessment[a]	Best practice	Individual assessment
Comprehensive	**Substantially met**	1. Capturing all activities	**Substantially met**
		3. Assigning resources to all activities	**Partially met**
		4. Establishing the durations of all activities	**Substantially met**
Well constructed	**Partially met**	2. Sequencing all activities	**Partially met**
		6. Confirming that the critical path is valid	**Partially met**
		7. Ensuring reasonable total float	**Partially met**
Credible	**Partially met**	5. Verifying that the schedule is traceable horizontally and vertically	**Partially met**
		8. Conducting a schedule risk analysis	**Partially met**
Controlled	**Substantially met**	9. Updating the schedule with actual progress and logic	**Substantially met**
		10. Maintaining a baseline schedule	**Substantially met**

Source: GAO Analysis of NASA Data

[a]Not Met - project provided no evidence that satisfies any of the criterion, Minimally Met – project provided evidence that satisfies a small portion of the criterion, Partially Met – project provided evidence that satisfies about half of the criterion, Substantially Met – project provided evidence that satisfies a large portion of the criterion, and Fully Met – project provided complete evidence that satisfies the entire criterion.

The GPM schedule included a sufficient amount of detail and data that enabled the program to ensure that all activities were included. Resources were not identified in the schedule because they were managed in the earned value system instead. Durations were mostly identified at a manageable level, but we did find some durations that were too long to effectively monitor status. While almost all activities reflected schedule logic, we found an abundance of constraints that were causing breaks in the critical path and kept the schedule from responding dynamically to changes. We also found activities with high amounts of total float, some of which could be delayed anywhere from 4 to 6 years without affecting the program end date, which was not realistic.[2] In addition, the program provided evidence that a rigorous process was followed to conduct a schedule risk analysis that identified schedule reserve, however, we had no insight into the details of this analysis and we could not verify the results. Finally, the schedule had been recently

[2]Total float, or slack, is the amount of time an activity can be delayed before the dates of its successor activities or the program's finish milestone are affected. Float is calculated from an activity's early start date and is the amount of time the activity can be delayed before delaying the early start of its successor or the project finish date.

updated by a full time scheduler and had been baselined so that variances could be tracked. However, due to the abundance of constraints in the schedule, we questioned the ability of the schedule to forecast realistic start and finish dates and the program did not have a schedule baseline document for tracking changes to the schedule.[3] According to officials in the GPM project office, best practices collected for the GAO Schedule Assessment Guide are not requirements for NASA schedules. Project officials provided GAO with explanations for a number of instances when GPM's schedule did not fully meet best practices. In addition, the GPM project office noted that an independent Standing Review Board produced the schedule risk analysis provided to GAO for assessment against best practices. Officials also indicated that the project has successfully used current scheduling practices through GPM's development and integration and test period, and that scheduling practices are consistent with the current phase of the project.

Table 6: Summary Assessment of MMS Schedule Estimate Compared to Best Practices

Characteristic	Overall assessment[a]	Best practice	Individual assessment
Comprehensive	**Substantially met**	1. Capturing all activities	**Fully met**
		3. Assigning resources to all activities	**Partially met**
		4. Establishing the durations of all activities	**Substantially met**
Well constructed	**Partially met**	2. Sequencing all activities	**Partially met**
		6. Confirming that the critical path is valid	**Minimally met**
		7. Ensuring reasonable total float	**Partially met**
Credible	**Partially met**	5. Verifying that the schedule is traceable horizontally and vertically	**Partially met**
		8. Conducting a schedule risk analysis	**Partially met**
Controlled	**Partially met**	9. Updating the schedule with actual progress and logic	**Partially met**
		10. Maintaining a baseline schedule	**Partially met**

Source: GAO analysis of NASA data

[a]Not Met - project provided no evidence that satisfies any of the criterion, Minimally Met – project provided evidence that satisfies a small portion of the criterion, Partially Met – project provided evidence that satisfies about half of the criterion, Substantially Met – project provided evidence that satisfies a large portion of the criterion, and Fully Met – project provided complete evidence that satisfies the entire criterion.

[3]Constraints can be placed on an activity's start or finish date and can limit the movement of an activity into the past or future or both. Because constraints override network logic and restrict how planned dates respond to actual accomplished effort or resource availability, they should be used only when necessary and only if they are justified in the schedule documentation. Generally, constraints are used to demonstrate an external event's effect on the schedule.

