United States Government Accountability Office

Report to Congressional Committees

March 2015

NASA

Assessments of Selected Large-Scale Projects

GAO-15-320SP

GAO Highlights

Highlights of GAO-15-320SP, a report to congressional committees

Why GAO Did This Study

In 2014, GAO reported that NASA's major projects continued a general positive trend of limiting cost and schedule growth, maturing technologies, and stabilizing designs, but that NASA faced several challenges that could affect its ability to effectively manage its portfolio, such as completing a series of complex and expensive projects within constrained budgets and competing priorities.

In 2009, GAO was mandated to prepare status reports on selected large-scale NASA programs, projects or activities. Since then, GAO has reported annually on NASA's major projects. This report is GAO's 2015 assessment and it provides a snapshot of how well NASA is planning and executing its major acquisitions. This report assesses (1) the current performance of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies and stabilizing design, and (3) NASA's initiatives to reduce acquisition risk and work that remains to strengthen management of the agency's largest, most complex projects. GAO also reviewed NASA's 16 major projects, all with an estimated life-cycle cost of over $250 million. GAO assessed 2014 and 2015 cost, schedule, technology maturity, design stability, and other data; analyzed monthly project status reports; and interviewed NASA officials.

What GAO Recommends

GAO is not making recommendations in this report, but its findings provide evidence to support the importance of continuing to take action on prior recommendations. NASA generally agreed with GAO's findings.

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March 2015

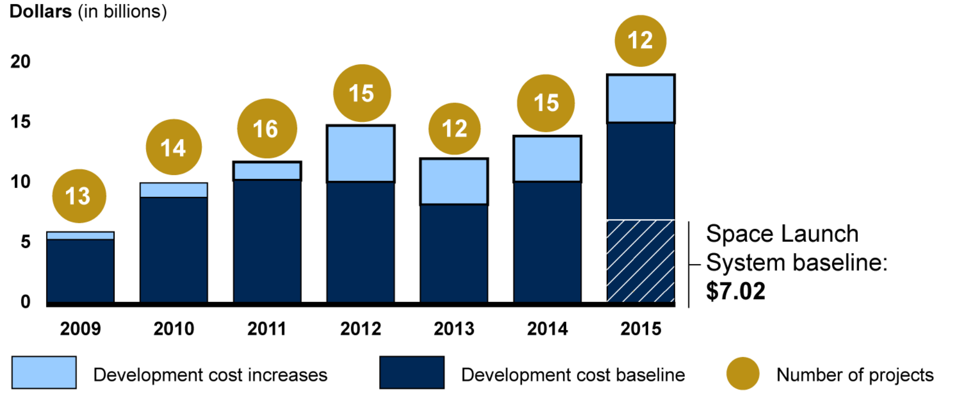
NASA

Assessments of Selected Large-Scale Projects

What GAO Found

The National Aeronautics and Space Administration's (NASA) portfolio of major projects experienced cost and schedule growth in 2015, although that growth remains relatively low compared to historical levels. Cumulative cost growth was 2.4 percent and average schedule growth was 3 months. The growth within the past year is attributable to only a few projects. However, five projects, including the Space Launch System (SLS)—the largest program in NASA's portfolio—only recently established cost and schedule baselines, and as expected, has not yet experienced any cost growth in 2015, which masks growth of several smaller projects in the portfolio. The 2015 portfolio is among the smallest assessed to date, yet for the 12 projects with established baselines, it has the largest amount of total costs, largely due to SLS, as shown below.

Total Number and Development Cost Growth of Selected NASA Major Projects with Established Cost Baselines



Source: GAO analysis of NASA data. | GAO-15-320SP

NASA continues to make progress in meeting best practices for maturing technology and stabilizing design. Of the 13 projects in this assessment that have held a preliminary design review, 77 percent have met the best practices standards for technology maturity, a significant improvement over prior years.

In 2015, five of NASA's largest, most complex projects, several of which are at critical points in their development, are expected to consume 78 percent of the funds for NASA's major projects. Therefore, existing and new projects will be competing for remaining funds. Fully accounting for the funding, schedule, and technical challenges facing these projects is important due to the cascading effects these challenges could have across the portfolio. NASA has implemented several initiatives to reduce acquisition risk, but management of some of these initiatives remains a concern. For example, while NASA has implemented tools in recent years to provide better insight into and oversight of its acquisition projects, the training for and implementation of these tools have not been consistently and thoroughly applied.

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Abbreviations

AFB	Air Force Base
ATLAS	Advanced Topographic Laser Altimeter System
CNES	Centre National d'Etudes Spatiales (French Government Space Agency)
CSA	Canadian Space Agency
DCI	data collection instrument(s)
DLR	German Aerospace Center
DT&E	Developmental Test and Evaluation
EFT-1	The first Exploration Flight Test for the Orion vehicle, December 2014
EM-1	Exploratory Mission 1, the first non-crewed launch of the Space Launch System and the Orion vehicle, planned for fiscal year 2018
EM-2	Exploratory Mission 2, the first crewed launch of the Space Launch System and the Orion vehicle planned for fiscal year 2021/2022
EMTGO	ExoMars Trace Gas Orbiter
ESA	European Space Agency
EVM	earned value management
GFZ	German Research Centre for Geosciences
GLAST	Gamma-ray Large Area Space Telescope
GNC LIDAR	guidance, navigation, and control light detection and ranging instrument
GPM	Global Precipitation Measurement
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	Gravity Recovery and Climate Experiment Follow On
GRAIL	Gravity Recovery and Interior Laboratory
GSLV	Geosynchronous Satellite Launch Vehicle
HP3	Heat Flow and Physical Properties Package
ICESat-2	Ice, Cloud, and Land Elevation Satellite-2
ICPS	Interim Cryogenic Propulsion Stage
InSight	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport
ISRO	Indian Space Research Organization
JCL	Joint Cost and Schedule Confidence Level
JWST	James Webb Space Telescope
KaRIn	Ka Band Radar Interferometer
KDP	key decision point
LADEE	Lunar Atmosphere and Dust Environment Explorer
LDCM	Landsat Data Continuity Mission
LRO	Lunar Reconnaissance Orbiter
MAVEN	Mars Atmosphere and Volatile EvolutioN
MMS	Magnetospheric Multiscale
MPCV	Multi-Purpose Crew Vehicle

MSL	Mars Science Laboratory
NASA	National Aeronautics and Space Administration
NISAR	NASA ISRO Synthetic Aperture Radar
NPP	NPOESS Preparatory Project
NPR	NASA Procedural Requirements
OCFO	Office of the Chief Financial Officer
OCO	Orbiting Carbon Observatory
OCO-2	Orbiting Carbon Observatory 2
OLA	OSIRIS-REx laser altimeter
Orion	Orion Multi-Purpose Crew Vehicle
OSIRIS-REx	Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
OT&E	Operational Test and Evaluation
RBSP	Radiation Belt Storm Probes
SCaN	Space Communications and Navigation
SDO	Solar Dynamics Observatory
SEIS	Seismic Experiment for Interior Structure
SGSS	Space Network Ground Segment Sustainment
SLS	Space Launch System
SMAP	Soil Moisture Active and Passive
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPP	Solar Probe Plus
SWOT	Surface Water and Ocean Topography
TDRS	Tracking and Data Relay Satellite
TESS	Transiting Exoplanet Survey Satellite
TRL	technology readiness level(s)
UKSA	United Kingdom Space Agency
WISE	Wide-field Infrared Survey Explorer

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March 24, 2015

Congressional Committees

This is our annual assessment of the National Aeronautics and Space Administration's (NASA) major projects. This report provides an overview of NASA's planning and execution of its major systems. It includes assessments of NASA's key priorities such as the continued development of the Space Launch System (SLS), Orion Multi-Purpose Crew Vehicle (Orion), and the James Webb Space Telescope (JWST), and the successful launches of the Orbiting Carbon Observatory 2 (OCO-2), Soil Moisture Active and Passive (SMAP), and Magnetospheric Multiscale missions. Since 2009, our annual assessments have reported on 24 NASA development project launches, 22 of which have been successful. Additionally, we have reported on steps NASA has taken to improve its oversight of acquisition projects and NASA's positive trend in reducing cost and schedule growth in recent years.[1] For example, last year's portfolio contained three projects that launched with a combined cost of $148 million less than estimated. This progress is important because, since 1990, we have designated NASA's acquisition management as high risk due to NASA's history of persistent cost growth and schedule slippage in many of its major projects.[2]

The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009 required GAO to prepare project status reports on selected large-scale NASA programs, projects, and activities.[3] This is the seventh annual report responding to that mandate. Specifically, we assessed (1) the current performance of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies and efforts NASA has taken to improve

[1]GAO, *NASA: Assessments of Selected Large-Scale Projects,* GAO-14-338SP (Washington, D.C.: Apr 15, 2014); *NASA: Assessments of Selected Large-Scale Projects*, GAO-13-276SP (Washington, D.C.: April 17, 2013).

[2]GAO, *High-Risk Series: An Update,* GAO-15-290 (Washington, D.C.: Feb. 11, 2015).

[3]See Explanatory Statement, 155 Cong. Rec. H1653, 1824-25 (daily ed., Feb. 23, 2009), on H.R. 1105, the Omnibus Appropriations Act, 2009, which became Pub. L. No. 111-8. In this report, we refer to these projects as major projects rather than large-scale projects as this is the term used by NASA.

design stability of its projects, and (3) the initiatives NASA has under way to reduce acquisition risk, along with work that remains to strengthen management of the agency's largest and most complex projects. This report also includes summary assessments of 16 major NASA projects, each with a life-cycle cost of over $250 million.

In prior reports, we have made recommendations that have focused on improving oversight of NASA's projects including developing improved life-cycle cost estimates for its human exploration programs, following best practices when updating cost risk analyses, developing an executable business case that matches resources to requirements, improving the use of earned value management (EVM), implementing best practices for design stability and technology maturity, and providing more transparency into project costs.[4]

For this annual update, we examined 16 major projects, each with an estimated life-cycle cost of over $250 million. The development cost baselines of projects included in the 2015 portfolio vary from $264 million for the Gravity Recovery and Climate Experiment Follow On (GRACE-FO) project to over $7 billion for the SLS program. We assessed Mars 2020, NASA ISRO Synthetic Aperture Radar (NISAR), and Transiting Exoplanet Survey Satellite (TESS) for the first time in this review.

We reviewed and compared the current cost and schedule data for the 12 projects in the implementation phase during our review to previously established cost and schedule baselines and characterized growth as significant if it exceeded the thresholds that trigger cost or schedule

[4]GAO, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining,* GAO-15-100 (Washington, D.C: Dec. 15, 2014); *Space Launch System: Resources Need to be Matched to Requirements to Decrease Risk and Support Long Term Affordability*, GAO-14-631 (Washington, D.C.: July 23, 2014); *NASA: Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs,* GAO-14-385 (Washington, D.C.: May 8, 2014); *NASA: Earned Value Management Implementation Across Major Spaceflight Projects Is Uneven,* GAO-13-22 (Washington, D.C.: Nov. 19, 2012); *Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects*, GAO-11-364R (Washington, D.C.: Mar. 3, 2011); and *NASA: Implementing a Knowledge-Based Acquisition Framework Could Lead to Better Investment Decisions and Project Outcomes*, GAO-06-218 (Washington, D.C.: Dec. 21, 2005).

reporting to certain congressional committees by law.[5] The remaining four projects were in an early stage of development called formulation where there are still unknowns about requirements, technology, and design. For those projects, we reported preliminary cost ranges and schedule estimates.

To assess NASA's progress in developing and maturing its critical technologies, we identified the number of technologies each project was developing and compared them against historical levels and compared projects' technology maturity against GAO-identified best practices and NASA policy on technology maturity.[6] To understand efforts taken by NASA to improve projects' design stability, we reviewed historical data on past projects and compared it to current performance. We reviewed criteria for knowledge-based acquisitions and compared projects' design stability against these criteria to the extent possible. We also examined the top five metrics as ranked by a group of experts convened by GAO and asked project managers how they used the top five design metrics as identified by the experts.[7] We discussed with project managers the point at which project performance as measured against the metrics indicate that a problem would occur, and what other measurements of design maturity and stability the project typically uses for project management purposes.

To assess NASA's progress and approach for reducing acquisition risk, we reviewed NASA's metrics for measuring acquisition management and supporting data and updates to NASA's acquisition management plans as part of our High Risk update work.[8] We evaluated joint cost and schedule confidence levels (JCL) for projects that developed them as required by

[5]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).

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

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

[8]GAO-15-290.

NASA policy.[9] We examined NASA's efforts to make progress on outstanding issues identified in our prior work, such as the quality of the cost and schedule risk analyses conducted for JWST—one of NASA's most technologically advanced and costly projects—and EVM implementation issues.[10] We also reviewed our previous work on NASA's human exploration programs, such as SLS and Orion.[11] To identify work that remains to strengthen management of the agency's largest and most complex projects, we examined studies commissioned by NASA to identify lessons learned and potential areas for opportunities to strengthen processes and performance in future, large-scale complex projects as well as other NASA studies.

We analyzed information provided by project officials, such as monthly status reports, and interviewed project officials to identify other types of challenges that can affect project outcomes and reported on these challenges in the project assessments. 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 checking the data against NASA's budget documentation. We determined that the data were reliable for the purposes of this report. The individual project offices were given an opportunity to provide comments and technical clarifications on our assessments prior to their inclusion in the final product, and their comments were incorporated as appropriate. Appendix I contains detailed information on our scope and methodology.

We conducted this performance audit from May 2014 to March 2015 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

[9]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.

[10]GAO-15-100; GAO-13-22.

[11]GAO, *NASA: Human Space Exploration Programs Face Challenges,* GAO-15-248T (Washington, D.C., December 10, 2014); GAO-14-631; GAO-14-385.

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

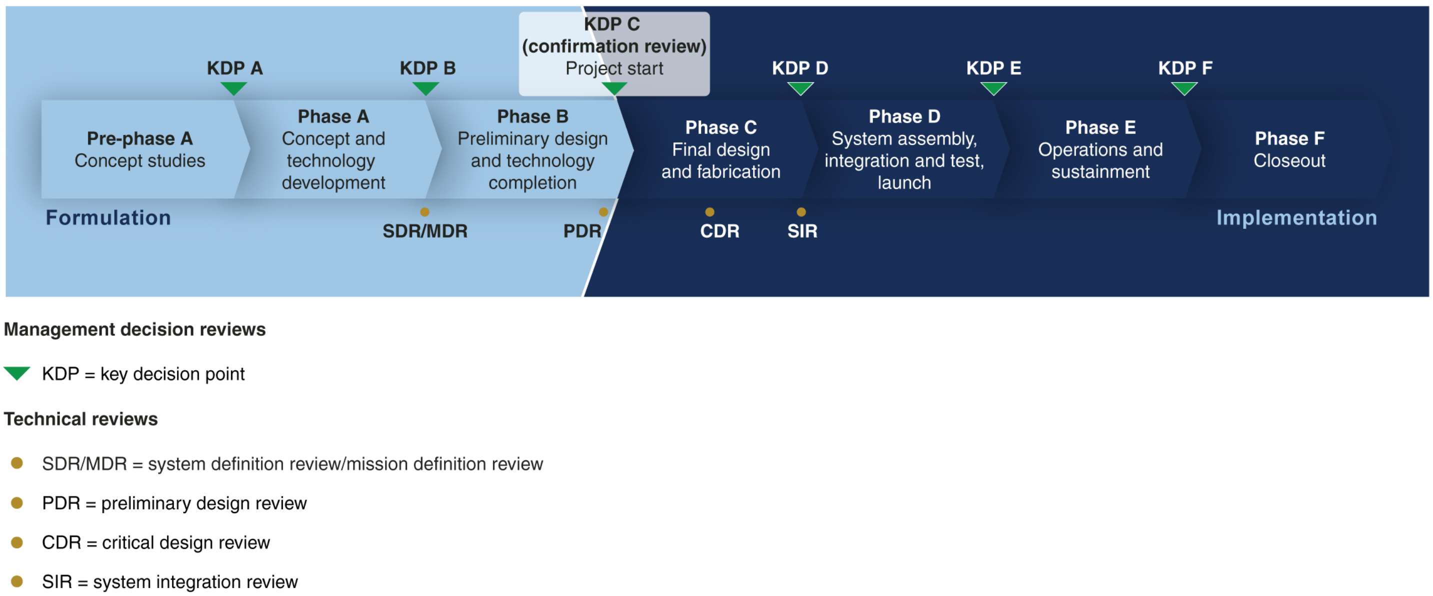
Background

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.[12] 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.

[12]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 7120.5E NASA Space Flight Program and Project Management Requirements para 1.3.1.a (Aug. 14, 2012) (hereinafter cited as NPR 7120.5E (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, para 1.3.1.c (Aug. 14, 2012).

Figure 1: NASA's Life Cycle for Flight Systems



Source: NASA data and GAO analysis. | GAO-15-320SP

Project formulation consists of phases A and B, during which the projects develop and define requirements and the cost/schedule basis and design for implementation, including developing an acquisition strategy. Prior to entering phase B, projects utilize a probabilistic analysis to develop a range of the project's expected cost and schedule which is used to inform the budget planning for that project. During the end of the formulation phase, leading up to the preliminary design review, the project team completes its preliminary design and technology development.[13] 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 is to identify new technologies and their planned

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

development, the use of heritage technologies, risk mitigation plans, and testing plans to ensure that technologies will work as intended in a relevant environment. During the formulation phase, the project is also to develop programmatic measures and technical leading indicators which track various project metrics such as requirement changes, staffing demands, and mass and power utilization. The formulation phase culminates in a review at key decision point C, known as project confirmation, where cost and schedule baselines are to be established and documented in the agency baseline commitment.[14] Project progress can subsequently be measured against these baselines.

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

NASA Projects Reviewed in GAO's Annual Assessment

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

[14]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 the Office of Management and Budget and Congress. NPR 7120.5E, Appendix A (Aug. 14, 2012).

For 2015, we assessed 16 major projects—4 projects in formulation and 12 projects in implementation. Three of the 12 projects in implementation covered in this year's review, OCO-2, SMAP, and MMS, successfully launched in July 2014, January 2015, and March 2015, respectively. We excluded our assessment of the Commercial Crew Program—NASA's effort to facilitate the private demonstration of safe, reliable, and cost effective transportation services to low earth orbit—from the 2015 review due to a bid protest that was ongoing during our review. The year after a project launches or reaches full operational capability, we no longer include a project assessment in our annual report. When NASA determines that a project will have a life-cycle cost estimate of more than $250 million, we include that project in the next review. See figure 2 for information on the projects reviewed in this year's assessment, and appendix II for a list of the projects that have been reviewed from 2009 to 2015.

Figure 2: Selected Major NASA Projects Reviewed in GAO's 2015 Assessment

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

Projects in formulation

Status	Project	Full name	Preliminary estimate of project life-cycle cost:
	Mars 2020	Mars 2020	**$2.14 – 2.35 billion**
	NISAR	NASA ISRO Synthetic Aperture Radar	**$718 – 808 million**
	Orion	Orion Multi-Purpose Crew Vehicle	**$8.53 – $10.29 billion**
	SWOT	Surface Water and Ocean Topography	**$647 – $757 million**

Projects in implementation

Status	Project	Full name	Latest estimate of total project cost
	GRACE-FO	Gravity Recovery and Climate Experiment Follow On	**$431.9 million**
	ICESat-2	Ice, Cloud, and Land Elevation Satellite-2	**$1.06 billion**
	InSight	Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport	**$675.1 million**
	JWST	James Webb Space Telescope	**$8.83 billion**
Launched	**MMS**	Magnetospheric Multiscale	**$1.12 billion**
Launched	**OCO-2**	Orbiting Carbon Observatory 2	**$427.6 million**
	OSIRIS-REx	Origins–Spectral Interpretation-Resource Identification-Security-Regolith Explorer	**$1.06 billion**
Launched	**SMAP**	Soil Moisture Active and Passive	**$914.6 million**
	SPP	Solar Probe Plus	**$1.55 billion**
	SLS	Space Launch System	**$9.7 billion**
Under review	**SGSS**	Space Network Ground Segment Sustainment	**$493.9 million**
	TESS	Transiting Exoplanet Survey Satellite	**$351.7 million**

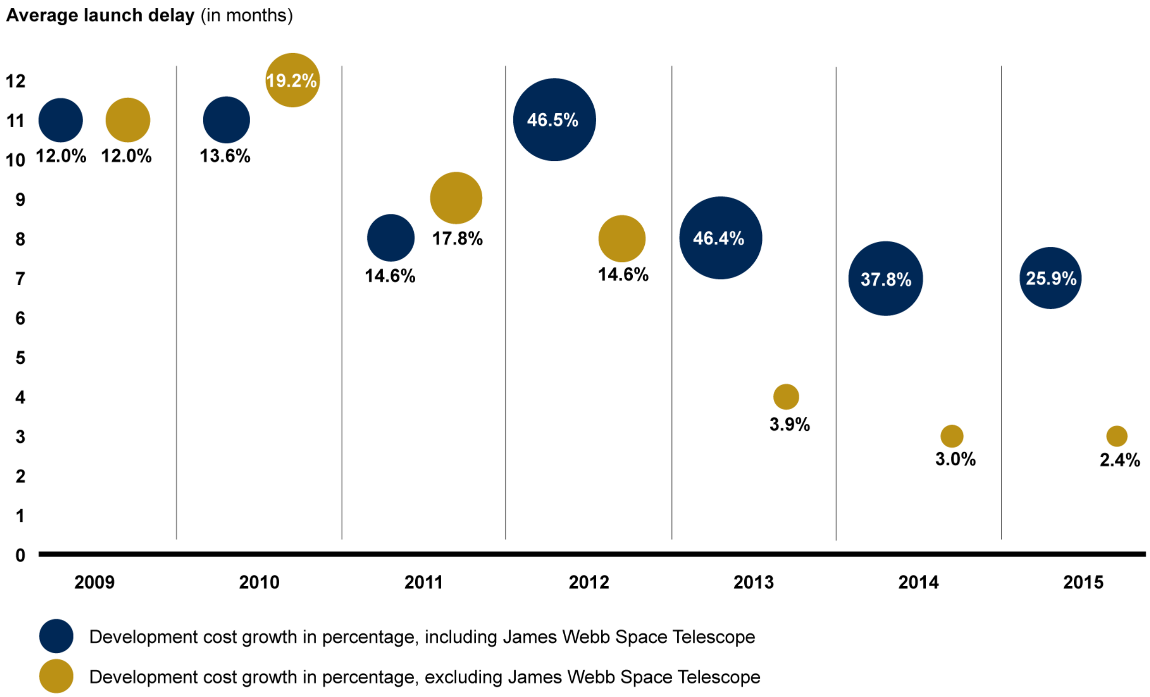
● Launched
○ Under review

Source: GAO analysis of NASA data. | GAO-15-320SP

NASA's Portfolio Maintains Low Cost and Schedule Growth with the Addition of Five Projects Lessening the Effect of Poor Performance in Less Expensive Projects

Cost and schedule growth measured across NASA's projects in 2015 remains low compared to previous years. Figure 3 below shows that the projects in the 2015 portfolio experienced total cost growth of 2.4 percent and average schedule growth of 3 months from original baselines.

Figure 3: Development Cost and Schedule Growth of Selected Major NASA Projects in the Implementation Phase from 2009 through 2015



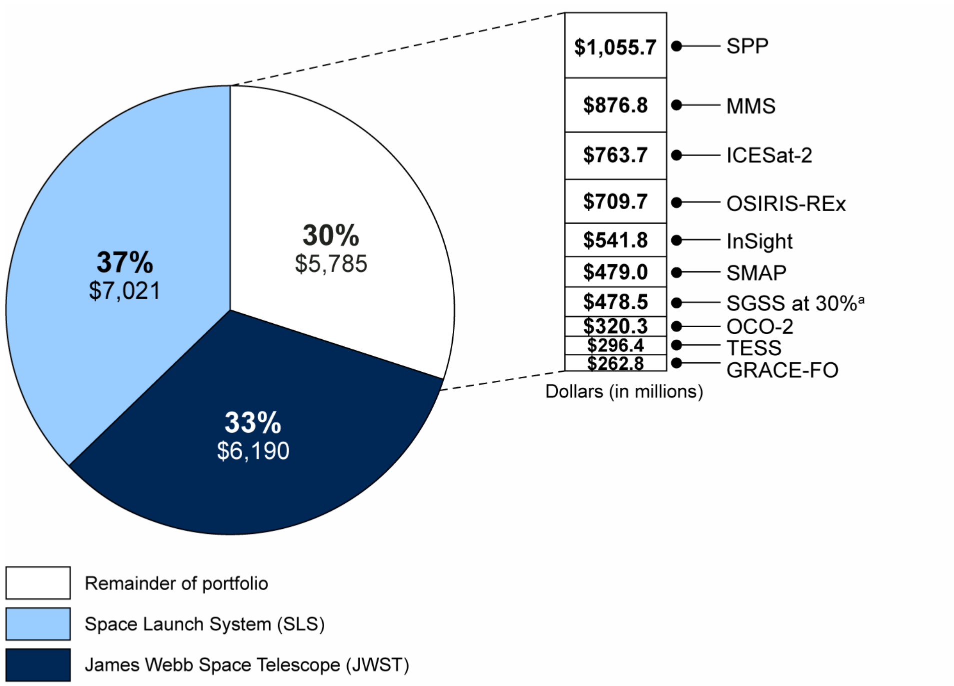
Source: GAO analysis of NASA data. | GAO-15-320SP

We have historically presented cost and schedule growth both excluding and including JWST because, prior to 2015, it was the only project with a development cost baseline significantly larger than the other projects in implementation. Further, the magnitude of JWST's cost growth is considerably larger than that of the other projects in the portfolio. Thus, it overshadows any changes to the remainder of the portfolio. The cost growth of 2.4 percent—which excludes JWST—represents an estimated cumulative increase of more than $302 million from original baselines. In 2014 we found that, excluding JWST, the portfolio exhibited 3 percent cost growth—an increase of almost $229 million from original baselines.[15] While 2015's cost growth was 0.6 percent less than that of 2014, this represents $73.5 million in cost growth over last year. Additionally, the cost and schedule growth calculations incorporate five projects—including SLS—that established and confirmed their cost and schedule baselines in 2014. As these projects recently established cost and schedule baselines, and as expected, have not experienced cost growth, their addition lessens the portfolio's total cost growth. However, if these five recently confirmed projects are removed from the calculation, cumulative cost growth from the sum of the original baselines for 2015 for the remaining projects is 10 percent.

The confirmation of the SLS program and its inclusion in the 2015 portfolio significantly increased the total baseline costs. The SLS program was confirmed in August 2014 with a development baseline of over $7 billion and is now the most expensive program in NASA's portfolio. As shown in figure 4 below, the development cost baseline for SLS now singularly comprises 37 percent of the portfolio's current development costs. Figure 5 further shows that, while this year's portfolio is among the smallest assessed to date in terms of number of projects, it also has the highest amount of total baseline costs.

[15] GAO-14-338SP.

Figure 4: Space Launch System Baseline Comprises 37 Percent of NASA Major Project Portfolio Current Development Costs

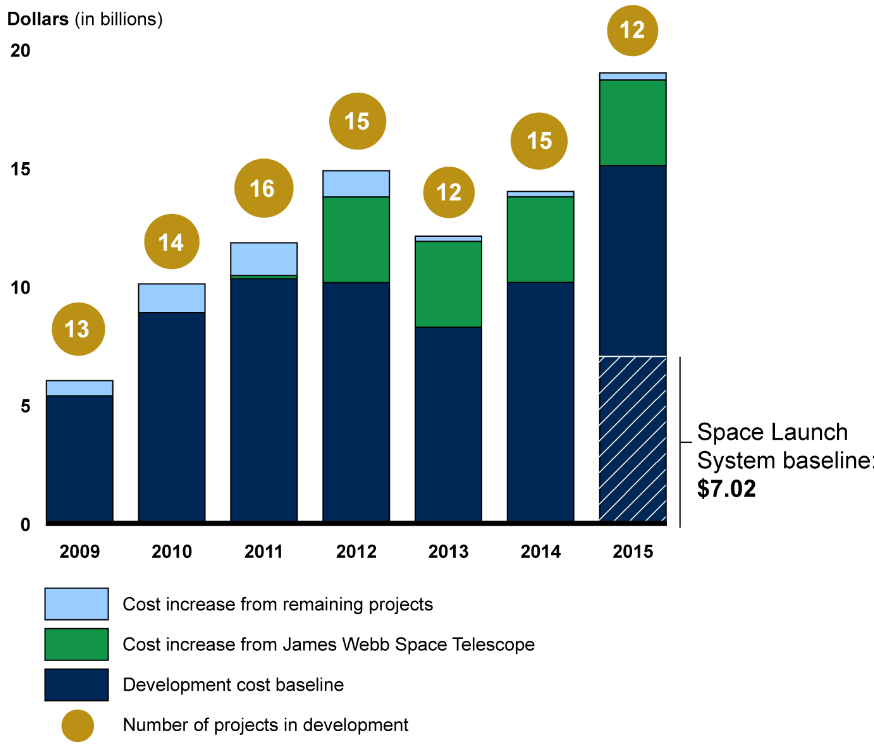


SPP: Solar Probe Plus
MMS: Magnetospheric Multiscale
ICESat-2: Ice, Cloud, and Land Elevation Satellite - 2
OSIRIS-REx: Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer
InSight: Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport
SMAP: Soil Moisture Active and Passive
SGSS: Space Network Ground Segment Sustainment
OCO-2: Orbiting Carbon Observatory – 2
TESS: Transiting Exoplanet Survey Satellite
GRACE-FO: Gravity Recovery and Climate Experiment Follow On

Source: GAO analysis of NASA data. | GAO-15-320SP

[a]The SGSS project is expected to be rebaselined, which will likely affect project cost and/or schedule. The development cost for SGSS reflects the minimum anticipated cost growth of 30 percent as the project prepares for its rebaseline in June 2015.

Figure 5: Total Number and Development Cost Growth of Selected NASA Major Projects with Established Cost Baselines



Source: GAO analysis of NASA data. | GAO-15-320SP

The remaining four projects that were confirmed in 2014 have development cost baselines ranging from $264 million to over $1 billion with no growth reported. It is too early for these projects to incur cost growth as we found that, on average, cost increases were reported approximately one year after the projects' confirmation dates. For example, five of the seven projects that established baselines before or during 2013 have reported development cost growth while four have reported schedule growth, as shown in table 1 below.

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

		Since reported in 2014		Cumulative		
Project name	**Confirmation date**	**Cost growth (in millions of dollars)**	**Launch delay (in months)**	**Cost Growth (in millions of dollars)**	**Cost growth (by percentage)**	**Launch delay (in months)**
James Webb Space Telescope (JWST)	2008	0	0	3,609.3	139.8	52
Magnetospheric Multiscale (MMS)	2009	20.1	0	19.4	2.3	0
Orbiting Carbon Observatory 2 (OCO-2)	2010	-51.3	-7	71.3	28.6	17
Soil Moisture Active and Passive (SMAP)	2012	-11.0	-2	-6.7	-1.4	-2
Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	2012	204.8	13	204.8	36.6	13
Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx)	2013	-11.9	0	-68.9	-8.8	0
Space Network Ground Segment Sustainment (SGSS)[a]	2013	110.4	6	110.4	30.0	6
Gravity Recovery and Climate Experiment Follow On (GRACE-FO)	2014	-1.2	0	-1.2	-0.5	0
Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight)	2014	0	0	0	0	0
Solar Probe Plus (SPP)	2014	0	0	0	0	0
Space Launch System (SLS)	2014	0	0	0	0	0
Transiting Exoplanet Survey Satellite (TESS)	2014	-26.8	0	-26.8	-8.3	0
Includes all Projects in Portfolio						
Total		**233.1**	**10**	**3911.6**		**86**
Excludes JWST						
Total		**233.1**	**10**	**302.3**		**34**

Source: GAO analysis of NASA data. | GAO-15-320SP

Note: Shaded rows indicate projects that experienced cost and/or schedule growth in 2014 and the amount of growth that occurred.

[a]The SGSS project is expected to be rebaselined, which will likely affect project cost and/or schedule. These are preliminary results and reflect the minimum anticipated cost growth of 30 percent and schedule growth of 6 months expected as the project prepares for its rebaseline in June 2015.

Each of the projects that have experienced cost growth reported a cost increase within 3 years after receiving baselines, and all but one reported a cost increase within 2 years. Also, JWST, OCO-2, ICESat-2, and SGSS—all projects that received baselines before or during 2013—have exceeded their development cost and schedules to the extent necessary to notify Congress.[16]

The 2015 cost and schedule growth is attributable to three projects, each with development cost baseline amounts under $1 billion: ICESat-2, MMS, and SGSS. While the inclusion of five recently confirmed projects—with a combined total development cost baseline of over $9 billion—reduces the overall impact of these less expensive projects' negative performance on the portfolio as a whole, these three projects exceeded their committed cost baselines by an estimated combined total of $334.6 million, while ICESat-2 and SGSS exceeded schedule baselines by an estimated combined total of 19 months. In April 2014, we found that these three projects could negatively impact NASA's positive cost and schedule performance.[17] We found that both ICESat-2 and SGSS had risks that were underestimated when these projects confirmed cost and schedule baselines. Shortly after confirmation, each project experienced significant cost growth resulting in the need to rebaseline. For example, NASA managers noted concerns with contractor plans and estimates for the SGSS project during confirmation, and the project reported significant concerns with contractor performance one month after the project's April 2013 confirmation. These concerns included the expansion of planned design activities leading to slips in subsystem critical design reviews and unrealistic staffing estimates. In May 2014, ICESat-2 established a new baseline, and in June 2014, MMS underwent a replan. SGSS project officials told us that the project's new baseline is expected in June 2015. The cost and schedule increases for SGSS reported in table 1 are preliminary and reflect the minimum increases expected to the project's cost and schedule at its rebaseline. However, project officials told us that total cost increases could be as much as 38 percent beyond the project's original baseline and that the project's schedule might increase by approximately 2 years.

[16]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. Further, if the development cost of a program will exceed the baseline estimate by more than 30 percent, NASA is required to prepare a new baseline if the program is to be continued. 51 U.S.C. § 30104(e),(f). NASA typically refers to the programs covered by this requirement as projects.

[17]GAO-14-338SP.

None of the three projects exiting the portfolio this year will substantially offset overall cost growth of the portfolio by completing development under their baseline levels. Only one of the three projects exiting the portfolio—SMAP—will do so within its agency baseline commitment for life-cycle costs. The remaining two projects—MMS and OCO-2—have an expected combined cost growth of almost $91 million.[18] Last year's cost growth was partially offset by the positive performance of three projects that launched collectively $148 million under their committed cost baselines.

NASA Continues Positive Progress in Improving Technology Maturity and Design Stability

NASA Has Demonstrated Significant Improvement in Meeting Best Practice of Maturing Project Technology

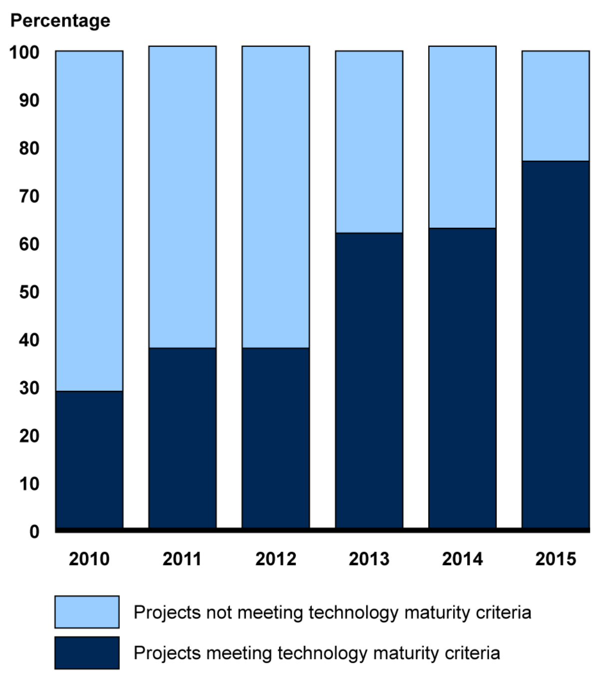
Over the past 3 years, major projects in NASA's portfolio have continued to improve in meeting the best practice standard for technology maturity. Our best practices work has shown that a technology readiness level (TRL) of 6—demonstrating a technology as a fully integrated prototype in a relevant environment that simulates the harsh conditions of space—is the level of technology maturity that can minimize risks for space systems entering product development.[19] Demonstrating that both critical and heritage 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 before preliminary design review—the point at which the TRL is assessed—often experience subsequent technical problems, which can increase the risk of cost growth and schedule

[18]The cost growth and schedule delay in the OCO-2 project largely resulted from changing launch vehicles following two failures of the originally chosen launch vehicle, the second of which occurred after the project's cost and schedule baselines had been established.

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

delays.[20] In our review, 10 of the 13 projects that have held a preliminary design review, or 77 percent, have met the best practices standard for technology maturity. This is a significant improvement over prior years and reflects a continued increased focus by NASA on maturing technologies prior to making significant commitments—up from 63 percent of projects meeting the standard in 2014 and 29 percent in 2010, as shown in figure 6.

Figure 6: Percentage of NASA's Major Projects Attaining Technology Maturity at the Preliminary Design Review



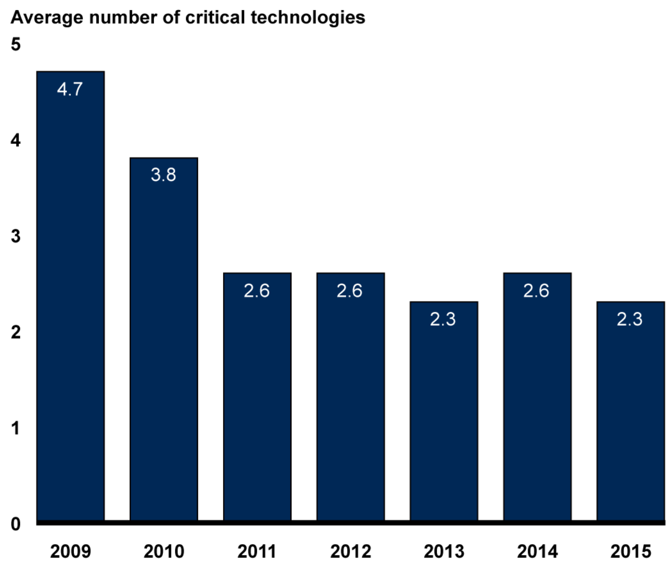
Source: GAO analysis of NASA data. | GAO-15-320SP

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

Fewer NASA Projects Now Rely on the Development of Critical Technologies

NASA has developed roughly the same average number of critical technologies per project in implementation in the 2015 portfolio as in the past few years and continues to develop fewer critical technologies than it has historically. This year, NASA is developing on average 2.3 critical technologies per project, down from 4.7 in 2009 as shown in figure 7 below.

Figure 7: Average Number of NASA's Critical Technologies for Selected Major Projects in Implementation



Source: GAO analysis of NASA data. | GAO-15-320SP

Over the past 7 years, the majority of new projects added to NASA's portfolio have generally relied on the use of existing technology and planned less technology development. In 2009, approximately 47 percent, or 7 of 15 projects, developed 2 or fewer critical technologies. Currently, 75 percent, or 9 of 12 projects, develop 2 or fewer critical technologies. Of the 3 remaining projects in implementation, JWST and SPP—with 9 and 10 technologies respectively—account for approximately half of the entire portfolio's technology development effort. For example, SPP, a project with significant technology development, is developing 10 critical technologies including a thermal protection system which is designed to allow spacecraft instruments to operate at near room temperature despite their close proximity to the sun. However, approximately half of the projects in the portfolio are continuations of previous missions or based on heritage systems and thus, the majority of these are developing few, if any, critical technologies. For example, GRACE-FO—a follow on to the original GRACE mission—is not developing any critical technologies but is employing technologies developed for the original GRACE mission.

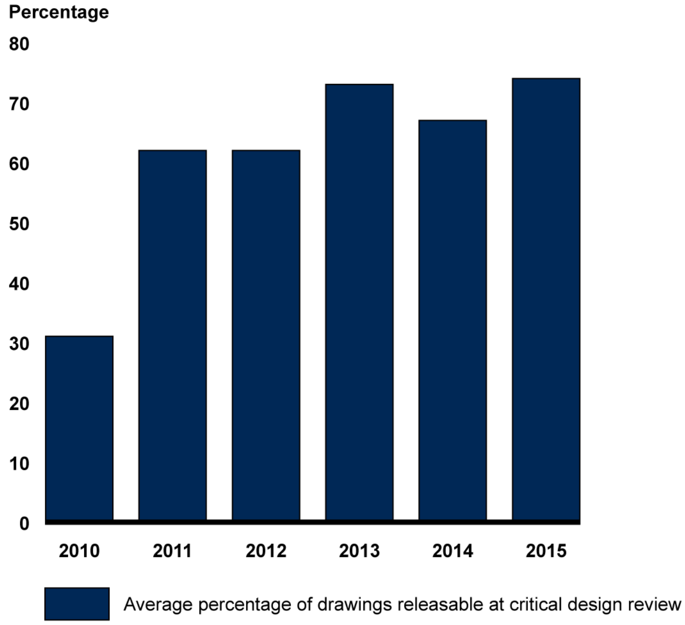
Two of the four projects currently in formulation, Mars 2020 and SWOT, are each developing 4 critical technologies. The majority of these technologies are currently considered immature—as they are assessed as a TRL of 5 or less—and will require significant development work to reach maturity by the projects' preliminary design reviews. As NASA continues to add more complex projects with a high number of new critical technologies to its portfolio, ensuring that these technologies are matured prior to project implementation will help to decrease the risk of cost and schedule growth or likelihood of project cancellation.

NASA Continues Positive Trend in Meeting Best Practices for Design Stability

Over the past 5 years, NASA has continued to improve project design stability by the critical design review. 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.[21] The NASA Systems Engineering Handbook mirrors this metric. While most projects have yet to meet the 90 percent metric, the percentage of drawings releasable at critical design review is the highest it has been since 2010. The eight projects that have completed their critical design review averaged 74 percent of engineering drawings releasable at the time of that review, compared to 31 percent in 2010 as shown in figure 8.