The MMS schedule covered the entire scope of work including both government and contractor efforts, but half of the remaining activities did not have resources assigned. For the activities that did reflect resources, we found that many of the resources were over allocated. Project officials indicated that total resources were not identified in the schedule but they were managed in the financial system. In keeping with best practices, activity durations were mostly short allowing for effective management. In addition, while logic links were in place for the majority of the remaining activities, about 20 percent were missing predecessor and successor logic and 28 percent had constraints that caused us to question the validity of the critical path. Furthermore, several activities had high total float values with some greater than 1,000 days meaning that an activity could slip up to 4 years without affecting the program end date which may not be reasonable. There were also several activities with negative float implying that this work was behind schedule. The problems with missing logic and constraints affected the credibility of the schedule. For example, when we extended two activity durations by hundreds of days, there was no corresponding effect on the schedule end date due to constraints which prohibited the finish date from moving. The project had conducted a joint confidence level assessment, but the review was done more than 4 years ago so the results were outdated. While project officials indicated that they received subsequent schedule risk analysis reviews conducted by independent groups, due to the problems with the schedule network, we questioned the results of these analyses. Finally, although the schedule had been baselined and the project office provided evidence that they continually monitored the schedule as part of their project management efforts, the overall integrated master schedule showed a status date from 4 years ago. Moreover, out of the 23 underlying sub-schedules only 3 reflected valid status dates. There were also some activities with start and finish dates recorded in the future which suggested a lack of control.

The JWST project has an integrated master schedule,[4] but it is not finalized because major contracts have yet to be negotiated and

[4]As a document that integrates the planned work, the resources necessary to accomplish that work, and the associated budget, the integrated master schedule should be the focal point of project management. In this guide, an integrated master schedule constitutes a project schedule that includes the entire required scope of effort, including the effort necessary from all government, contractor, and other key parties for a project's successful execution from start to finish.

definitized. Because we did not assess the project's integrated master schedule, we conducted a preliminary assessment of two JWST major subsystems—the Integrated Science Instrument Module and the Optical Telescope Element and Integrated Science Instrument Module (OTIS)—that represent key in-house efforts for the project. Most of the issues we identified lay in the OTIS schedule, including the lack of a valid critical path—defined as time associated with activities that drive the overall schedule.[5] Until the schedule can produce a true critical path, the project will not be able to provide reliable timeline estimates or identify when problems or changes may occur and their effect on work occurring later in the development life cycle. If left unaddressed, these issues could affect the reliability of the overall project's integrated master schedule once finalized. We plan to conduct a best-practices assessment of JWST's integrated master schedule as part of our next annual review of JWST.

[5]A project's critical path indicates the path of longest duration through a sequence of scheduled activities. Establishing a valid critical path is necessary for examining the effects of any activity's slipping along this path. A project's critical path determines the project's earliest completion date and focuses the team's energy and management's attention on the activities that will lead to the project's success.

Appendix VI: Comments from the National Aeronautics and Space Administration

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

February 26, 2013

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) report entitled "Assessments of Selected Large-Scale Projects" (GAO-13-276SP). 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 open and constructive communications between NASA and the GAO on this effort and appreciates the ongoing work by the GAO assessment team.

NASA is pleased that the GAO has recognized NASA's achievements over the past years, including our successful launch of three projects in 2012 and early 2013. NASA launched the Radiation Belt Storm Probes (RBSP), the Tracking and Data Relay Satellite (TDRS-K), and Landsat Data Continuity Mission (LDCM). Since its launch on August 30, 2012, RBSP has completed its commission phase of operations, all of the spacecraft's systems and instruments are now active, and the satellite is now in its prime science mission. RBSP was renamed the Van Allen Probes to honor Dr. James Van Allen who led the first efforts to study Earth's magnetic environment *in situ* via the first Explorer mission; the first of NASA's three next-generation Tracking and Data Relay Satellites (TDRS), TDRS-K launched on January 30, 2013. TDRS-K bolsters our network of satellites that provides essential communications to support space exploration. It will improve the overall health and longevity of our system. LDCM launched on February 11, 2013, and is the eighth satellite in the joint NASA-U.S. Geological Survey (USGS) Landsat program. Following its commissioning later this year, LDCM will continue the over 40-year record of the Landsat land imaging data set.

NASA also recognizes that continued refinement, improvement, implementation, and monitoring of sound acquisition practices, policies, and processes are essential to reducing project cost and schedule growth on future missions. As highlighted in the GAO's draft report, NASA continues to implement several initiatives to mitigate acquisition management risks. We are extremely pleased to see progress toward improving cost and schedule performance, although we will look to see if this trend continues over the next several years before claiming success that our processes have reached the level of maturity and stability to endure the continuing challenges NASA faces in future years.