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

Figure 8: Average Percentage of Releasable Engineering Drawings for Selected NASA Major Projects at Critical Design Review



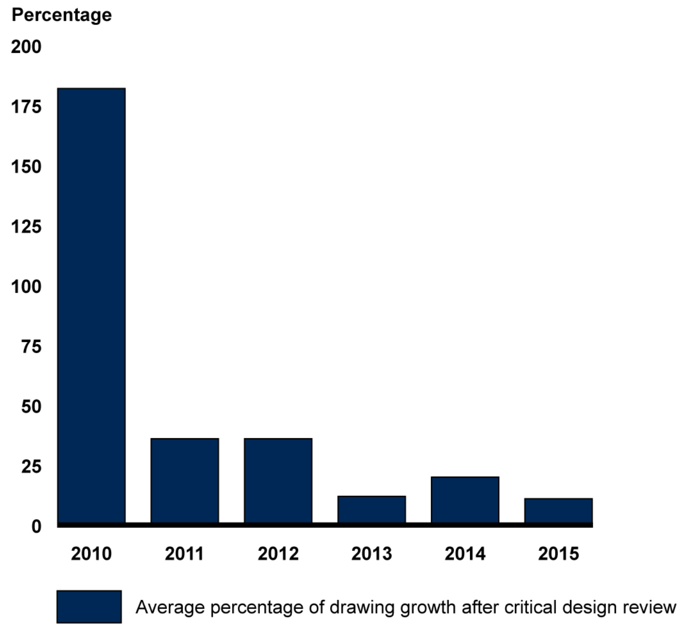
Source: GAO analysis of NASA data. | GAO-15-320SP

In our 2014 assessment, the ICESat-2 project was identified as having met the criteria by releasing 91 percent of its drawings at critical design review; however, a subsequent increase in design drawings—indicative of an unstable design—has caused this value to drop below the design stability criteria, and the project has since undergone a replan due to the project underestimating the complexity of some parts of the project's instrument design.[22]

Another assessment of project stability is the degree to which projects' design drawings increase in number after the critical design review, and since 2010, projects have generally improved in maintaining stability following the critical design review, as shown in figure 9 below.

[22]GAO-14-338SP.

Figure 9: Average Percentage of Drawing Growth after Critical Design Review for Selected NASA Major Projects from Fiscal Year 2010 through 2015



Source: GAO analysis of NASA data. | GAO-15-320SP

The percentage of drawing growth after the critical design review is at its lowest level since 2010. Of the eight projects assessed, the average percentage of drawing growth after the critical design review for projects is at 11 percent, down from approximately 182 percent in 2010. Monitoring growth in the number of drawings after the critical design review can provide a continuing assessment of design stability. By maintaining design stability following the critical design review, NASA may reduce the likelihood of cost and schedule growth.

Projects Generally Track Most Useful Design Metrics

Our work has shown that programs are more likely to succeed in terms of cost, schedule, and performance if agencies collect specific knowledge early, in preparation for critical points in the development process. This knowledge includes establishing that the program's design is stable and capable of meeting program requirements, among other elements. In order to identify whether there were any new metrics or approaches that should be considered to enhance our methodology, in February 2013, we convened a group of experts in the space community that identified and subsequently ranked the most informative metrics for assessing design stability on unique space acquisitions. From the 12 metrics identified during the meeting—of which many focused on an ongoing assessment of project progress, rather than a measurement at any one point in the project's life cycle—the top five identified were: (1) the level of funding reserves and schedule margin at various points in the development life cycle; (2) percentage of verification and validation plans complete at preliminary design review and critical design review; (3) definition of the project's top level requirements that define mission success criteria and are imposed by NASA, to requirements at the sub-system level by the time of the preliminary design review; (4) maturity of technologies to a TRL 6 by preliminary design review; and (5) percentage of actual mass margin versus planned mass margin over time.[23]

When we shared these metrics with NASA project officials, they told us that they generally track all of these metrics either continuously throughout development or at key points in the project life cycle as appropriate. For further detail on project use of the design metrics identified by the group of experts, see appendix VI. Some project officials told us they used additional metrics beyond the five listed, such as monitoring requirements changes, engineering change requests, staffing plans, and percentage of design drawings released at critical design review.[24] Project officials' responses varied regarding when "red flags"—signifying a warning sign or a problem—would be triggered for a particular design metric, and when a project would take action in the case of a red flag. Projects officials said that they often interpret red flags in reference to falling below an institutional requirement, such as falling below a set percentage of cost or schedule reserves or falling below a mass margin requirement. The discussion also varied by project phase, with projects that had not yet gone through the preliminary design review or the critical design review much less likely to discuss what could constitute red flags with respect to the project's performance than projects that had completed these milestones.

[23]Verification and validation plans outline how the project is going to document that the final product satisfies the program's requirements. This process helps to identify design issues and concerns.

[24]Engineering change requests are requests for changes to the draft or established design and can be major or minor. A major engineering change involves a change to the design that will have a significant impact to the project such as a retrofit to delivered products or impact cost or baselined specifications. A minor change corrects or modifies documentation or a process without impacting the system.

NASA Continues to Reduce Acquisition Risk, but Work Remains to Address Challenges and Strengthen Management of Largest, Most Complex Projects

NASA Has Undertaken Several Initiatives to Reduce Acquisition Risk, but Implementation Has Not Been Thorough and Consistent

Since 1990, we have designated NASA's acquisition management as a high risk area because of NASA's history of cost growth and schedule slippage in the majority of major projects.[25] As a result, NASA has taken several noteworthy steps to reduce acquisition risk. For example:

- In 2014, NASA drafted revisions to its acquisition planning regulations. If these revisions are issued as final rules, they would require acquisition plans to include an independent government cost estimate that describes the estimating methodology, including detailed sources, assumptions, and supporting rationale.
- As of 2014, all NASA projects required to develop a joint cost and schedule confidence level (JCL)—a tool which assigns a confidence level, or likelihood, of a project meeting its cost and schedule estimates—have done so. The JCL approach was instituted by NASA in 2009 to ensure that projects are thoroughly planning for anticipated risks and that cost and schedule estimates are realistic. Our prior work assessing large-scale acquisitions at the Department of Defense, the Department of Homeland Security, and NASA indicates that NASA remains the only agency among these three that currently requires its projects to complete such an analysis.
- NASA has taken steps to improve the agency's use of earned value management (EVM)—a tool designed to help project managers

[25] GAO-15-290

monitor risks. In 2013, the agency began a phased rollout of the EVM capability process on the SLS program at the Marshall Space Flight Center and the ICESat-2 project at Goddard Space Flight Center. In addition, the agency plans to implement the process for the Orion program at Johnson Space Center in fiscal year 2015. During the rollout phase, NASA is providing support to the respective Centers to develop the institutional capability to support future projects.

While NASA has implemented tools in recent years to provide better insight into its acquisition projects, the training for and implementation of these tools have not been consistently and thoroughly applied. For example, NASA has used the JCL process since January 2009, but did not release agency-wide guidance until February 2015, which may have been a contributing factor to the inconsistent JCL quality issues that we have previously found for several projects.[26] Specifically, in 2012, we found that in some instances, when providing data for JCL calculations, projects have excluded or not fully considered cost inputs and risks, such as launch vehicle costs and development partner challenges.[27] Additionally, the SLS program, which performed a JCL analysis prior to its confirmation in 2014, omitted known risks, such as development test requirements growth, from the calculations. Agency officials stated that draft guidance was made available to the projects prior to the release of the updated cost estimating handbook, which includes detailed guidance on JCL analyses, in February 2015. Agency officials further stated that they continue to work closely with the projects to provide consultation and ensure that good practices are used as projects complete their JCL analysis.

We also found in 2012 that the JCL conducted for the 2011 rebaseline of the JWST project had yet to be updated despite only partially meeting criteria to be considered well-documented, accurate, or credible according to best practices.[28] In 2012, we made a recommendation to NASA to perform an updated JCL using a schedule that meets best

[26]National Aeronautics and Space Administration, *NASA Cost Estimating Handbook, Version 4.0*; February 2015.

[27] GAO, *NASA: Assessments of Selected Large-Scale Projects,* GAO-12-207SP (Washington, D.C.: March 1, 2012).

[28]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).

practices and includes enough detail so that risks can be appropriately mapped to activities and costs. In January 2014, we recommended that Congress consider requiring the NASA administrator to direct the JWST project to update its JCL analysis.[29] However, we found in December 2014 that a new JCL has not been conducted and that NASA has indicated it does not intend to update the JCL for JWST.[30] We believe that action on this recommendation is still needed because it is an important best practice to complete an updated cost risk analysis as new risks emerge so that realistic estimates are being communicated to Congress.

Cost and schedule growth in the ICESat-2 and SGSS projects shortly after the projects were confirmed led to a rebaseline and an expected rebaseline, respectively. For both projects, while risk assessments identified the risks that led to cost growth, the impact of these risks was underestimated. More specifically, project officials for ICESat-2 acknowledged that important information at the project's confirmation review was likely overlooked as evidenced by how quickly the project's cost and schedule posture worsened in the months immediately following the milestone decision. As a result, NASA officials reported that conducting a JCL analysis alone is not sufficient to improve the agency's insight into the performance of its acquisition projects. Additionally, the risks that are assessed as part of the input to the JCL analysis must be fully understood and adequately characterized in the analysis. However, according to agency officials, the JCL process has enabled management to have more robust conversations and make more informed decisions about project risks.

The implementation of EVM across NASA's major projects has been critical to better understanding project development needs and in reducing cost and schedule growth; however, the expertise available at NASA centers regarding how to both construct and apply the collected information is lacking. Specifically, in 2012, we found that the agency lacked adequate numbers of staff with the skill set needed to analyze EVM data, and this was confirmed by a skills gap analysis completed in May 2013 by NASA. For example, the skills gap analysis showed that

[29]GAO-13-4; *James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress*, GAO-14-72 (Washington, D.C.: Jan. 8, 2014).

[30]GAO-15-100.

over 40 percent of respondents had four years of experience or fewer in EVM at NASA. The analysis further showed that the workforce was significantly lacking in experience with cost tools. Also, about one third of agency personnel who responded to the survey were found to have no experience in preparing and analyzing EVM performance data. To address these issues, the agency released an EVM training plan in August 2014, and the training is currently under way. However, consistent with our findings in 2012, NASA has yet to ensure that all of its in-house projects, which represent a significant portion of the agency's work, are implementing an EVM system that includes independent surveillance of EVM data, which may affect the quality of EVM data and lead to less than optimal project management decisions.[31]

In addition, NASA's analysis of cost and schedule performance uses projects' rebaseline data rather than original project baseline data for measuring outcomes. In other words, cost and schedule growth that occurred prior to the rebaseline of a troubled project would be excluded from tracking of overall progress, which tends to make project and portfolio performance appear better than it actually is. Thus, decision makers are not fully informed by transparent and complete performance data.

NASA Projects Have Experienced Lag Time between Interim Replans and Formal Rebaselines

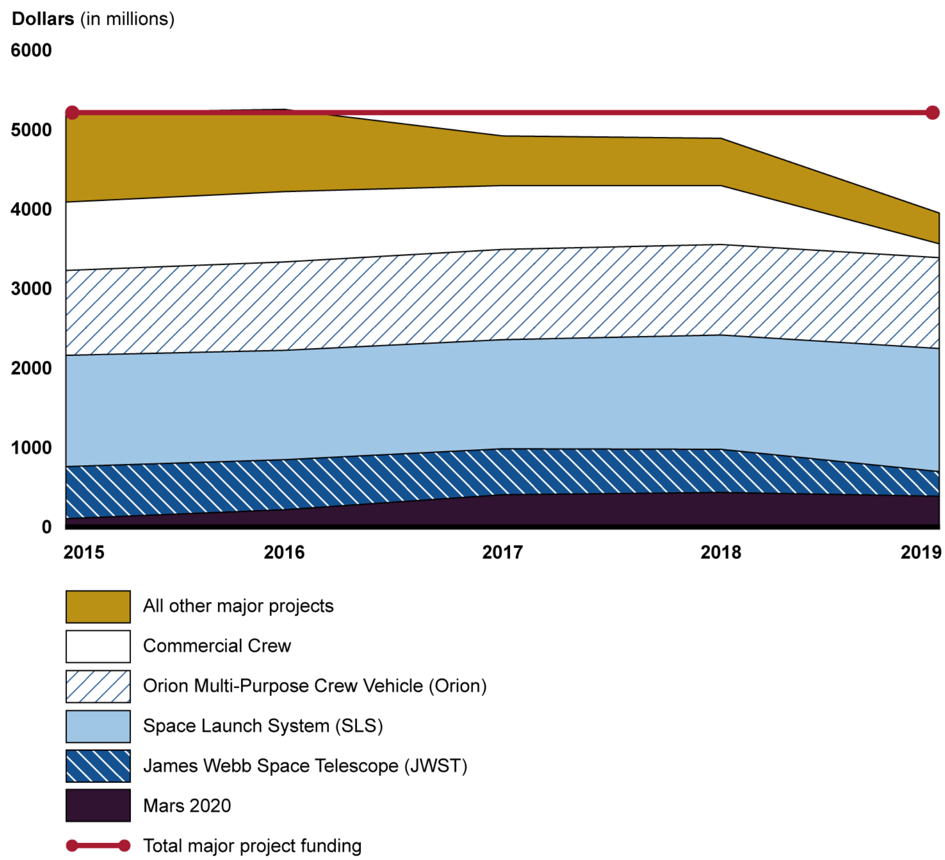
Two NASA projects have effectively operated for almost a year or more without cost and schedule baselines that have been reviewed and approved by agency leadership, leaving Congress without key information to conduct oversight. The ICESat-2 project was rebaselined in May 2014, nearly one year after the project reported that it would exceed its agency baseline cost commitment. The SGSS project expects to conduct a rebaseline review—where new cost and schedule baselines will be established—in June 2015, which is nearly 2 years from the time that the agency learned that the project would exceed its agency baseline commitment. Although both projects established interim plans to work toward during the rebaseline process, without approved cost and schedule baselines, it is difficult to hold project managers as well as contractors accountable and ensure that Congress continues to have the information it needs to provide oversight of these projects.

[31] GAO-13-22.

NASA's Largest Projects Face Significant Risks in 2015

We found in 2014 that a primary challenge for NASA in the next few years will be to complete a series of complex, technically challenging, and expensive projects within the context of constrained budgets.[32] As shown in figure 10, in 2015, five of these projects—JWST, Orion, SLS, Mars 2020, and the Commercial Crew program—are expected to consume 78 percent of anticipated funds for NASA's major projects.

Figure 10: Fiscal Year 2015 NASA Budget Request for Five Costliest Projects and All Other Major Projects, 2015 through 2019



Source: GAO analysis of NASA data. | GAO-15-320SP

Note: Budget data are from the fiscal year 2015 President's budget request. Total line indicates the 2015 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

[32]GAO-14-338SP.

included projects. The NASA ISRO Synthetic Aperture Radar project is not included in Other Major Projects because funding information was not included in the fiscal year 2015 President's Budget.

As figure 10 shows, the remaining wedge of funding available—the difference between anticipated budgets and the current portfolio's requirements—increases over the next 5 years as projects launch and leave the portfolio. This wedge of funding is intended to fund new projects or, if necessary, cover cost growth that may occur on other projects. However, as we have previously reported, any cost or schedule overrun on NASA's largest, most complex projects could have a ripple effect on the portfolio and has the potential to postpone or even cancel altogether projects in earlier development stages.[33] As a result, fully accounting for the funding, schedule, and technical challenges facing NASA's largest, most complex, and multi-billion dollar projects is important due to the cascading impacts that these challenges could have across the portfolio. For example, the JWST project has both continuing and new technical issues that are consuming cost and schedule reserves early during the integration and test phase, which can be the most risky phase of development. As we found in December 2014, JWST has 11 months of schedule reserve remaining, more than required by Goddard's standards.[34] However, the most significant risks lie ahead in the remaining 4 years, as the project must complete five integration and test periods, three of which have not yet started. The scale of JWST's integration and test effort is more complex than most NASA or Goddard projects. While JWST's total integration and test cycle runs almost 7 years, the next longest integration and test cycle for a current project managed by Goddard Space Flight Center is over 3 years, and the average length of integration and testing for all other current Goddard projects, excluding JWST, is just over 2 years. All of JWST's five elements and major subsystems have just weeks of reserve left before their schedules become pacing items on the project's critical path, potentially reducing the reserve further. More milestones established annually for the various elements and subsystems have been delayed or deferred during fiscal year 2014 than in the previous 3 years following the project's replan in 2011. Schedule risks are further heightened as the project entered fiscal year 2015 with approximately 40 percent of its cost

[33] GAO-14-338SP.

[34] GAO-15-100.

reserves already committed, leaving fewer dollars available to mitigate other threats to the project schedule.

Similarly, the Orion program is facing several design issues that will need to be considered as cost and schedule baselines for the program are established. For example, in 2014, the program identified that during parachute testing when only two of the three main parachutes are deployed, they begin to swing past each other, creating a "pendulum" effect. This effect could cause the capsule to increase speed and land incorrectly for a safe water landing. Additionally, the program continues to struggle with the design of its heat shield. During manufacturing of the current heat shield, cracks were found in 6 percent of the seams. While the repaired heat shield was used for Orion's first exploration flight test, it does not meet the more stringent requirements for future flights. As a result, the program is studying two designs for applying the heat shield material, though the alternative design has also experienced problems during testing. Program officials stated that data collected from the December 2014 exploration flight test would provide valuable insight into these and other issues. However, if these issues are not adequately accounted for prior to confirmation, the program is increasing the likelihood of costly redesign in the future, because the program will not have the opportunity to leverage economies of scale from producing multiple copies if design changes are necessary to address these issues. Further, Orion faces several additional potential risks to consider as it prepares to establish cost and schedule baselines. For example, data from Orion's first test flight, which it completed in 2014, is required to address several risks that must be resolved before the program's first crewed flight in 2021 because they represent risks to crew safety.[35]

In addition, NASA recently acknowledged the significant risk in the SLS program by setting cost and schedule baselines at approximately $1 billion and 11 months over previous agency estimates, which may not have fully accounted for unknown risks. However, the program continues to face challenges adapting hardware originally designed for legacy systems into the SLS design. SLS has also recently encountered unexpected cost and testing delays associated with the five-segment booster. The program continues to work to resolve this issue, but the contractor is forecasting over $80 million in unplanned costs, and a 20-

[35] GAO-15-248T.

month delay to the program's test schedule, as a result of this issue. The program was able to use available cost and schedule reserves to address the issue; however, according to agency officials, if the latest redesign is not successful, further cost and schedule growth may occur. Additionally, the SLS program has not defined its future missions or finalized its plans regarding future flight rate. Further, NASA's cost estimates do not provide any information about the longer-term, life-cycle costs of developing, manufacturing, and operating the SLS. For example, NASA's baseline estimate for SLS does not cover program costs after the first non-crewed launch or costs to design, develop, build, and produce either of the program's two variants. As a result, the long-term affordability of the program is uncertain.

The SLS and Ground Systems Development and Operations programs are also pursuing ambitious and varying target dates for the first exploration mission test flight.[36] The Orion program has not yet established cost and schedule baselines, but is currently tracking to the same internal date as SLS. As we found in 2014, the agency acknowledges differences in the target dates the programs are pursuing and has indicated that it will develop an integrated target launch date after all three systems hold their critical design reviews.[37] The SLS program has assigned a low confidence level—30 percent—associated with meeting the program's internal date of December 2017. Even if SLS does meet that goal, it is unlikely that both Orion and the Ground Systems Development and Operations program will achieve launch readiness by that point. As a result, NASA risks exhausting limited human exploration resources to achieve an aggressive program schedule when those resources may be needed to resolve other issues within the human exploration effort. We found in April 2014 that, in pursuing internal schedule goals, some programs have exhausted cost reserves, which has resulted in the need for additional funding to support the agency baseline commitment date once the target date is not achieved.[38]

[36]The Ground Systems Development and Operations program is developing systems and infrastructure to support such activities as assembly, test, and launch of the SLS and Orion.

[37]GAO-15-248T.

[38]GAO-14-338SP.

The types of challenges noted above are not new or unique given NASA's past history of managing large-scale projects such as the Constellation program—which included the Orion crew exploration vehicle and the Ares I and Ares V launch vehicles—and the Mars Science Laboratory (MSL). NASA's experiences on such large-scale projects indicate that opportunities exist to leverage lessons learned for better acquisition outcomes. For example, in 2011, the agency released a lessons learned study following the cancellation of the Constellation program.[39] The study reported that the program struggled to remain flexible in the face of funding constraints and instability and the requirement to maintain schedule without reductions in program scope, which allowed risks to accrue. Additionally, the program was managed as separate components, without a sufficient integration function between them. Further, integrated analyses by the program uncovered technical issues that could have been caught earlier and resolved more efficiently.

In 2014, the agency completed a study which identified a set of lessons learned based on the performance of the MSL project, which launched 2 years later than planned and with a $900 million cost increase. The report noted that the agency's culture is susceptible to excessive optimism, which contributed to the problems experienced by MSL. The culture of optimism was also noted in a 2012 NASA Inspector General report, which stated that this culture may lead managers to overestimate their ability to overcome risks in delivering completed projects within available resources.[40] The MSL study identified several specific factors that led to cost and schedule growth in the project. For example, the MSL study noted that the project did not satisfactorily complete the formulation phase by project preliminary design review and the confirmation review. Specifically, technologies were not sufficiently mature and key design decisions were finalized late, which allowed the project's architecture to remain unstable beyond the preliminary design review. Additionally, only one of six criteria for the formulation phase was completed by the preliminary design review. The MSL study also noted that the agency's management and oversight functions did not sufficiently assess and control progress.

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[39]National Aeronautics and Space Administration*, Constellation Program Lessons Learned Volume 1: Executive Summary,* NASA/SP-2011-6127-VOL 1; Spring 2011.

[40]National Aeronautics and Space Administration, Office of the Inspector General, *NASA Challenges to Meeting Cost, Schedule, and Performance Goals*, IG-12-021.

Both the Constellation and MSL studies noted that previous agency lessons learned from other large scale projects may not have been incorporated. However, NASA has made significant progress in its management of spaceflight projects and this is evidenced by improved portfolio performance in the years since the Constellation program and MSL project. For example, in the last three years, 70 percent of projects we have included in our reviews have launched under their agency baseline commitments for costs, which is a significant improvement over prior years. By heeding these lessons, in conjunction with the steps the agency has under way to reduce acquisition risk, such as continuing to improve the agency's use of the JCL and EVM tools, NASA can avoid repeating these mistakes, perpetuating past problems, and thereby missing opportunities to achieve more favorable acquisition outcomes for its largest, most complex projects.

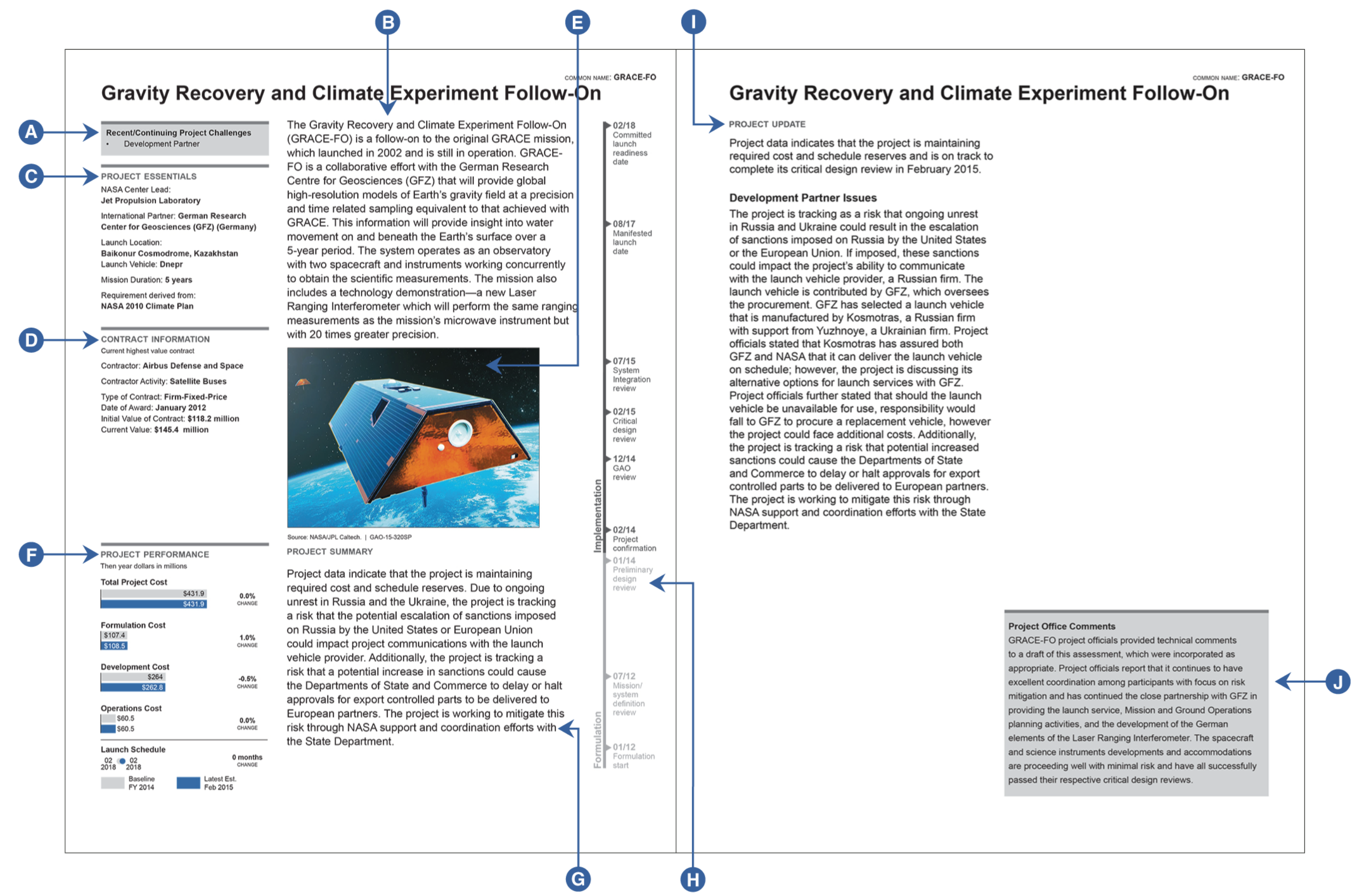
Project Assessments

The individual assessments of the projects we reviewed provide a profile of each project and are tailored in length, from 1 to 2 pages, to capture information about the project.

Each project assessment includes a description of the project's objectives, information about the related NASA center, primary contractor(s), and/or external partners involved in the project, the project's cost and schedule performance, a timeline identifying key project dates, and a brief narrative describing the current status of the project. The two-page assessments—15 in total—describe the challenges we identified this year, as well as challenges that we have identified in the past. On the first page, the project profile presents the standard information listed above. On the second page of the assessment, we provide an analysis of the project challenges, and outline the extent to which each project faces cost, schedule, or performance risk because of these challenges, if applicable. The one-page assessment—1 in total—is structured similarly to the two-page assessments and captures the same information with the exception of an in-depth review of the program challenges since this project had few, if any, challenges to report. As needed, the challenges are captured on the first page, in the project summary section. 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 11 for an illustration of a sample assessment layout.

Figure 11: Illustration of a Sample Project Assessment



A **Project Challenges** Summary listing of the challenges facing the project

B General description of the mission's objectives

C **Project Essentials** Programmatic information including the responsible NASA center, international or domestic partners, launch information, mission duration, and the driver for the mission's requirements

D **Contract Information** Current highest value contractor, contractor activity, the type of contract and when it was awarded, and initial and current value of the contract

E Illustration of the spacecraft, aircraft or ground system

F **Project Performance** Cost and schedule baseline estimates and the latest estimate updates

G **Project Summary** Brief narrative describing the current status of the project

H Schedule timeline identifying key dates for the project including when the project began formulation, major design reviews, confirmation to begin the implementation phase, and launch or operating capability information

I **Project Update** Analysis of the project challenges and the extent to which each project faces cost, schedule, or performance risk because of these challenges

J **Project Office Comments** General comments provided by the cognizant project office

Source: GAO analysis. | GAO-15-320SP

Gravity Recovery and Climate Experiment Follow-On

Recent/Continuing Project Challenges

- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

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

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

Mission Duration: **5 years**

Requirement derived from:
NASA 2010 Climate Plan

CONTRACT INFORMATION

Current highest value contract

Contractor: **Airbus Defense and Space**

Contractor Activity: **Satellite Buses**

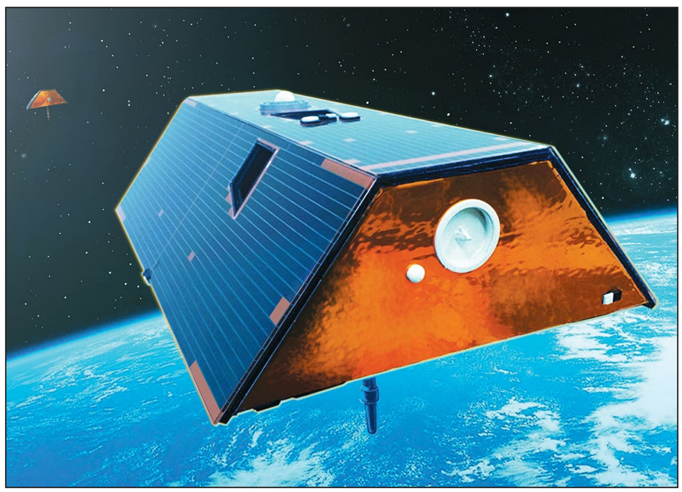
Type of Contract: **Firm-Fixed-Price**
Date of Award: **January 2012**
Initial Value of Contract: **$118.2 million**
Current Value: **$145.4 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2014	Latest Est. Feb 2015	Change
Total Project Cost	$431.9	$431.9	0.0%
Formulation Cost	$107.4	$108.5	1.0%
Development Cost	$264	$262.8	-0.5%
Operations Cost	$60.5	$60.5	0.0%
Launch Schedule	02 2018	02 2018	0 months

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



Source: NASA/JPL Caltech. | GAO-15-320SP

PROJECT SUMMARY

Project data indicates that the project is maintaining required cost and schedule reserves. Due to ongoing unrest in Russia and the Ukraine, the project is tracking a risk that the potential escalation of sanctions imposed on Russia by the United States or European Union could impact project communications with the launch vehicle provider. Additionally, the project is tracking a risk that a potential increase in sanctions could cause the Departments of State and Commerce to delay or halt approvals for export controlled parts to be delivered to European partners. The project is working to mitigate this risk through NASA support and coordination efforts with the State Department.

Implementation

- **02/18** Committed launch readiness date
- **08/17** Manifested launch date
- **07/15** System Integration review
- **02/15** Critical design review
- **12/14** GAO review
- **02/14** Project confirmation

Formulation

- **01/14** Preliminary design review
- **07/12** Mission/system definition review
- **01/12** Formulation start

Gravity Recovery and Climate Experiment Follow-On

PROJECT UPDATE

Project data indicates that the project is maintaining required cost and schedule reserves and is on track to complete its critical design review in February 2015.

Development Partner Issues

The project is tracking as a risk that ongoing unrest in Russia and Ukraine could result in the escalation of sanctions imposed on Russia by the United States or the European Union. If imposed, these sanctions could impact the project's ability to communicate with the launch vehicle provider, a Russian firm. The launch vehicle is contributed by GFZ, which oversees the procurement. GFZ has selected a launch vehicle that is manufactured by Kosmotras, a Russian firm with support from Yuzhnoye, a Ukrainian firm. Project officials stated that Kosmotras has assured both GFZ and NASA that it can deliver the launch vehicle on schedule; however, the project is discussing its alternative options for launch services with GFZ. Project officials further stated that should the launch vehicle be unavailable for use, responsibility would fall to GFZ to procure a replacement vehicle, however the project could face additional costs. Additionally, the project is tracking a risk that potential increased sanctions could cause the Departments of State and Commerce to delay or halt approvals for export controlled parts to be delivered to European partners. The project is working to mitigate this risk through NASA support and coordination efforts with the State Department.

Project Office Comments

GRACE-FO project officials provided technical comments to a draft of this assessment, which were incorporated as appropriate. Project officials report that the project continues to have excellent coordination among participants with focus on risk mitigation and has continued the close partnership with GFZ in providing the launch service, Mission and Ground Operations planning activities, and the development of the German elements of the Laser Ranging Interferometer. The spacecraft and science instruments developments and accommodations are proceeding well with minimal risk and have all successfully passed their respective critical design reviews.

Ice, Cloud, and Land Elevation Satellite-2

Recent/Continuing Project Challenges
- Schedule
- Parts (new)

Previously Reported Challenges
- Design
- Funding
- Launch
- Workforce

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **None**

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

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital Sciences Corp.**

Contractor Activity: **Spacecraft development**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **September 2011**
Initial Value of Contract: **$135.1 million**
Current Value: **$146.8 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$860.3
$1,063.5
23.6% CHANGE

Formulation Cost
$248.8
$249.1
0.1% CHANGE

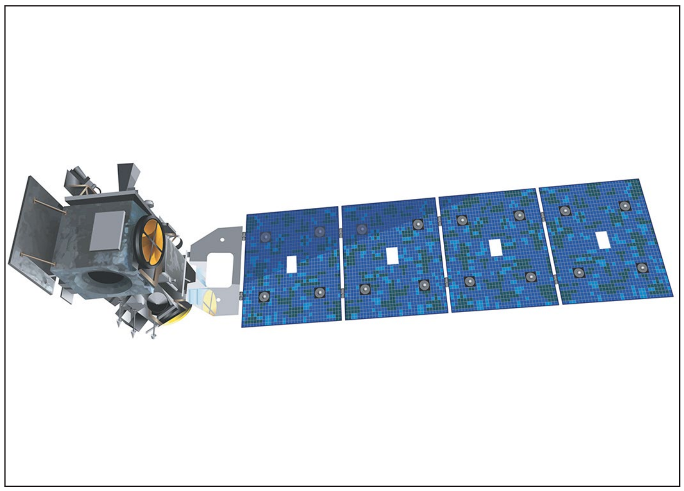
Development Cost
$558.9
$763.7
36.6% CHANGE

Operations Cost
$52.9
$50.7
-4.2% CHANGE

Launch Schedule
05 2017 — 06 2018
13 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2015

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



Source: Orbital Sciences Corporation. | GAO-15-320SP

PROJECT SUMMARY

In May 2014, ICESat-2 was rebaselined as a result of cost and schedule overruns stemming primarily from underestimating the complexity of the optics design associated with the project's only instrument, the Advanced Topographic Laser Altimeter System (ATLAS), which is being built by the Goddard Space Flight Center. As a result of the rebaseline, project lifecycle costs have increased by $203.2 million and the project's committed launch readiness date has slipped by 13 months from May 2017 to June 2018. However, ATLAS continues to encounter challenges. Additionally, due to a large number of spacecraft defects, the project is monitoring a risk related to the spacecraft that defects in the flight electronics could impact mission performance.

Implementation
- **06/18** Committed launch readiness date
- **10/17** Manifested launch date
- **10/16** System integration review
- **12/14** GAO review
- **02/14** Critical design review
- **12/12** Project confirmation

Formulation
- **10/12** Preliminary design review
- **05/11** Mission/system definition review
- **12/09** Formulation start

Ice, Cloud, and Land Elevation Satellite-2

PROJECT UPDATE

In May 2014, ICESat-2 was rebaselined as a result of cost and schedule overruns stemming primarily from underestimating the complexity of the optics design on ATLAS. As a result of the rebaseline, project lifecycle costs have increased by $203.2 million and the project's committed launch readiness date has slipped by 13 months. The rebaseline decision provided the project with 10 months of schedule reserve, with 8 of those months allocated specifically to ATLAS. Given the complexity of ATLAS, these levels were established well above Goddard Space Flight Center reserve requirements. Further, project officials stated that higher levels of reserves were appropriate due to the level of risk associated with the remaining ATLAS instrument development and integration and test activities.

Schedule Issues

The ATLAS schedule remains the project's top risk and is driving the overall project schedule. ATLAS is comprised of 15 subsystems, each of which must complete integration and test prior to delivery to ATLAS for instrument level integration and test. Any delays to subsystems could impact the delivery or integration of other ATLAS subsystems which may delay the completion of ATLAS. Project officials stated that they try to mitigate schedule delays or slips by rearranging the order that subsystems are delivered to integration and test or by streamlining the schedule to preserve schedule reserve as long as possible. For example, the project was able to mitigate several delayed deliveries of a sub-component of the detector electronics module by rearranging the schedule. However, as a result of these mitigations, when a manufacturing issue caused a mirror to detach from its backing on another subsystem, the project had to use 1.5 months of reserve to address the late delivery of the mirror.

While 13 of the 15 subsystems have been delivered to ATLAS integration and testing, the final subsystem deliveries have been delayed until summer 2015. Delays have been prevalent across ATLAS subsystems entering integration and test due to testing equipment failures such as failed thermal vacuum chamber pumps, personnel availability, ground support equipment delays, and contractor testing equipment availability. For example, the contractor building the instrument's lasers has continued to exhibit poor schedule performance. As a result, the contractor had to develop a new schedule. While the new schedule addressed several resource conflicts that had developed as a result of trying to build three lasers concurrently, it also required the project to use almost 3 more months of schedule reserve. Since it was rebaselined in May 2014, the ATLAS instrument has used more than one half of its schedule reserve and it has yet to enter the instrument integration and test period. Integration and test is the point at which cost growth and schedule delays are most likely to occur.

Parts Issues

The project is tracking a risk that defects within spacecraft flight model electronics including an unusually large number of defects such as board layout errors and parts failures could impact mission performance. The spacecraft is being developed under a firm-fixed-price contract so this risk should not impact cost; however, project officials expressed concern that defects could remain after launch. To address this, officials have planned and funded a risk mitigation period to fully test the spacecraft while awaiting delivery of the ATLAS instrument.

Project Office Comments

ICESat-2 project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. Officials also report that they will complete the spacecraft and commence testing activities in fiscal year 2015. All ATLAS instrument subsystems will be completed, delivered, and integrated and overall instrument testing will begin during fiscal year 2015.

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

Recent/Continuing Project Challenges
- Design/Technology (new)

Previously Reported Challenges
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

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

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

Mission Duration: **29 months**

Requirement derived from:
2010 Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft development**

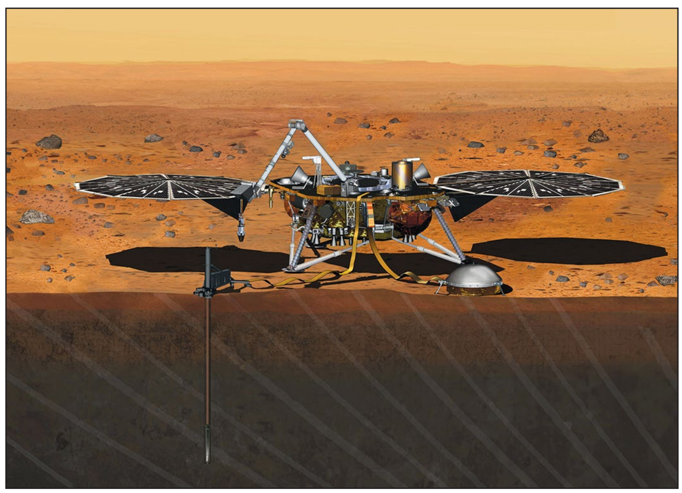
Type of Contract: **Cost-Plus-Fixed-Fee and Cost-Plus-Award-Fee**
Date of Award: **October 2012**
Initial Value of Contract: **$216 million**
Current Value: **$237 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2014	Latest Est. Feb 2015	Change
Total Project Cost	$675.1	$675.1	0.0% CHANGE
Formulation Cost	$98.9	$98.9	0.0% CHANGE
Development Cost	$541.8	$541.8	0.0% CHANGE
Operations Cost	$34.4	$34.4	0.0% CHANGE
Launch Schedule	03 2016	03 2016	0 months CHANGE

The Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) is a Mars lander based on the design of the Phoenix lander, which arrived at Mars in 2008. InSight's first objective is to understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars by determining the size, composition, and physical state of the core; the thickness of the crust; and the composition and structure of the mantle, as well as the thermal state of the interior. InSight's second objective is to determine the present level of tectonic activity—the magnitude, rate, and geographical distribution of internal seismic activity—and the meteorite impact rate on Mars.



Source: © California Institute of Technology. | GAO-15-320SP

PROJECT SUMMARY

The Seismic Experiment for Interior Structure (SEIS) instrument, which is critical to meeting InSight mission objectives, is experiencing several design challenges that have led to delivery delays of about 1 month to integration and testing, and delayed the project's system integration review by 4 months. The delivery of the Heat Flow and Physical Properties Package (HP3) has also been delayed due to design and workmanship challenges with a component that drills into the Martian surface to measure temperature. Additionally, the project continues to closely monitor limited available spacecraft mass margin to mitigate the risk of potentially costly redesigns.

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

Design/Technology Issues

The Seismic Experiment for Interior Structure (SEIS), which is contributed by the Centre National d'Etudes Spatiales, is experiencing several design challenges which have eroded the instrument's schedule margin and led to a 1 month delivery delay to spacecraft integration and testing. The instrument's pressure sensor and tether, which provide power and telemetry data and connect the instrument to the spacecraft, are being redesigned to address high levels of noise that could interfere with the instrument's measurements and prevent mission success. Additionally, the project has discovered contamination in the instrument's critical sensors and has yet to identify the source. The project's system integration review, which ensures that the instrument can be successfully integrated into the spacecraft, will be delayed by 4 months to allow time for the project to address the redesign and contamination issues. The SEIS instrument is critical for meeting three of the project's six top level mission requirements, and contributes to the other three.

The project is also concerned with the development progress of the mole component of the Heat Flow and Physical Properties Package (HP3). The mole component of the instrument is designed to hammer 5 meters into the Martian subsurface to investigate the thermal history of Mars. The original design of the mole broke during testing and failed to reach a technology readiness level of 6 by the preliminary design review, a best practice to minimize risks for projects entering product development. Testing to confirm a redesigned mole has been delayed due to late delivery of required parts and workmanship challenges that resulted in a prototype model that did not adequately match the design for the flight model. As a result, project officials expect the delivery for the flight units to be delayed about 2 months from December 2014 to February 2015. According to project officials, the HP3 instrument, which is contributed by the German Aerospace Center (DLR) is not required to meet top level mission requirements, and could, if necessary, be descoped late into the integration and test process; though project officials report that it is unlikely that these schedule delays impact the project's critical path to a point where they would consider descoping it.

The project is also concerned with spacecraft mass, particularly with respect to the entry, descent, and landing configuration of the spacecraft. Current available mass margins are below institutional guidelines, and according to project officials, the project is seeking a waiver for institutional mass margin requirements because many components of the spacecraft's design are based on existing hardware designs with established and well-understood final masses. The project has recently made progress defining expected mass and improving the mass margin as detailed designs for the spacecraft and instruments have been finalized, and the project continues to look for additional opportunities to reduce mass. However, best practices indicate that by the time of a critical design review, which InSight held in May 2014, a project's design should be finalized. If the project experiences a design issue at this point in development, additional mass would likely be needed to address the issue. If the spacecraft is unable to accommodate additional mass, a redesign could result in significant cost or schedule impacts.

Other Issues to be Monitored

While it meets agency guidelines, the project continues to monitor the amount of energy that the spacecraft will have to conduct science experiments on Mars, due to dust storms which could reduce power and impact scientific capabilities.