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 to improve the assessment of the likelihood of project success at the specified funding level. The JCL is one of many inputs into the baseline decision process when a project is confirmed at Key Decision Point (KDP)-C, and has the desired effect of increasing insight by both the project manager and NASA's leadership by appropriately taking into account risk-based uncertainties associated with the integrated cost and schedule plan. NASA continues to implement and improve the use of the JCL process and will continue to assess the impact of this process on cost and schedule performance as more projects baselined under this policy complete their development phase. Another aspect to the continuous improvement in cost estimating policies and processes policy is the implementation of probabilistic analyses for project cost and schedule for those projects that are transitioning into the last phase of formulation.

The draft report identifies four challenges that could affect NASA's continued progress including: (1) managing competing priorities within the context of constrained budgets, (2) estimating costs associated with several large-scale projects, (3) improving overall cost and schedule estimation, and (4) using consistent and proven design stability metrics. 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 flagship missions--James Webb Space Telescope (JWST), Space Launch System (SLS), and Orion Multi-Purpose Crew Vehicle (MPCV) would make it challenging for NASA to manage its portfolio of projects. In addition, programs are experiencing an uncertain and unstable funding environment, which can drive less than optimal phasing of current and future program work and can result in program cost increases.

Since the rebaseline of JWST in 2011, the project has consistently remained within its new cost and schedule baseline. The project continues to make excellent progress meeting its annually established milestones and is actively working toward spacecraft critical design review (CDR) later this year. While challenges will remain throughout the implementation phase, the project has implemented several new mechanisms to improve communication between NASA and its contractors, at all levels of the project, in order to proactively respond to any issues as they arise. NASA credits the rigor placed into the continuous improvement plan, as stated previously. Orion and SLS are making excellent progress, though the current lack of flexibility to internally rebalance funding across the major elements of the Human Exploration and Operations (HEO) Mission Directorate is a challenge.

Improving cost and schedule estimating practices is important to NASA as mentioned previously. In the draft report, GAO mentions a long-term weakness in cost and schedule estimating practices leading to optimistic and unrealistic plans based on lack of adherence to GAO's best practices, insufficient resources, and qualified staff. NASA does take pride in

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having an optimistic view, which is why NASA has accomplished great achievements throughout the years. We also take pride in being good stewards to our stakeholders and thus work hard to define, and then manage, project cost and schedule commitments. Although our practices and policies may not completely align with GAO's best practices, NASA is confident in our project management practices and takes the necessary steps to address any gaps as they relate to an identified weakness. The report specifically mentions earned value management (EVM) as important to estimating practices. NASA is willing to focus on these concerns, as demonstrated by the steps we are taking to address GAO's recommendations in its EVM audit. Another area noted in your draft report is the development of realistic, dynamic, and logic driven schedules. While GAO could not validate NASA projects against GAO's best practices for project scheduling, we hope that GAO would agree that the NASA projects demonstrated an understanding of the critical path and scheduling practices, based on NASA policy and practices.

With regard to use of consistent and proven design stability metrics, NASA has continued to work with the GAO to adapt the recommendations related to design metrics, as indicated by the implementation of changes to NASA policy to identify technical indicators to assess project maturity. As noted in the draft report, GAO mentions the differing approaches to design stability between NASA and GAO. NASA has identified many technical indicators to assess a project's design stability and maturity over time, and projects have begun to consistently track their progress against these metrics. NASA's opinion is that there are many indicators to measure a project's readiness as they move forward from CDR and a one-size-fits-all approach may not be appropriate. NASA's plan is to continue to enhance the ability to monitor and assess the stability of programs and projects as well as the maturity of their products through the development process using a more comprehensive approach, including a set of technical indicators developed and implemented, based on the project's unique complexity and mission objectives. This approach is consistent with our policies and handbooks for program and project management.

Finally, NASA would like to thank the GAO for considering and incorporating many technical corrections provided by 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, and as such, NASA looks forward to working with GAO to make sure the number of approved technical corrections continues to increase.

NASA is committed to working with 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 Tracy Osborne at (202) 358-3795.

Sincerely,

Lori B. Garver
Deputy 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; Richard A. Cederholm; Tisha D. Derricotte; Laura Greifner; Jeffrey L. Hartnett; Don Kiggins; Ramzi N. Nemo; Kenneth E. Patton; Sylvia Schatz; Ryan Stott; and Roxanna T. Sun made key contributions to this report.

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