Project Office Comments

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

James Webb Space Telescope

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

Previously Reported Challenges
- Design/Technology
- Test and Integration

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partners:
European Space Agency (ESA), Canadian Space Agency (CSA) (Canada)

Launch Location: **Kourou, French Guiana**
Launch Vehicle: **Ariane 5**

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

Requirement derived from:
2001 Astrophysics Decadal Survey

CONTRACT INFORMATION

Current highest value contract

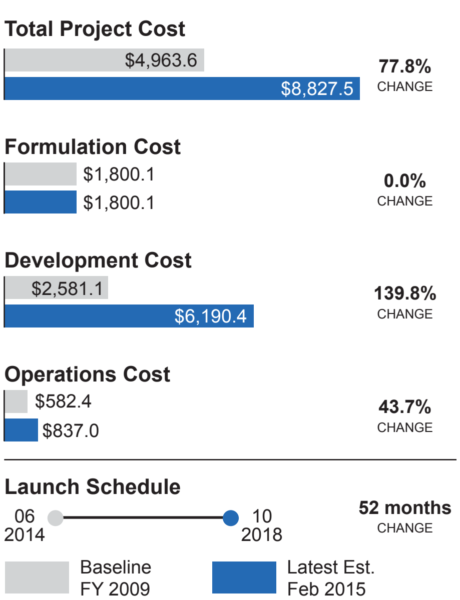
Contractor: **Northrop Grumman Aerospace Systems**

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

Type of Contract: **Cost-Plus-Award-Fee/ Incentive-Fee**
Date of Award: **2002**
Initial Value of Contract: **$824.8 million**
Current Value: **$3.57 billion**

PROJECT PERFORMANCE

Then year dollars in millions

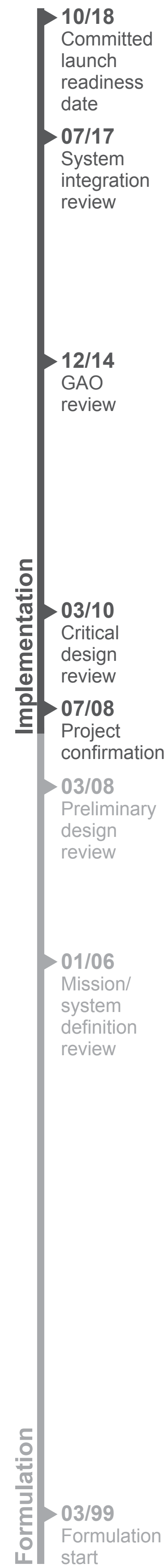


The James Webb Space Telescope (JWST) is a large, infrared-optimized space telescope that is designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, the formation of stars and planetary systems, and further the search for earth-like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

Source: NASA. | GAO-15-320SP

PROJECT SUMMARY

During the past year, delays have occurred on every element and major subsystem schedule leaving all at risk of negatively affecting the overall project schedule reserve if further delays occur. As a result, the project's overall schedule reserve has diminished. Much work remains as only two of the five integration and test periods have begun and none have been completed. The most significant technical risks this year include difficulties manufacturing the sunshield support structure and the cryocooler, which cools one JWST instrument. As the cryocooler compressor assembly manufacturing challenges have yet to be resolved, it will continue to drive increased schedule risk for the project in 2015.



James Webb Space Telescope

PROJECT UPDATE

In December 2014, GAO found that JWST faced increased schedule risk with most of its complex and lengthy integration and testing cycle still remaining at that time. JWST has the longest integration and test schedule of any current project at Goddard Space Flight Center. GAO found that JWST's spacecraft had successfully completed a major design review and began manufacturing; the sunshield's deployment concept had been successfully tested; and the Integrated Science Instrument Module–the subsystem composed of all four of JWST's science instruments–had completed its second cryovacuum test. However, GAO also identified a number of potential issues that could inhibit JWST's progress in 2015 and beyond, including low cost reserves and a lack of insight on new risks that had been identified since the 2011 replan. Below is a summary of key issues identified in that report with updated information.[a]

Schedule Issues

JWST currently holds 11 months of schedule reserve. While this is above the project's plan and center standards, significant risk and almost 4 years of integration and test remain ahead, which is when schedules tend to slip and problems are most likely to be identified. The cryocooler, which cools one JWST instrument, is driving the project's schedule and has used more of its own schedule reserve than any other element or major subsystem schedule on JWST in the past year. One component of the cryocooler, the compressor assembly, is over 15 months late, continues to face significant delays, and has yet to be delivered. Additionally, in the last year, schedule reserve for all elements and major subsystems has been diminished and each is within weeks of becoming the driver of the project's schedule. As a result, new problems that cause delays to any of these elements or major subsystems would negatively affect the overall project schedule and leave management with limited flexibility to address problems on other elements or major subsystems.

Manufacturing Issues

Manufacturing the pieces of the sunshield and cryocooler compressor assembly challenged the project and contractors in fiscal year 2014. Upon completion, the contractor of the sunshield support structure identified weaknesses in the composite material of the largest panel. After months of delays to determine the root cause—moisture absorption into the composite material—the panel was rebuilt and now meets strength requirements. The project also remanufactured a piece of composite at the center of the sunshield—where all of the sunshield layers meet—caused by a similar issue with the composite material, which may require the use of schedule reserve. Additionally, manufacturing errors when building pieces of the cryocooler compressor assembly and the time lost to investigate the cause of some of those problems, among others, has led to the use of schedule reserve and further increased risk on the project's schedule. Given the subcontractor's history of late deliveries, a top issue for the project in fiscal year 2015 is resolving these manufacturing errors and getting the compressor delivered.

Funding Issues

Neither the JWST project nor the prime contractor have updated their cost risk analyses since the project underwent a replan in 2011, leaving uncertainty about whether there is enough funding to accommodate the many new risks that have been realized since that time. Project officials plan to update JWST's cost risk analysis for the prime contract; if this analysis follows best practices, it should provide NASA and the Congress with reliable information on cost and risk. JWST entered fiscal year 2015 with approximately 40 percent of its cost reserves for the year already allocated to known issues, which will constrain the project's ability to respond to technical and schedule challenges until fiscal year 2016 when more program cost reserves become available.

Project Office Comments

JWST project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

[a]GAO, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining,* GAO-15-100 (Washington, D.C.: Dec. 15, 2014).

Magnetospheric Multiscale

Continuing Project Challenges

- Funding
- Parts

Previously Reported Challenges

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

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partners:
Space Research Institute (Austria), Laboratoire de Physique des Plasmas (France), Institute of Space and Aeronautical Science (Japan), Royal Institute of Technology (Sweden)

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

Mission Duration: **2 years**

Requirement derived: **NASA Strategic Plan**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Southwest Research Institute**

Major Contractor: **Instrument development**

Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **April 2004**
Initial Value of Contract: **$229 million**
Current Value: **$237 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline	Latest Est.	Change
Total Project Cost	$1,082.7	$1,122.5	3.7% CHANGE
Formulation Cost	$173.0	$172.9	-0.1% CHANGE
Development Cost	$857.4	$876.8	2.3% CHANGE
Operations Cost	$52.3	$72.8	39.2% CHANGE
Launch Schedule	03 2015	03 2015	0 month CHANGE

Baseline FY 2009 — Latest Est. Feb 2015

The Magnetospheric Multiscale (MMS) will investigate how magnetic fields around Earth connect and disconnect, explosively releasing energy via a process known as magnetic reconnection. MMS will provide a three-dimensional view of this fundamental process, which occurs throughout the universe and is one of the most important drivers of space weather. MMS consists of four identical spacecraft, each with 25 instruments. The four spacecraft will fly in a tetrahedron formation, adjustable over a range of approximately 6 to 250 miles.

Source: NASA. I GAO-15-320SP

PROJECT SUMMARY

MMS launched successfully on March 12, 2015. Prior to launching, the project exceeded its committed cost baseline by $39.8 million following a replan in June 2014. Following the government shutdown in October 2013, MMS was no longer able to meet its October 2014 launch manifest date; however, the project successfully launched within its original committed launch window. One of the project's top issues had been a drop in performance of its navigator boxes, which help the spacecraft maintain a required relative distance from each other. Such a failure could temporarily disrupt MMS navigation among the four spacecraft.

Magnetospheric Multiscale

PROJECT UPDATE

On March 12, 2015, MMS successfully launched. Prior to launching, in June 2014, NASA's Science Mission Directorate Program Management Council approved the MMS project's replan of cost and schedule.

Funding Issues

The project has exceeded its committed cost baseline by $39.8 million. Following the government shutdown in October 2013, MMS was no longer able to meet its October 2014 launch manifest date. However, the project successfully launched within its original committed launch window 5 months later. The project needed $19.4 million to meet the new launch date and to cover 5 additional months of staffing, plus 2 extra months in orbit, as the position of the Earth during this launch window is not optimal for placing MMS within its orbital alignment.

In addition, the project needed $20.5 million to address a funding shortfall for the operations and sustainment phase, scheduled to begin in September 2015. For the past 3 years, the project has tracked the risk of insufficient funding for this phase as the complexity of operating the science instruments and managing the mission data flow to satisfy the mission's level one science requirements has greatly increased. Project officials told us that the original funding was based on the assumption that the project would created automation software intended to lessen the number of staff necessary for this phase. The project was not able to develop this software at a reasonable cost due to the complexity of the project.

Parts Issues

One of the project's recent top issues had been a drop in performance of its navigator boxes which help the spacecraft maintain a required relative distance from each other necessary for the mission to meet its science requirements. This degraded performance occurred with a navigator box despite the recent replacement of all navigator parts that were thought to be problematic. A failure review board was established to assess and mitigate this problem. The root cause of the most recent navigator problem was identified as an isolated part issue, due to workmanship errors. The part was replaced and retested and there is no residual risk associated with the navigator system. The project reintegrated the navigator boxes at the Kennedy Space Center. While a similar failure on orbit could temporarily disrupt MMS navigation, a project official stated that the issue will not jeopardize the mission's level one science requirements as each observatory contains a back-up navigator side.

Issue Update

The project has successfully completed the test program of all the optocouplers which are high voltage electronic parts for the two sensors in the Fast Plasma Investigation instruments. Last year, we reported that the project had completed testing half of the required 288 optocouplers following the flight unit testing failure of some optocouplers.[a] However, given that the root cause of these failures is unknown, the project carries a moderate residual risk that these parts may fail on orbit, leading to instrument degradation or failure. Three of the four Fast Plasma Investigation instrument electron and ion sensors on each observatory are required to meet the mission science requirements.

Project Office Comments

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

[a]GAO, *NASA: Assessment of Selected Large-Scale Projects,* GAO-14-338SP (Washington, D.C.: Apr 15 2014).

Mars 2020

Project Challenges
- Design
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partner: **NASA Human Exploration and Operations Mission Directorate, NASA Space Technology Mission Directorate, U.S. Department of Energy, Centre National d'Etudes Spatiales (CNES)(France), Centro de Astrobiología (Spain), Norwegian Defence Research Establishment (Norway)**

Launch Location: **Eastern Range, FL**
Launch Vehicle: **TBD**

Mission Duration: **2 years**

Requirement derived from:
2011 National Research Council Decadal Survey and Mars Program

CONTRACT INFORMATION

Current highest value contract

Contractor: **Aerojet Rocketdyne**

Contractor Activity: **Mars Lander Engines**

Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **October 2013**
Initial Value of Contract: **$8 million**
Current Value: **$7 million**

PROJECT PERFORMANCE

Then year dollars in billions

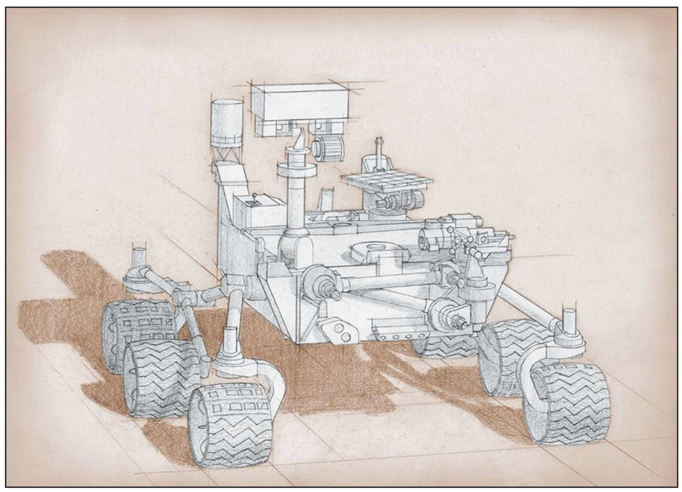
Preliminary Estimate of Project Life Cycle Cost*:

Latest: **February 2015** **$2.14 – $2.35** BILLIO

**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: **July 2020**

Mars 2020 is part of the Mars Exploration Program which seeks to understand whether Mars was, is, or can be a habitable planet. Mars 2020 will be based heavily on architecture of the Mars Science Laboratory (MSL), or Curiosity, which landed on Mars in 2012 and remains in operation. With a new set of science instruments, Mars 2020 will continue the systematic exploration of Mars by conducting geological assessments, searching for signs of ancient life, determining potential environmental habitability, and preparing well-documented samples for potential future return to Earth. NASA considers Mars 2020 to be the next step in an evolving Mars Exploration Program that will ultimately involve the return of Martian soil or rock samples and human exploration.



Source: NASA/JPL Caltech. | GAO-15-320SP

PROJECT SUMMARY

As a result of the significant reliance on the existing design of MSL, project officials note that any design changes could impact the project's ability to control cost and schedule. In July 2014, NASA announced that it had selected the project's seven-instrument payload through a competitive process; project officials have reported that this selection did not incur significant changes in the heritage rover design. The project is currently carrying a risk that if parts become obsolete, the project may need to alter its design, which could have cost and schedule impacts.

Implementation
- **07/20** Projected launch date
- **11/17** System integration review
- **09/16** Critical design review
- **12/15** Project confirmation

Formulation
- **12/15** Preliminary design review
- **12/14** GAO review
- **10/14** System requirements review/ mission definition review
- **11/13** Formulation start

Mars 2020

PROJECT UPDATE

In July 2014, NASA announced that it had selected the project's seven-instrument payload through a competitive process. Project officials have reported that this selection did not incur significant changes in the heritage rover design. The payload instruments are designed to allow the project to fulfill its proposed science objectives. Two of the instruments will be provided by international partners and a third will include contributions from an international partner. NASA will provide approximately $180 million in funding for payload instrument development, which does not include international partner contributions. The project expects to enter the preliminary design and technology completion phase in April 2015 and is scheduled to go through a two-part preliminary design review in September and December 2015.

Design Issues

In order to control cost, schedule, and technical risks, the project will be based heavily on the MSL design and will use some of MSL's remaining hardware. Project officials stated that because Mars 2020 is relying on existing technology and designs, any changes could impact the project's ability to control cost and schedule. The project, however, is already tracking several potential design changes, such as those related to landing site selection, planetary protection requirements, the sample caching system, and rover wheels. For example, a proposed top level mission requirement, which according to NASA policy must be finalized before confirmation, states that the landing site may be selected as late as 1 year before launch and that the project must be able to land without compromising overall mission safety. In order to optimize the science and operations of the proposed mission, some candidate landing sites could require the use of terrain relative navigation, which would require changes to the existing spacecraft design. To reduce the impact of this risk, project officials stated that some resources are being dedicated to developing the technology in case it is needed and the project is also developing plans for how they would incorporate the technology. Project officials expect to use information from a landing site workshop scheduled for summer of 2015 to determine if the terrain relative navigation will be required.

Funding Issues

While project officials believe that the funding they are projected to receive overall is viable for the work they need to complete, they have stated that the timing of the funding will require the project to defer building existing technologies until fiscal year 2017, which may add cost, schedule and technical risk. Specifically, because the project cannot procure these technologies for many years, the risk of obsolesce increases, which in turn increases the risk that the existing design would need to be altered due to parts unavailability. The project has not yet determined the total number of critical technologies to be developed, but officials have identified at least four critical technologies.

Other Issues to be Monitored

The project will incorporate contributions from multiple international, domestic, and NASA partners. GAO has previously found that receiving and integrating contributions from multiple partners may complicate development efforts and could contribute to cost and schedule growth.[a]

It will be important for Mars 2020 to maintain its schedule and launch in 2020. Because of the planetary launch window, if the project misses its 2020 launch window, it would be 26 months before another launch window is available, a delay that occurred on MSL.

Project Office Comments

Mars 2020 project officials provided technical comments to a draft of this assessment, which were incorporated as appropriate. The project currently is implementing heritage items as funding allows. While obsolescence of heritage items is a concern, 99 percent of the electronic parts, which are the highest risk items have been procured and all critical propulsion components for entry, descent, and launch are on contract with MSL heritage vendors. The work being performed under these contracts is currently under the project's cost estimates.

[a]GAO, *NASA: Assessments of Selected Large-Scale Projects,* GAO-11-239SP (Washington, D.C.: March 3, 2011).

NASA ISRO – Synthetic Aperture Radar

Project Challenges
- Technology
- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **Indian Space Research Organization (ISRO) (India)**

Launch Location: **Satish Dhawan Space Centre, India**
Launch Vehicle: **Geosynchronous Satellite Launch Vehicle (GSLV) Mark II**

Mission Duration: **3 years**

Requirement derived from:
2007 National Research Council Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **TBD**

Contractor Activity: **TBD**

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

PROJECT PERFORMANCE

Then year dollars in millions

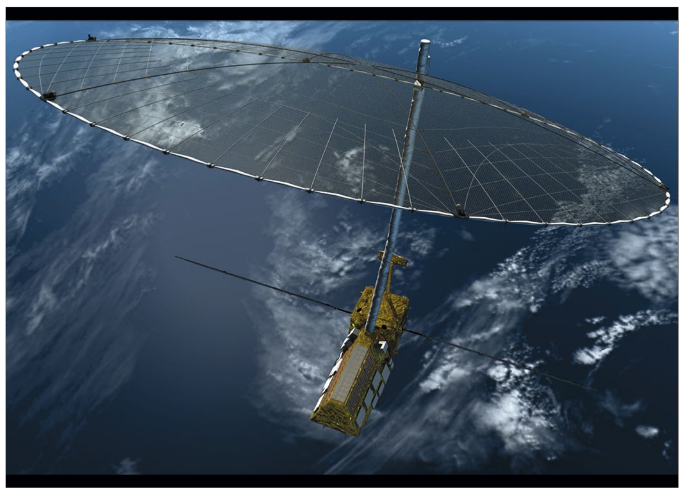
Preliminary Estimate of Project Life Cycle Cost*:

Latest: **February 2015** **$718 – $808** MILLION

**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: **December 2020**

The NASA ISRO - Synthetic Aperture Radar (NISAR) mission's objectives are to systematically and globally study the solid Earth, ice masses, and ecosystems to address questions such as what drives changes in ice masses and how this relates to Earth's climate, how the Earth's carbon cycle and ecosystem are changing and the implications of these changes, and how to mitigate the impact of natural hazards such as earthquakes and volcanoes. The project will include the world's first dual frequency synthetic aperture radar instrument which will employ advanced radar imaging to provide large-scale data sets of the earth's movements.



Source: © 2014 California Institute of Technology/Jet Propulsion Laboratory. | GAO-15-320SP

PROJECT SUMMARY

The project spent several years and approximately $63 million prior to beginning the concept and technology development phase in order to mature the technology associated with the synthetic aperture radar and reduce associated risks. The project is tracking a risk regarding the reliability of the launch vehicle which will be contributed by the Indian Space Research Organization (ISRO), which has not yet been verified to meet NASA's applicable launch requirements. Additionally, the project is concerned that the spacecraft bus provided by ISRO will not be able to meet the project's strict requirements to obtain measurement accuracy.

Implementation
- **12/20** Projected launch date
- **02/19** System integration review
- **01/18** Critical design review
- **09/16** Project confirmation

Formulation
- **08/16** Preliminary design review
- **12/14** GAO review
- **12/14** Mission/ system definition review
- **03/14** Formulation start

NASA ISRO – Synthetic Aperture Radar

PROJECT UPDATE

The NISAR project spent several years and approximately $63 million prior to the concept and technology development phase, or Phase A, in order to mature the synthetic aperture radar instrument to a technology readiness level of 6 and reduce risks. According to project officials, the majority of the funds were spent on the electronics components of the instrument, which were new items. The early investment will allow the project to have early prototypes for testing. NISAR is being jointly developed by NASA and ISRO, which is expected to provide the spacecraft bus, launch vehicle and launch services, the S-band synthetic aperture radar science payload, and observatory integration and test at ISRO facilities, among other contributions.

Technology Issues

The project is tracking a risk that the development of the reflector boom assembly could be more complicated than currently planned, which could increase development costs or cause a launch delay. The reflector boom assembly is part of the instrument antenna and will be shared by and used to transmit and receive the separate feeds from the L- and S-band radars. The project is incorporating lessons learned from the Soil Moisture Active and Passive (SMAP) project, which has encountered numerous design issues with its reflector boom assembly. Based on SMAP's experiences and to mitigate this risk, the reflector boom assembly has been identified as a long lead procurement item, and it is currently on the project's critical path. The project is considering various options for the reflector boom assembly, including a NASA-developed boom, with a commercially-acquired reflector.

Development Partner Issues

The project is monitoring a risk regarding the reliability of the ISRO-provided Geosynchronous Satellite Launch Vehicle (GSLV) Mark II because the launch vehicle has not yet met the mission's reliability requirements. NASA and ISRO jointly agreed on a set of criteria that ISRO must meet before launch, including three successful launches with one occurring just prior to NISAR's planned launch. The launch vehicle has had one successful launch in 2014 with seven additional launches planned prior to the NISAR launch. According to project officials, if ISRO cannot achieve the criteria for a medium risk mission with the GSLV Mark II, then launch may be delayed 2 years and result in an approximately $20 million to $30 million cost increase in order to verify that the vehicle is acceptable for launch.

The project is also concerned that the spacecraft bus, which is based on an ISRO heritage design, will not be able to meet the project's required level of measurement accuracy. The observatory must be able to point the instrument at the same location to within a fraction of a degree; however, the spacecraft bus has not yet demonstrated the ability to meet this requirement. According to project officials, if the spacecraft bus design cannot meet this requirement, then its development may be delayed or the quality of science data gathered may be degraded and some primary mission objectives may not be met.

Other Issues to be Monitored

The requirement for a high rate telecom modulator, capable of downlinking 24 terabits of data per day, will drive the project's technology development effort. According to project officials, this would be the highest rate of data downlink by a NASA satellite. The project will conduct a trade study in Phase A to decide between a NASA-built modulator or a commercial modulator. The modulator will be the project's single critical technology, and is currently at technology readiness level 4 or 5.

Project Office Comments

NISAR project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Orbiting Carbon Observatory 2

Previously Reported Challenges
- Funding
- Parts
- Design
- Launch

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **None**

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

Mission Duration: **2 years**

Requirement derived from:
Directed Mission; OCO Reflight

CONTRACT INFORMATION

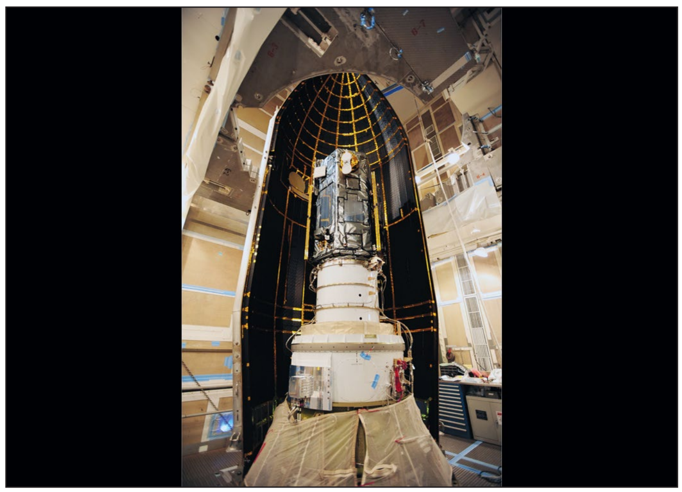
Current highest value contract

Contractor: **Orbital Science Corporation**

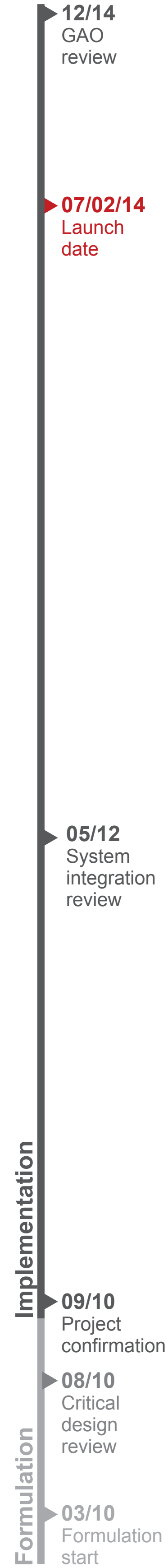
Contractor Activity: **Spacecraft development**

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

NASA's Orbiting Carbon Observatory 2 (OCO-2) is 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 making precise, time-dependent global measurements of atmospheric carbon dioxide. These measurements will be combined with data from a ground-based network to provide scientists with information needed to better understand the processes that regulate atmospheric carbon dioxide and its role in the carbon cycle. NASA expects enhanced understanding of the carbon cycle will improve predictions of future atmospheric carbon dioxide increases and the potential impact on the climate.



Source: NASA. | GAO-15-320SP



PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$349.9
$467.5
33.6% CHANGE

Formulation Cost
$60.9
$60.9
0.0% CHANGE

Development Cost
$249.0
$320.3
28.6% CHANGE

Operations Cost
$40.0
$46.4
16.0% CHANGE

Launch Schedule
02 2013 — 07 2014
17 months CHANGE

Baseline FY 2010 | Latest Est. Feb 2015

PROJECT SUMMARY

The OCO-2 project successfully launched on July 2, 2014. It maneuvered into its final orbit and began collecting science data on August 6. The calibrated data will be available to the global science community by the end of 2014. OCO-2 requested a $5.5 million increase to its operations and sustainment phase budget, which was originally reduced in fiscal year 2013, when the project was rebaselined as a result of switching from the Taurus XL to the Delta II launch vehicle. However, it has been approved for $2.9 million agreed upon by the project after the mid-October completion of in-orbit checkout to configure the observatory for in-flight operations and ensure the systems are functioning properly.

Project Office Comments

OCO-2 project officials provided technical comments on this draft, which were incorporated as appropriate.

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

Recent/Continuing Project Challenges

- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **Canadian Space Agency (CSA) (Canada)**

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

Mission Duration: **7 years**

Requirement derived from: **Vision and Voyages for Planetary Science in the Decade 2013-2022**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin Space Systems Company**

Contractor Activity: **Spacecraft development**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **January 2012**
Initial Value of Contract: **$315.9 million**
Current Value: **$334.1 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$1121.4
$1064.2
-5.1% CHANGE

Formulation Cost
$144.3
$144.3
0.0% CHANGE

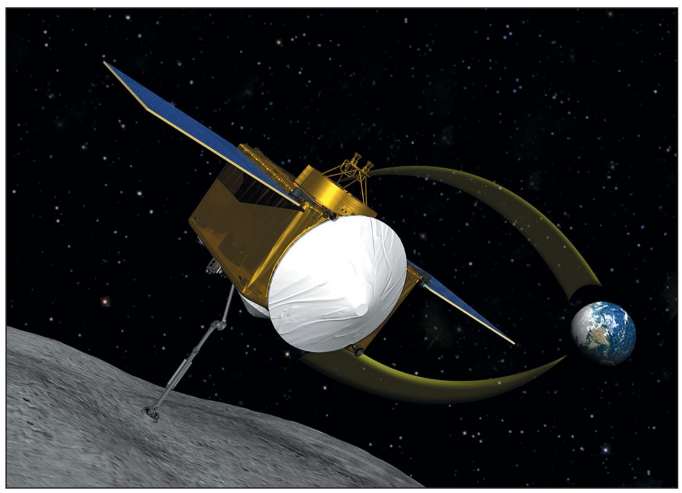
Development Cost
$778.6
$709.7
-8.8% CHANGE

Operations Cost
$198.5
$210.3
5.9% CHANGE

Launch Schedule
10 2016 — 10 2016
0 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2015

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 make 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. | GAO-15-320SP

PROJECT SUMMARY

The project is tracking several technical risks related to the delivery of instruments and key flight hardware components; however, officials expect these risks to be mitigated without exhausting its reserves and that the project will complete development under its committed cost baseline. Due to its criticality to mission objectives, the project is concerned that the contractor for the guidance, navigation, and control light detection and ranging component may not complete development in time for spacecraft integration. As a result, the project is developing a back-up approach.

Implementation

- **10/16** Committed launch readiness date
- **02/15** System integration review
- **12/14** GAO review
- **04/14** Critical design review
- **05/13** Project confirmation

Formulation

- **03/13** Preliminary design review
- **05/12** Mission/ system design review
- **05/11** Formulation start

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

PROJECT UPDATE

The project's internal cost baseline, reflected in its management agreement, was reduced by $55.5 million in early 2014, reflecting a $57 million savings in launch vehicle costs and the addition of $1.7 million in funds necessary to mitigate the effects of the October 2013 government shutdown. The cost reduction did not alter the agency baseline commitment. Based on current risks and project funding and schedule status, project officials stated that they expect the project to be completed under its committed cost baseline.

Development Partner Issues

The project is tracking a risk regarding the development of the OSIRIS-REx laser altimeter (OLA) flight unit—one of the five planned mission instruments which will be used to create a 3-dimensional model of the asteroid—and its schedule margin. Project officials reported that the laser altimeter instrument will be delivered 3 months later than planned for integration onto the spacecraft due to the Canadian Space Agency (CSA) receiving the funds later than expected from the Canadian government. As a result, CSA's schedule for building the first flight unit of the laser altimeter instrument is delayed. Late delivery of the instrument will require the project to replan some integration activities and may potentially repeat tests which could require the use of some of the project's cost and schedule reserves. Agency officials have informed CSA that the instrument must be delivered no later than November 2015, as delivery after this date would cause the project to incur significant cost and schedule risk unsupportable within project resources. The project could also decide to descope the laser altimeter and fly a mass model instead, because the instrument is not required to meet the top level mission objective of returning an asteroid sample.

Other Issues to be Monitored

The project has been tracking a risk regarding the potential impact of a late delivery of the guidance, navigation, and control light detection and ranging (GNC LIDAR) instrument, which uses a light sensing technology to guide the spacecraft toward the asteroid, to the spacecraft for integration. The technology is critical to the mission because without it, the spacecraft could not navigate accurately to the asteroid to collect the sample. According to project officials, they are tracking this risk, in part, because the company providing the units has never built them for the duration of flight that the mission would require. In December 2014, the GNC LIDAR experienced an anomaly which resulted in a decrease in laser output energy. While the project has identified the root cause, incorporating the fix will delay the delivery of the flight units and the spacecraft integration schedule has been adjusted to accommodate the late delivery. If additional testing challenges arise and the GNC LIDAR is not ready to be integrated on the spacecraft on time, then costs could increase in order to accommodate a late delivery or the launch could be delayed. To address the risk of development issues or late delivery the project has undertaken development of a back-up approach called natural feature tracking that will provide similar navigation data as the GNC LIDAR. A critical design review for the natural feature tracking technology, which has been assessed as fully mature, was held in September 2014.

Project Office Comments

OSIRIS-REx project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Orion Multi-Purpose Crew Vehicle

Recent/Continuing Project Challenges

- Schedule (new)
- Design
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Johnson Space Center

International Partner: **European Space Agency (ESA)**

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

Mission Duration:
Minimum 21 day active mission duration capability with 4 crew

Requirement derived from:
NASA Authorization Act of 2010

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin**

Contractor Activity: **Spacecraft Development**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **September 2006**
Initial Value of Contract*: **$3.89 billion**
Current Value: **$12.08 billion**

**The initial value of the contract was established under the Constellation program in 2006. In February 2014, the contract was modified to extend the period of performance until 2020.*

PROJECT PERFORMANCE

Then year dollars in billions

Preliminary estimate of Project Life Cycle Cost*

Latest: **February 2015** **$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: **Fiscal year 2018**
First Crewed Launch Date: **Fiscal year 2021/2022**

The Orion Multi-Purpose Crew Vehicle (Orion) is being developed to conduct crewed in-space operations beyond low-Earth orbit, including traveling to Mars or an asteroid. Under the Orion program, NASA is continuing to advance development of the human safety features, designs, and systems of the former Orion project under the Constellation program, which was cancelled in February 2010. Orion is planned to launch atop NASA's Space Launch System. The current design of Orion consists of a crew module, service module, and launch abort system.

Source: NASA. | GAO-15-320SP

PROJECT SUMMARY

The Orion program successfully conducted its first exploration test flight, or EFT-1, in December 2014. NASA has delayed the Orion program's confirmation review until at least May 2015 at which time the agency will establish cost and schedule baselines for both the first non-crewed exploration mission (EM-1) and first crewed exploration mission (EM-2). The program continues to work towards a September 2018 launch date; however, until the program's cost and schedule baselines are established in spring 2015, there is uncertainty about the launch date. In August 2014, the project completed its preliminary design review. However, for a majority of the success criteria, review officials highlighted known risks that could compromise Orion's success.

Implementation

Fiscal year 2021/2022 First crewed launch date

Fiscal year 2018 First non-crewed launch date

10/15 Critical design review

05/15 Project confirmation (projected)

12/14 GAO review

12/14 First exploration test flight

Formulation

08/14 Orion preliminary design review

02/12 Orion formulation start

02/10 Orion cancelled under Constellation Program

08/09 Orion preliminary design review

07/06 Orion Project formulation start

Orion Multi-Purpose Crew Vehicle

PROJECT UPDATE

The Orion program successfully conducted its first exploration test flight, or EFT-1, in December 2014. Preliminary results indicate that the flight met 85 of its 87 test objectives. However, in order to allow the program time to review the data from EFT-1, the program's confirmation review has been delayed from December 2014 to at least May 2015 at which time baseline cost and schedule estimates will be established. GAO has previously reported that these estimates are not expected to cover the costs for production, operations, or sustainment of additional crew capsules, despite plans to use and possibly enhance this capsule after 2021.[a]

Schedule issues

As of December 2014, NASA's Human Exploration and Operations directorate has identified a launch readiness window for EM-1 from December 2017 to September 2018. The program is currently working towards a September 2018 launch readiness date; however, until the program receives official cost and schedule baselines at the confirmation review in spring 2015, there is uncertainty about the launch date.

Design issues

The program passed its preliminary design review in August 2014, as it met the minimum standards for all 10 success criteria. However, for 7 of the 10 criteria, review officials also highlighted known issues that could compromise Orion's success. For example, the review officials noted several unresolved design risks, including technical challenges with the parachute system and heat shield. Program officials told us that some of these issues would be evaluated as part of EFT-1. Significant cost and schedule impacts could result if a redesign is required to address any of these unresolved risks.

In 2014, the program identified that during parachute testing when only two of the three main parachutes are deployed, they begin to swing past each other creating a "pendulum" effect. This effect could cause the capsule to increase speed and land incorrectly for a safe water landing. The program did not address this risk for EFT-1 because a solution had not been identified and the system had been installed on the capsule. As of October 2014, officials had yet to determine how to address this risk. However, program officials plan to make a decision, based on additional testing and analysis, about how to resolve this risk in 2015. This issue must be resolved before EM-2 because it is a risk to crew safety.

The program continues to struggle with the heat shield design, which may need to be modified for EM-1. During manufacturing of the current heat shield design for EFT-1, cracks were found in 6 percent of the seams. While the repaired heatshield was usable for EFT-1, it does not meet the more stringent requirements for future flights. As a result, the program is studying two designs for applying the heat shield material, though the alternative design has also experienced problems during testing. As of October 2014, the program had yet to select the design it will use and was waiting for results of the design study as well as data from EFT-1 to provide additional information upon which to base the decision.

Funding issues

The program's top risk is that technical risks and budgetary uncertainty could require an additional $560 to $840 million dollars to meet the yet-to-be-established EM-1 flight date. Program officials report that they have many options to address this risk. However, program officials report that the program only carries a small amount of cost reserves each fiscal year, so that it can devote almost all available resources to current development activities. As a result, cost reserves are not likely to be available as new technical issues arise and scheduled work may need to be delayed.

Project Office Comments

Orion program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

[a]GAO, *NASA: Actions Needed to Improve Transparency and Assess Long-Term Affordability of Human Exploration Programs.* GAO-14-385 (Washington, D.C.: May 8, 2014).

Soil Moisture Active and Passive

Recent/Continuing Project Challenges

- Parts/Test and Integration
- Funding

Previously Reported Challenges

- Launch
- Design
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partner: **None**

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

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Northrop Grumman Aerospace Systems**

Contractor Activity: **Reflector Boom Assembly**

Type of Contract: **Cost-Plus-Fixed-Fee**
Date of Award: **June 2009**
Initial Value of Contract: **$20.0 million**
Current Value: **$51.0 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$916.5
$914.6
-0.2% CHANGE

Formulation Cost
$388.2
$388.2
0.0% CHANGE

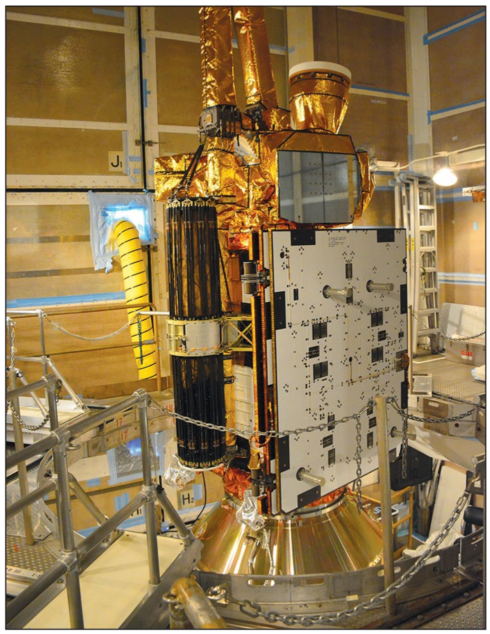
Development Cost
$485.7
$479.0
-1.4% CHANGE

Operations Cost
$42.6
$47.4
11.3% CHANGE

Launch Schedule
03 2015 01 2015
-2 months CHANGE

Baseline FY 2012
Latest Est. Feb 2015

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



Source: NASA. | GAO-15-320SP

PROJECT SUMMARY

On January 31, 2015, SMAP successfully launched. The project's planned launch date had been rescheduled from November 2014 to January 2015 as a result of technical difficulties with the reflector boom assembly. In fiscal year 2014, the project required $45 million of its headquarters reserves in order to address technical difficulties as well as fund the rescheduled launch date. The project received an additional $10.6 million in headquarters-managed cost reserves for the operations and sustainment phase to address issues identified with calibrating and validating the data as well as incorporating lessons learned from other projects.

Implementation
- **01/31/15** Launch date
- **12/14** GAO review
- **04/13** System integration review
- **07/12** Critical design review
- **06/12** Project confirmation

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

Soil Moisture Active and Passive

PROJECT UPDATE

On January 31, 2015, SMAP successfully launched. As a result of recent difficulties with a critical component, the agency had rescheduled SMAP's planned launch date from November 2014 to January 2015. According to project officials, all technical challenges that triggered the request for launch delay have been resolved. SMAP will be commissioned over the next three months and expects to return initial data later in 2015.

Parts/Test and Integration Issues

During the integration and test period, the reflector boom assembly, which includes a deployable mesh antenna used by the radar and radiometer instruments used to collect soil moisture data, experienced two anomalies which caused the mesh antenna to not open or "bloom" correctly. The project adjusted the design of the reflector boom assembly and conducted three additional deployment tests to confirm these changes. During these tests, the reflector boom assembly deployed as expected. Despite eliminating the root causes of the bloom anomalies, project officials report they will fly the reflector boom assembly with a medium residual deployment risk because limitations in testing capabilities prevented the project from testing the deployed reflector bloom assembly in space-like conditions. These anomalies during deployment tests drove NASA's decision to postpone the planned launch date and allow more time for testing and resolution of the issues.

The project had also encountered earlier difficulties in thermal vacuum testing with the high powered amplifier and diplexer components. The diplexer, which allows the radiometer and radar to share a common antenna, experienced a failure; however, the unit was redesigned and passed additional testing and the project is tracking this as a medium residual risk. Additionally, the high powered amplifier did not perform as expected; however, the project believes the most likely root causes are benign and the behavior is not expected to impact science capabilities as the failure did not reappear during additional testing. As a result, the project plans to fly the high powered amplifier with a medium residual risk, because the officials were not able to identify the root cause and it is possible that the issue may reoccur during the mission.

Funding Issues

At the operations and sustainment review in December 2014, the project expected to launch in January 2015 within its established cost baseline; however, throughout 2014, the project required the majority of its headquarters-managed cost reserves to address technical issues. In May 2014, the project received $23 million in headquarters-managed cost reserves to address the cost of the activities required to mitigate the technical challenges with several critical components. In July 2014, further test anomalies with the reflector boom assembly necessitated a replan in September 2014. As part of that replan, the project's planned launch date was moved from November 2014 to January 2015 which had an additional cost impact. As a result, the project received an additional $22.4 million in headquarters reserves which covers the shift in the launch date and restores project cost reserves to comply with the Jet Propulsion Laboratory's institutional guidelines. In December 2014, the project received $10.6 million in headquarters-managed cost reserves for the operations and sustainment phase. Specifically, the funding is intended to address identified and anticipated issues related to calibrating and validating science data and incorporating lessons learned from other projects.

Project Office Comments

SMAP project officials provided technical comments on a draft of this assessment which were incorporated as appropriate.

Solar Probe Plus

Recent/Continuing Project Challenges
- Launch

Previously Reported Challenges
- Design
- Funding
- Parts/Test and Integration
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **None**

Launch Location: **Kennedy Space Center, FL**
Launch Vehicle: **Delta IV-heavy class with NASA-provided upper stage**

Mission Duration: **7 years**

Requirement derived from:
2013-2022 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-Fixed-Fee**
Date of Award: **May 2010**
Initial Value of Contract: **$676.9 million**
Current Value: **$728.8 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$1,553.4
$1,553.4
0.0% CHANGE

Formulation Cost
$247.1
$247.1
0.0% CHANGE

Development Cost
$1,055.7
$1,055.7
0.0% CHANGE

Operations Cost
$250.6
$250.6
0.0% CHANGE

Launch Schedule
08 2018 08 2018
0 months CHANGE

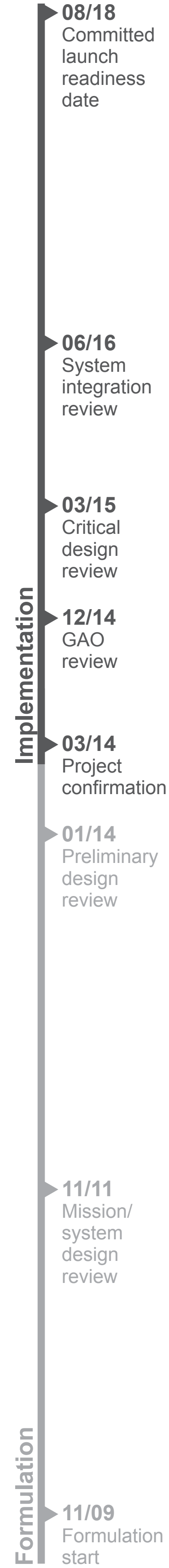
Baseline FY 2014
Latest Est. Feb 2015

Solar Probe Plus (SPP) will be the first mission to visit a star. The spacecraft will orbit the Sun 24 times and its instruments will observe the generation and flow of solar winds from very close range. SPP will directly probe the Sun's outer atmosphere, or the solar corona, where solar energetic particles are energized. This mission will gather information to increase knowledge about the solar wind, including its origin, acceleration, and how it is heated. 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: Johns Hopkins University/Applied Physics Lab (artist depiction). | GAO-15-320SP

PROJECT SUMMARY

Project data indicate that SPP has performed well against its cost and schedule baselines, which were established at the project's confirmation review in March 2014. As part of this confirmation review, SPP received direction to change from an Atlas 551 to a Delta IV-heavy class launch vehicle which reduced two concerns for the project. However, as a result of the switch, the project must now wait until the launch vehicle contract is awarded before it can develop the mechanical connections between the spacecraft and the launch vehicle's upper stage. Because this will not occur until after the project's critical design review, there is an increased risk that any design changes to accommodate the launch vehicle could have adverse cost or schedule impacts.



Solar Probe Plus

PROJECT UPDATE

Project data indicate that SPP has performed well against the cost and schedule baselines which were established when the project was confirmed above the 70 percent joint cost and schedule confidence level in March 2014.

All 10 of the project's critical technologies, including the thermal protection shield, were matured to a technology readiness level of 6 by the project's preliminary design review in January 2014. The thermal protection shield was a significant technology development for the project as it allows the instruments on the spacecraft to operate at or near room temperature while traveling closer to the Sun than any previous spacecraft.

Launch Issues

As part of the confirmation review, SPP received direction to change its launch vehicle from an Atlas 551 to a Delta IV-heavy class launch vehicle, which officials told us reduced two concerns for the project. First, project officials told us this switch eliminated concerns about the availability of the Atlas 551's Russian engine arising from unrest between Ukraine and Russia. Second, the project no longer needs to develop and mature an upper stage motor for the Atlas 551 that would have been required to provide the necessary launch energy for SPP to reach its intended orbit.

However, as a result of moving to the Delta IV-heavy launch vehicle, the project now carries a design risk into its critical design review. The procurement for the launch vehicle and required upper stage is underway, but the project does not expect to know the results until after it holds its critical design review in March 2015. Project officials told us that pending this acquisition, the design for the connection between the spacecraft and the launch vehicle's upper stage is unknown as there are several different options. Because the critical design review is the point at which the spacecraft design needs to be stable so manufacturing can begin, any changes to the design after this point could have significant impacts on cost or schedule. Officials report that the project is addressing this risk by allowing as much flexibility in the design of the connections as possible. The project also met with officials from NASA's Launch Services Program, which is responsible for acquiring the project's launch vehicle, to gain more insight into the connection areas. For example, as a result of that meeting, the project is incorporating several features related to the bolts that connect the spacecraft to the upper stage, including how they separate during launch, into its current design.

Project Office Comments

SPP project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Space Launch System

Recent/Continuing Project Challenges
- Funding
- Integration of Existing Hardware

Previously Reported Challenges
- Schedule

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

CONTRACT INFORMATION

Current highest value contract

Contractor: **Boeing**

Contractor Activity: **SLS Core Stage**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **August 2007***
Initial Value of Contract: **$4.389 billion**
Current Value: **$4.185 billion**

This contract was originally awarded under the Constellation program with a different cost and scope of work.

The Space Launch System (SLS) is intended to be the nation's first human-rated heavy-lift launch vehicle since the Saturn V was developed for the Apollo program. SLS is planned to launch NASA's Orion vehicle and other systems on missions to an asteroid and eventually to Mars. The vehicle is being designed to provide an initial lift capacity of 70 metric tons to low-Earth orbit and be evolvable to 130 metric tons, enabling deep space missions. The initial 70-metric ton capability will include a core stage, powered by four RS-25 engines and two five-segment boosters. The 130-metric ton capability will include a core stage, new upper stage, engine, and advanced boosters.

Source: NASA. | GAO-15-320SP

PROJECT SUMMARY

In August 2014, SLS was confirmed and NASA established baseline commitments for cost, schedule, and performance for the initial 70-metric ton version of the launch vehicle with a committed launch readiness date of November 2018 and a life-cycle cost of $9.7 billion. However, the program is still pursuing its goal of achieving launch readiness by December 2017. According to program officials, the program has also encountered $80 million in unplanned cost growth and an approximate 20 month testing delay associated with the five-segment booster. While the program had available cost and schedule reserves to address this issue, if the latest redesign is not successful, it could require additional resources.

Implementation
- **11/18** Committed launch readiness date
- **12/17** Internal launch readiness goal
- **10/15** Critical design review
- **12/14** GAO review
- **08/14** Project confirmation

Formulation
- **07/13 - 09/13** Preliminary design review
- **05/12** Mission/ system design review
- **11/11** Formulation start

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2014	Latest Est. Feb 2015	Change
Total Project Cost	$9,695.0	$9,695.0	0.0%
Formulation Cost	$2,674.0	$2,674.0	0.0%
Development Cost	$7,021.0	$7,021.0	0.0%
Operations Cost	N/A	N/A	0.0%
Launch Schedule	11 2018	11 2018	0 months

Space Launch System

PROJECT UPDATE

In August 2014, the program was confirmed and NASA established cost and schedule baselines for the initial version of the SLS, the 70-metric ton launch vehicle, with a committed launch readiness date of November 2018 and a life-cycle cost of $9.7 billion. This baseline reflects an 11-month delay and $1.1 billion increase over preliminary estimates. The program, however, continues to pursue its goal of achieving launch readiness by December 2017.

Funding Issues

The SLS program continued to track the availability of funding to launch by December 2017 as its top risk through calendar year 2014, even after delaying the committed launch readiness date from December 2017 to November 2018 as part of the confirmation process. However, officials stated that they have been able to reduce this risk, because the Congress has consistently appropriated more funding than the agency has requested for this program.

Integration of Existing Hardware

The SLS program continues to face challenges integrating existing hardware originally designed for legacy systems for use on SLS. In the case of the RS-25 engines the SLS is using from the Space Shuttle program, according to program officials, the new core stage will deliver fuel at higher pressure levels than those delivered by the shuttle's external tanks. As a result, according to program officials, the program had to install new fuel lines in its full-scale engine test stands. Upon inspection, the program found workmanship defects in the new fuel lines and sent them back to the vendor for rework. This delayed the RS-25 engine test program 2 months, but has not impacted the program's overall schedule.

SLS has also encountered unexpected cost and testing delays associated with the five-segment booster. The contractor discovered unexpected voids between the solid rocket fuel and insulation of the solid rocket boosters, which could potentially cause an explosion. The contractor implemented a fix, but discovered similar voids in a second test article. The program continues to work to resolve this issue, but the contractor is forecasting over $80 million in unplanned cost growth, and an approximately 20-month delay to full-scale qualification testing from June 2013 to March 2015, as a result of this issue. The program was able to use available cost and schedule reserves to address this issue, so this delay has not impacted the overall program schedule. According to officials, however, if the latest redesign does not resolve the issue, further cost and schedule growth may occur.

Other Issues to be Monitored

SLS plans to use a propulsion subsystem, called the Interim Cryogenic Propulsion Stage (ICPS), which was originally developed for an unmanned system. According to program officials, additional documentation and safety assessments may be needed for human spaceflight.

The long-term affordability of the SLS program is largely unknown because NASA has not selected specific human exploration missions beyond the second SLS test flight in 2021 and NASA's baseline cost estimate does not provide any information about the longer-term, life-cycle costs of developing, manufacturing, and operating the launch vehicle or costs associated with the 105- or 130-metric ton variants.

Issue Update

The core stage development effort is aggressive and is driving the overall schedule of the SLS program, as the program is working towards a December 2017 launch readiness date. However, the program mitigated this concern somewhat when it set its committed launch readiness date to November 2018-11 months later than planning estimates.

Project Office Comments

SLS program officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. Program officials report that SLS is on track for a program launch readiness date of no later than November 2018.

Space Network Ground Segment Sustainment

Project Challenges
- Funding
- Contractor

Previously Reported Challenges
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **None**

Mission Duration: **25 years with periodic, required upgrades to hardware and software**

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 million**
Current Value: **$720 million**

The Space Network Ground Segment Sustainment (SGSS) project plans to develop and deliver a new ground system that will enable the Space Network—which provides essential communications and tracking services to NASA and non-NASA missions—to continue safe, reliable, and cost efficient operations for the next several decades. Existing ground systems, based on 1980s technology and software, 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. | GAO-15-320SP

Implementation
- **06/17** Final acceptance review (under review)
- **12/14** GAO review
- **06/13** Critical design review
- **04/13** Project confirmation

Formulation
- **09/12** Preliminary design review
- **11/11** Mission/system definition review
- **09/10** Formulation start

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2013	Latest Est. Feb 2015[a]	Change
Total Project Cost[a]	$493.9	~~$493.9~~	~~0.0%~~
Formulation Cost	$125.8	~~$125.8~~	~~0.0%~~
Development Cost[a]	$368.1	~~$368.1~~	~~0.0%~~
Operations Cost	$0	~~$0~~	~~0.0%~~
Launch Schedule	06 2017	~~06 2017~~	~~0 months~~

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

PROJECT SUMMARY

SGSS is being rebaselined. The project's costs are expected to exceed the agency's committed baseline cost by 30 percent and the committed final acceptance review date is expected to be delayed by 23 months. The agency has postponed a rebaseline review with center and agency management to revise cost and schedule baselines from November 2014 to June 2015, which is over 2 years after the project began to experience significant cost and schedule growth. One of the project's top risks is that the contractor's optimistic and aggressive assumptions about staffing levels under the proposed replan could impact cost and schedule beginning in fiscal year 2016. We have previously reported that SGSS project officials had concerns about the contractor's optimistic assumptions for the project, which led, in part, to the current rebaseline.

Space Network Ground Segment Sustainment

Funding Issues

SGSS is being rebaslined. The project's costs are expected to exceed the agency's committed baseline cost by 30 percent and project officials said the committed final acceptance review date is expected to occur 23 months past the originally scheduled date, slipping from June 2017 to May 2019.

In March 2014, SGSS presented replan options to the Space Communications and Navigation (SCaN) program, which oversees SGSS. Pending agency approval, SCaN instructed SGSS to proceed under the proposed replan. The replan acknowledged the contractor's poor cost and schedule performance and proposed new cost and schedule baselines for the project that were developed by the contractor and evaluated by the project. Further, the replan accounted for limitations that the agency placed on funding available to the contractor in fiscal years 2014 and 2015.

The replan also implemented two of the potential descopes. The first descope eliminates the requirement for a Local Backup Space Network Operations Center at NASA's White Sands Grounds Terminal and the second descope eliminates planned user services simulation—an internal means of testing. Project officials told us that these descopes may reduce project capacity, but would not affect overall capability.

The agency originally planned to hold a rebaseline review with center and agency management in November 2014 to approve a path forward for the project. However, in October 2014, the agency made the decision to delay this review until June 2015 in order to account for fiscal year 2015 and 2016 budget information. The delay will also allow the project the time to develop an updated joint cost and schedule confidence level, or JCL. The JCL, which quantifies potential risks and calculates cost and schedule estimates, is needed to support the rebaseline review. However, by the time NASA establishes new cost and schedule baselines it will have been over two years after SGSS began to experience significant cost and schedule issues. In the interim, the project plans to hold a review with agency management to discuss detailed planning for fiscal year 2015 that will include an update on the contractor's cost and schedule performance against milestones established in March 2014.

Contractor Issues

Contractor staffing issues are currently the project's top risk. The SGSS contractor is currently operating with a limited number of staff, but under the proposed replan intends to greatly increase the number of staff in fiscal year 2016, the first year that the project will not be under a constrained funding profile. We previously reported that SGSS project officials had noted concerns with the contractor's optimistic assumptions which led, in part, to the ongoing rebaseline. Project officials said that the proposed staffing increase is based on optimistic and aggressive assumptions about bringing staff onto the project. They do not expect that the contractor will be able to achieve this planned staffing increase. However, if the staffing levels are not achieved, the anticipated levels of productivity may not be attained and this would impact the project's cost and schedule. To reduce any impacts on the schedule, the project has been approved to rephase $15 million from fiscal year 2016 to fiscal year 2015, which allows the contractor to retain experienced staff. SGSS is continuing to work with the contractors to minimize any disruptions that may arise as staff is quickly brought onto the project.

Project Office Comments

SGSS project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. In addition to increasing funding in fiscal year 2015, SGSS officials stated that they are actively mitigating other risks through mechanisms such as early testing with operations centers.

Surface Water and Ocean Topography

Recent/Continuing Project Challenges
- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

International Partner: **Centre National d'Etudes Spatiales (CNES) (France), Canadian Space Agency (CSA) (Canada), United Kingdom Space Agency (UKSA) (United Kingdom)**

Launch Location: **TBD**
Launch Vehicle: **TBD**

Mission Duration: **3 years**

Requirement derived from:
2007 National Research Council Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **TBD**

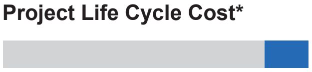
Contractor Activity: **TBD**

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

PROJECT PERFORMANCE

Then year dollars in millions

Preliminary estimate of Project Life Cycle Cost*

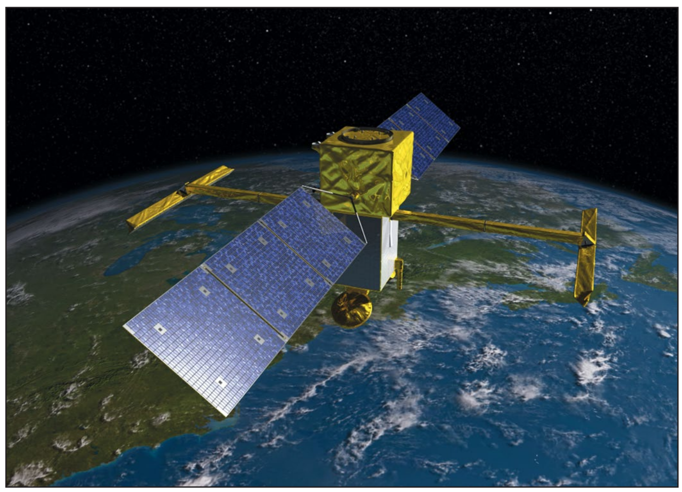


Latest: **February 2015 $647 – $757** MILLION

**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: **October 2020**

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



Source: NASA/JPL – Caltech (artist depiction). | GAO-15-320SP

PROJECT SUMMARY

SWOT is working toward the project's scheduled preliminary design review in January 2016. The project has added a new international partner, UKSA, who began partnering with CNES in 2014 to contribute to a key component of the Ka Band Radar Interferometer (KaRIn) radio frequency unit. Because KaRIn is receiving contributions from multiple international partners, the project is tracking a risk that KaRIn could face development challenges that could contribute to cost and schedule growth.

Implementation
- **10/20** Projected launch date
- **01/19** System integration review
- **06/17** Critical design review
- **03/16** Project confirmation

Formulation
- **01/16** Preliminary design review
- **12/14** GAO review
- **05/14** Mission design review/ system requirements review
- **11/12** Formulation start

Surface Water and Ocean Topography

PROJECT UPDATE

In June 2014, the project entered the preliminary design and technology completion phase and expects to hold its preliminary design review in January 2016. The project will establish cost and schedule baselines following that review. The project has a new international partner, UKSA, who began partnering with CNES in 2014 to contribute to a component of the KaRIn radio frequency unit. The project was granted a request to shift $29 million in funding from fiscal years 2017 and 2018 to fiscal year 2014 to reduce project risk and accelerate technology development.

Development Partner Issues

The project is tracking a risk that the significant investment of international partners in KaRIn's critical technologies could contribute to cost and schedule growth. GAO and the NASA Office of Inspector General have previously reported that receiving and integrating contributions from multiple partners may complicate development efforts and could contribute to cost and schedule growth.[a] NASA will develop, integrate, and test the primary science instrument, KaRIn, with multiple subsystems being developed with contributions from CSA, CNES, and UKSA. For example, CSA is building a radar transmitter subsystem, and CNES is building KaRIn's radio frequency unit which will include a duplexer, a key KaRIn instrument component that allows a radio antenna to both transmit and receive signals, with a contribution from UKSA. Project officials stated that the project's schedule was impacted as a result of delays that occurred while CNES was in partnership negotiations with the UKSA on KaRIn's radio frequency unit. The project intends to maintain concurrent development schedules with its international partners, to ensure that components being developed by international partners are delivered on time to NASA. To identify design issues early, project officials further stated that they plan to develop interfaces, or the connections between the instrument subsystems, to ensure that each international partner can accurately model how parts will fit together. This will help the project reduce the risk of a late delivery of the payload to CNES for spacecraft integration and testing.

[a]GAO, *NASA: Assessments of Selected Large-Scale Projects,* GAO-11-239SP (Washington, D.C.: March 3, 2011), National Aeronautics and Space Administration, Office of Inspector General, *NASA's Challenges to Meeting Cost, Schedule, and Performance Goals,* IG-12-021 (Washington, D.C.: September 27, 2012).

Project Office Comments

SWOT project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate. The project has recognized the additional complexity related to incorporating partner-supplied items and has proactively required early development of interface documentation, provision of emulators, exchange of simulators, and a robust test program. The project has developed detailed work plans and an integrated schedule that support the future development activities. NASA and the Jet Propulsion Laboratory's many years of experience working with CNES on three prior, successful, altimetry missions provide confidence in the partnership approach and methodology for SWOT.

Transiting Exoplanet Survey Satellite

Project Challenges
- Schedule
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

International Partner: **None**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **Falcom 9 v1.1**

Mission Duration: **3 years**

Requirement derived from:
2010 Decadal Survey

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital Sciences Corporation**

Contractor Activity: **Spacecraft Development**

Type of Contract: **Cost-Plus-Fixed Fee**
Date of Award: **May 2014**
Initial Value of Contract: **$64.3 million**
Current Value: **$68.0 million**

PROJECT PERFORMANCE

Then year dollars in millions

	Baseline FY 2015	Latest Est. Feb 2015	Change
Total Project Cost	$378.4	$357.7	-5.5%
Formulation Cost	$27.1	$27.1	0.0%
Development Cost	$323.2	$296.4	-8.3%
Operations Cost	$28.1	$28.2	0.4%
Launch Schedule	06 2018	06 2018	0 months

The Transiting Exoplanet Survey Satellite (TESS) science instrument is comprised of four identical, wide field-of-view cameras for conducting the first extensive survey of the sky from space. The mission's science goal is to discover exoplanets—or planets in other solar systems—orbiting nearby bright stars with an emphasis on discovering Earth-sized and super-Earth planets in the solar neighborhood. The TESS mission is planned to survey a significant portion of the sky and detect exoplanets during transit, the time when that planet's orbit carries it in front of its star as viewed from Earth. The information learned by the TESS mission is planned to enable further evaluation of the composition and atmosphere of identified exoplanets by ground- and space-based observations, such as the James Webb Space Telescope.

Source: NASA. | GAO-15-320SP

PROJECT SUMMARY

TESS was confirmed in October 2014, at which time it established cost and schedule baselines. However, the project has an aggressive schedule between the preliminary and critical design reviews. As a result, the project is tracking several technical risks that could lead to schedule delays or cost increases. Several of the project's top risks stem from the development of the data handling unit, which is necessary to process, store, and download the data collected by TESS.

Implementation
- **06/18** Committed launch readiness date
- **12/17** Manifested launch date
- **10/16** System integration review
- **07/15** Critical design review
- **12/14** GAO review
- **10/14** Project confirmation

Formulation
- **09/14** Preliminary design review
- **02/14** Mission system/ design review
- **04/13** Formulation start

Transiting Exoplanet Survey Satellite

PROJECT UPDATE

The project successfully held its preliminary design review in September 2014 and confirmation review in October 2014 when it established its cost and schedule baselines.

Schedule Issues

Many of the project's top concerns are schedule related due to an aggressive development schedule. The project's schedule originally had 7 months between the preliminary and critical design reviews, while according to project officials, NASA missions of this complexity or cost typically have one year between those reviews. As a result, project officials had been tracking a risk that the design for TESS may not be fully mature by the time of the critical design review. The compressed schedule was also raised by the Standing Review Board at the project's preliminary design review. GAO's best practice work on product development has shown that if a project's design is not sufficiently stable by the critical design review, the risk of cost and schedule impacts going forward increases.[a] To address this risk, in February 2015, the project has pushed its critical design review out by three months, to July 2015, so there are 10 months between the preliminary design review and the critical design review. However, the new schedule now compresses the time between the critical design review and the system integration review, which is a critical milestone before the project can begin system assembly, integration and test.

Design Issues

Several of the project's top risks stem from the development of the data handling unit, which is necessary to process, store, and download the data collected by TESS. For example, the project is still defining the requirements for this unit, which requires complex hardware and software developments on an aggressive schedule. Any technical issues that arise during development or increase the scope of requirements could impact the project's cost or schedule reserves. At the project's preliminary design review meeting, NASA's Standing Review Board raised concerns about the data handling unit. The Standing Review Board noted that its schedule is too aggressive, yet it remains months behind the other payload elements in terms of maturity, and that its combination of high power and small size is a thermal design challenge. In response to these concerns raised by the Standing Review Board, the project has approved the purchase of a flight-like engineering model of the data handling unit to mitigate schedule concerns with the data handling unit. The flight-like engineering model can be used in early instrument testing, which provides additional time for the flight unit to be completed.

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

Project Office Comments

TESS project officials provided technical comments on this draft, which were incorporated as appropriate. Project officials stated that the concerns raised by GAO were discussed during the project's confirmation review. As a result, the project is mitigating several design and schedule issues. However, project officials feel that they have sufficient cost and schedule reserve to meet the committed launch readiness date.

Agency Comments and Our Evaluation

We are not making any recommendations in this report. 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 the report provides a good opportunity for NASA to receive an independent perspective on its performance in acquisition of major programs and projects.

NASA agreed with our observation that there are several large, complex projects comprising the majority of the available budget over the next several years and that issues with any one of these projects could have large ramifications across the portfolio. The agency stated that it has learned from issues associated with JWST and reported that the project is making excellent progress against its new baselines. Similarly, the agency states that Orion and SLS are also making excellent progress. As we have reported, maintaining good performance on these projects is essential due to the cascading impacts negative performance of these projects could have across the portfolio.

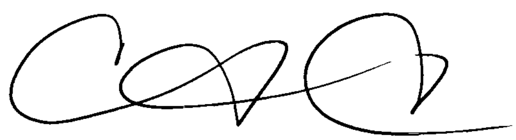
In its response, NASA also noted its continued dedication to improving its acquisition management processes and performance, which the agency believes will lead to its removal from the GAO High Risk list. NASA acknowledged that there continue to be areas for improvement as evidenced by the need to rebaseline the ICESat-2 and SGSS projects shortly after both projects were confirmed. NASA referred to several initiatives it currently has underway to strengthen management of its projects, including improving the JCL process and the agency’s use of earned value management. We are encouraged by NASA’s continued focus on and attention to these initiatives and believe that these efforts will facilitate the agency’s ability to successfully manage its portfolio of projects.

The agency noted that it has transitioned to a strategy of maturing critical technologies outside of specific projects and that this approach is better suited to its efforts to take on more challenging missions in both human space flight and earth and space science. Furthermore, the agency stated that this type of approach has the potential to enable new critical technologies to be incorporated in missions at lower cost risk than that incurred when the mission undertakes the technology maturation. GAO agrees and has previously reported that the approach of developing and maturing technologies outside of the acquisition program can reduce acquisition risk.[41] We look forward to further discussing this strategy with NASA in the future.

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

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

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



Cristina T. Chaplain
Director
Acquisition and Sourcing Management

[41]GAO, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes.* GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999).

List of Committees

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

The Honorable Ted Cruz
Chairman
The Honorable Gary C. Peters
Ranking Member
Subcommittee on Space, Science, and Competitiveness
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable John Culberson
Chairman
The Honorable Chaka Fattah
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

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

Appendix I: Objectives, Scope, and Methodology

Our objectives were to discuss broader trends and challenges faced by the agency in its management of large-scale acquisitions and to report on the status and challenges faced by 16 National Aeronautics and Space Administration (NASA) systems with life-cycle costs more than $250 million. Specifically, we assessed (1) the current performance of NASA's portfolio of major projects, (2) NASA's progress in developing and maturing critical technologies and efforts NASA has taken to improve design stability of its projects, and (3) the initiatives NASA has under way to reduce acquisition risk, along with work that remains to strengthen management of the agency's largest and most complex projects. In addition, this report includes assessments of 16 major NASA projects, each with life-cycle costs of more than $250 million.

To respond to these objectives, we analyzed data collected from May 2014 to March 2015 as well as data from prior reviews. We developed a standardized data collection instrument (DCI) which was completed by each project office. Through the DCI, we gathered and assessed data on each project's technology and design maturity, parts issues, and development partners. We developed other DCIs that were completed by NASA's Office of the Chief Financial Officer (OCFO) and Office of Procurement that gathered data on each project's cost performance, current and projected development activities (including the project's schedule and manifested/committed launch readiness dates), and contracts information.[1] NASA updated these DCIs in February 2015.

We also evaluated projects' monthly or quarterly status reports and other project documentation. We conducted interviews with officials from 13 of the 16 projects in our sample, as well as with NASA headquarters officials to identify and understand projects' progress to date and any risks. We reviewed the data and performed various checks to determine that the data were reliable for the purposes of this report. Where we discovered discrepancies, we clarified the data accordingly with agency and project officials. The information collected from each project office, OCFO, and Office of Procurement was summarized in a project assessment which provides a project overview; key cost, contract, and schedule data; and a

[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 estimated initial contract value when the government is required to reimburse the contractor for increased costs associated with performance.

discussion of the challenges associated with the deviation from relevant indicators from best practices standards. The aggregate measures and averages calculated were analyzed for meaningful relationships, for example, relationship between cost growth and schedule slippage and knowledge maturity attained both at critical milestones and through the various stages of the project life cycle.

To assess the current status of NASA's portfolio of major projects, we reviewed current cost and schedule data, technology maturity, design stability, and other challenges affecting each of the projects. To determine the extent to which each project exceeded its cost and schedule baselines, we compared the current cost and schedule data reported by NASA in February 2015 to previously established project cost and schedule baselines for the 12 projects in the implementation phase during our review. 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.[2] We also compared development cost growth and schedule delay in this year's portfolio against that of prior years to determine whether NASA major projects had improved in adhering to cost and schedule baselines. The remaining four projects were in an early stage of development called formulation where there are still unknowns about requirements, technology, and design. For those projects, NASA provided, and we reported, preliminary cost ranges and schedule estimates. All cost information is presented in nominal then-year dollars for consistency with budget data.[3] Current baseline costs reflect the cost accounting structure in NASA's fiscal year 2009 budget estimates. For the fiscal year 2009 budget request, NASA changed its accounting practices from full-cost accounting to reporting only direct costs at the project level.

To assess technology maturity, we asked project officials to provide the technology readiness levels of each of the project's critical and heritage technologies at various stages of project development—including the preliminary design review—and compared those levels against our

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

technology maturity best practice and NASA policy on technology maturity to determine the extent to which the portfolio was meeting the criteria. Our work has shown that a technology readiness level of 6—demonstrating a technology as a fully integrated prototype in a relevant environment—by the preliminary design review is the level of maturity needed to minimize risks for space systems entering product development. Originally developed by NASA, technology readiness levels are measured on a scale of one to nine, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. See appendix IV for the definitions of technology readiness levels. We 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 did not assess the average number of critical technologies being developed per project for projects that had not entered implementation at the time of this assessment. We also compared the number of critical technologies being developed per project with those in prior years to determine how the number of critical technologies developed per project had changed. 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.

To assess design stability, we asked project officials to provide the number of engineering drawings completed or projected for release by the preliminary and critical design reviews and as of our current assessment.[4] 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

[4]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.

released after the critical design review. In accordance with best practices, projects were assessed as having achieved design stability if at least 90 percent of projected drawings were releasable by the critical design review. We compared this year's results against those in prior years to assess whether NASA was improving in this area. We did not assess the design stability for those projects that had not yet reached the critical design review at the time of this assessment.

On February 14, 2013, we convened a meeting of experts, to discuss additional approaches for measuring design stability across a range of unique space acquisition projects. We contracted with the National Academy of Sciences to select and recruit a meeting of experts with a range of in-depth experience in engineering and managing unique space acquisition projects. We analyzed the input provided by the experts and following the meeting, distributed a questionnaire to each of the experts asking them to comment on the utility for measuring design stability of 12 metrics that were identified by the experts during the meeting. We also asked the experts to indicate, in their professional opinion, how important each metric was in assessing design stability on unique space acquisition programs and to identify the top 5 metrics. We asked project officials to describe how and to what extent they used each of the top five metrics—as identified by the design experts—to manage the project. We also asked project officials at what point would project performance as measured against the metrics raise a "red flag" for project management and what other measurements of design maturity and stability the project typically uses for project management purposes.

To assess NASA's progress and approach for reducing acquisition risk and improving its acquisition management practices, we reviewed NASA's metrics for measuring acquisition management and supporting data and updates to NASA's acquisition management plans as part of our High Risk update work.[5] To assess NASA's implementation of the joint cost and schedule confidence level (JCL) process, we reviewed JCLs for projects that had established them at the confirmation review. To identify the challenges associated with managing the performance of NASA's largest and most complex projects across the portfolio, we reviewed outstanding issues identified in our prior work on NASA, such as cost and schedule growth on one of NASA's most technologically advanced and

[5]GAO, *High Risk Series: An Update,* GAO-15-290, (Washington, D.C.: Feb. 11, 2015).

costly projects—the James Webb Space Telescope (JWST)—and earned value management implementation issues and assessed NASA's efforts to make progress on these issues. We also reviewed our previous work on NASA's Space Launch System (SLS) and Orion Multi-Purpose Crew Vehicle to determine the extent to which these projects have plans in place to achieve long term goals and promote affordability. To examine the challenges NASA faces in completing a series of complex, technically challenging, and expensive projects within available funding, we reviewed NASA budget documentation. To identify work that remains to strengthen management of the agency's largest and most complex projects, we examined studies commissioned by NASA to identify lessons learned and potential areas for opportunities to strengthen processes and performance in future, large-scale complex projects as well as other NASA studies.

Our work was performed primarily at NASA headquarters in Washington, D.C. In addition, we visited Goddard Space Flight Center in Greenbelt, Maryland; the Jet Propulsion Laboratory in Pasadena, California; Johnson Space Center in Houston, Texas; and Marshall Space Flight Center in Huntsville, Alabama.

Project Profile Information on Each Individual Project Assessment

This year, we developed project assessments for the 16 projects in the portfolio with an estimated life-cycle cost greater than $250 million. For each project assessment, we included a description of each project's objectives, information concerning the NASA center, major contractor, or other partner involved in the project, the project's cost and schedule performance, a schedule timeline identifying key project dates, and a brief narrative describing the current status of the project. We also provided a detailed discussion of project challenges for selected projects as applicable. We produced a one-page assessment for the Orbiting Carbon Observatory – 2 project, as the project was nearing the end of development work and preparing for launch and did not warrant a more detailed discussion.

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

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 the projected or actual launch date.[6] 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 Project Assessment

To assess the project challenges for each project, we submitted a DCI to each project office. In the DCI, we requested information on the maturity of critical and heritage technologies, the number of releasable design drawings at project milestones, and project partnerships. We also held interviews with representatives from 13 of the projects to discuss the information on the DCI. We then reviewed project documentation—including project plans, schedules, risk assessments, and major project review documentation—to corroborate any testimonial evidence we received in the interviews. These reviews led to identification of further challenges faced by NASA projects. A challenge was identified for a project if performance had been or could be affected by the issue. For this year's report, we identified the following challenges across the projects we reviewed: launch, contractor, integration of existing hardware, parts, development partner, funding, design, technology, test and integration,

[6]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.

schedule, and manufacturing. These challenges do not represent an exhaustive or exclusive list. They are subject to change and evolution as we continue this annual assessment in future years. The challenges, listed as "issues" in each project assessment, are based on our definitions and assessments, not that of NASA.

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

The individual project offices were given an opportunity to comment on and provide technical clarifications to the project assessments prior to their inclusion in the final product. We incorporated these comments as appropriate.

Data Limitations

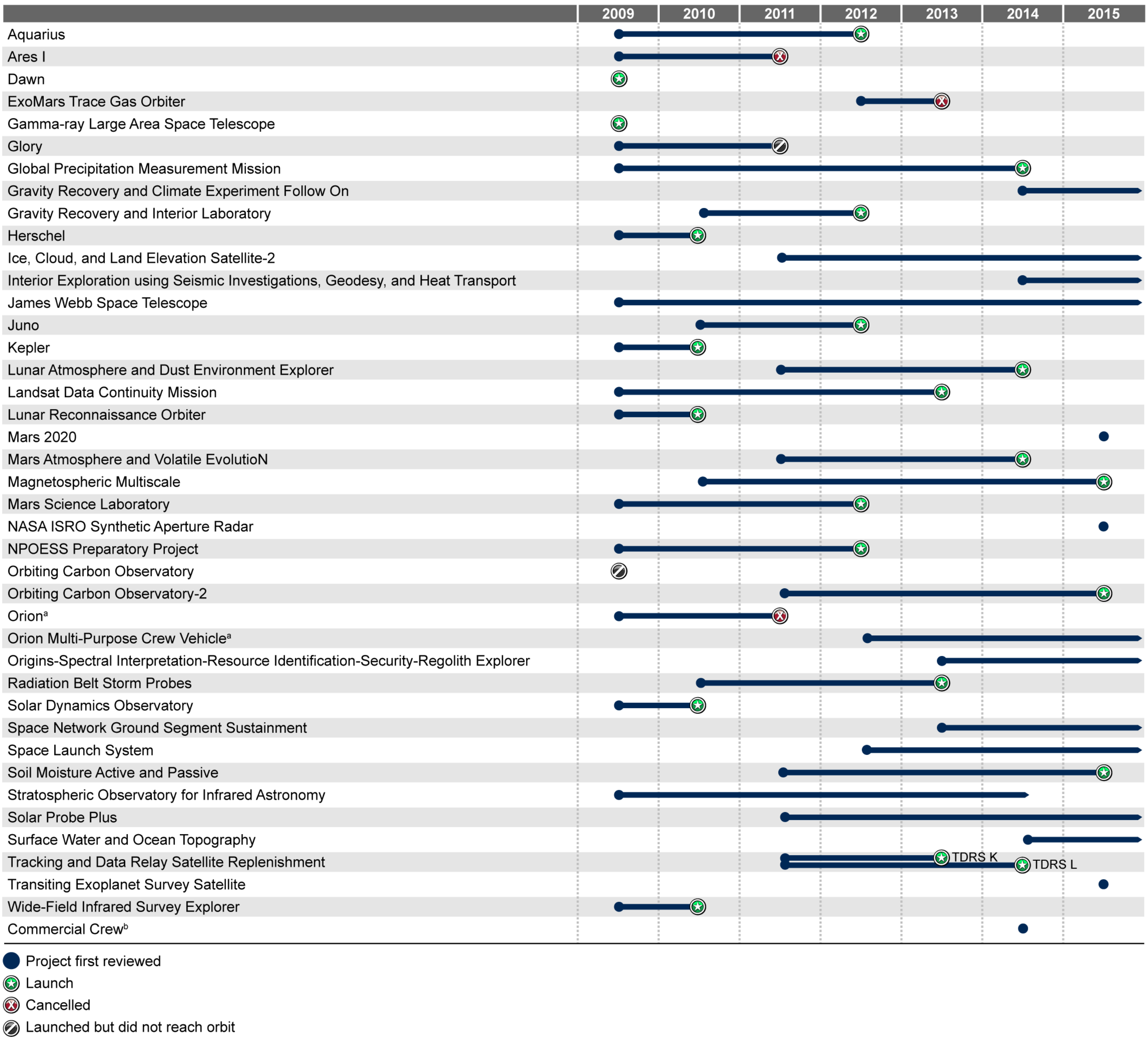
NASA provided updated cost and schedule data in February 2015 for projects in implementation, or 12 of the 16 projects in our review. NASA provided preliminary estimated life-cycle cost ranges and associated schedules for four of the projects that had not yet entered implementation, which are generally established at Key Decision Point-B. NASA formally establishes cost and schedule baselines, committing itself to cost and schedule targets for a project with a specific and aligned set of planned mission objectives, at Key Decision Point-C, which follows a preliminary design review. Key Decision Point-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 Key Decision Point-B, which occurs in the formulation phase, and hence, are not considered a formal commitment by the agency on cost and schedule for the mission deliverables. Due to changes that occur to a project's scope and technologies between Key Decision Point-B and Key Decision Point-C, the estimates of project cost and schedule can be significantly altered between the two key decision points.

We conducted this performance audit from May 2014 to March 2015 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 41 major National Aeronautics and Space Administration (NASA) projects or programs since our initial review in 2009. See figure 12 below for a list of projects included in our assessments from 2009 to 2015.

Figure 12: Selected Major National Aeronautics and Space Administration Projects Reviewed in GAO's Annual Assessments



Source: GAO analysis of NASA data. | GAO-15-320SP

[a]In 2014, NASA adopted Orion as the common name for Orion MPCV; the project did not change. This Orion project stems from the original Orion project that was cancelled in June 2011 when the Constellation program was cancelled after facing significant technical and funding issues. During the

closeout process for the Constellation program, NASA identified elements of the Ares I and Orion projects that would be transitioned for use on the new Space Launch System and Orion Multi-Purpose Crew Vehicle programs.

[b]A bid protest was filed on September 26, 2014, after NASA awarded Commercial Crew contracts. GAO issued a decision on the bid protest on January 5, 2015, which was after our review of projects had concluded; therefore we excluded the Commercial Crew Program from the 2015 review.

Appendix III: Selected Major NASA Projects Reviewed in GAO's 2015 Annual Assessment

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

PROJECTS IN FORMULATION

Project: Mars 2020
Launch Readiness Date: July 2020
Project Summary: Mars 2020, part of the Mars Exploration Program, will continue the systematic exploration of Mars by conducting geological assessments, searching for signs of ancient life, determining potential environmental habitability, and preparing well-documented samples for potential future return to earth.
Preliminary Estimate of Project Life-Cycle Cost: $2.14 – 2.35 billion

Project: NASA ISRO Synthetic Aperture Radar (NISAR)
Launch Readiness Date: December 2020
Project Summary: NISAR is a joint project between NASA and the Indian Space Research Organization that will systematically and globally study the solid Earth, ice masses, and ecosystems to address questions related to climate change, Earth's carbon cycle, and natural hazard impact mitigation.
Preliminary Estimate of Project Life-Cycle Cost: $718 – 808 million

Project: Orion Multi-Purpose Crew Vehicle (Orion)
Launch Readiness Date: Fiscal year 2021/2022
Project Summary: Orion is being developed to enable astronauts to explore deep space and to transport crew to the International Space Station as a backup capability if necessary.
Preliminary Estimate of Project Life-Cycle Cost: $8.53 – 10.29 billion

Project: Surface Water and Ocean Topography (SWOT)
Launch Readiness Date: October 2020
Project Summary: SWOT is a joint project between NASA and the French Space Agency that will collect measurements of the world's oceans and freshwater bodies to develop a global survey which will make it possible to estimate water discharge into rivers more accurately, and help improve flood and weather prediction.
Preliminary Estimate of Project Life-Cycle Cost: $647-$757 million

PROJECTS IN IMPLEMENTATION

Project: Gravity Recovery and Climate Experiment Follow On (GRACE-FO)
Launch Readiness Date: February 2018
Project Summary: GRACE-FO is a joint effort with the German Research Center for Geosciences (GFZ) that will provide global high-

resolution models of Earth's gravity field, which will provide increased insight into water movement on and beneath the Earth's surface over a 5-year mission period.
Latest Estimate of Total Project Cost: $431.9 million

Project: Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)
Launch Readiness Date: June 2018
Project Summary: ICESat-2, a follow-on mission to ICESat, will measure changes in polar ice-sheet mass in order to better understand mechanisms that drive changes in ice thickness and the impact of change on global sea level.
Latest Estimate of Total Project Cost: $1.06 billion

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

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

Project: Magnetospheric Multiscale (MMS)
Launch Date: March 12, 2015
Project Summary: MMS will provide insight into how magnetic fields around Earth connect and disconnect, explosively releasing energy via a process known as magnetic reconnection. MMS will provide a three-dimensional view of the magnetic reconnection process that occurs throughout the universe.
Latest Estimate of Total Project Cost: $1.12 billion

Project: Orbiting Carbon Observatory 2 (OCO-2)
Launch Date: July 2, 2014
Project Summary: OCO-2 is planned to make precise, time-dependent global measurements of atmospheric carbon dioxide and is expected to

enhance understanding of the carbon cycle which should improve predictions of future atmospheric carbon dioxide increases and their potential impact on the climate.
Latest Estimate of Total Project Cost: $427.6 million

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

Project: Soil Moisture Active and Passive (SMAP)
Launch Date: January 31, 2015
Project Summary: The SMAP mission is designed to provide soil moisture measurements and its freeze/thaw state that will improve understanding of regional and global water cycles and climate changes, and improve the accuracy of weather, flood, and drought forecasts.
Latest Estimate of Total Project Cost: $914.6 million

Project: Solar Probe Plus (SPP)
Launch Readiness Date: August 2018
Project Summary: SPP will be the first mission to visit a star. By directly probing the Sun's outer atmosphere or solar corona, this mission will increase our knowledge and understanding about the solar wind, including its origin, acceleration, and how it is heated.
Latest Estimate of Total Project Cost: $1.55 billion

Project: Space Launch System (SLS)
Launch Readiness Date: November 2018
Project Summary: SLS, a human-rated heavy-lift launch vehicle, is being developed to launch NASA's Orion vehicle and other systems, enabling deep-space exploration by humans.
Latest Estimate of Total Project Cost: $9.7 billion

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

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

Project: Transiting Exoplanet Survey Satellite (TESS)
Launch Date: June 2018
Project Summary: TESS will be used to conduct the first extensive survey of the sky from space with the goal of discovering Earth-sized and super-Earth planets orbiting nearby bright stars that can then be further evaluated through ground- and space-based observations.
Latest Estimate of Total Project Cost: $351.7 million

Appendix IV: Technology Readiness Levels

Technology readiness level	Description	Hardware	Demonstration environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis).	None.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis).	None.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytic 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. | GAO-15-320SP

Appendix V: Elements of a Sound Business Case

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

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

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

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

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

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

Appendix VI: National Aeronautics and Space Administration Projects' Use of Design Expert Panel Metrics

Over the course of our review, we discussed the use of the top five metrics as identified by the panel of experts GAO convened in February 2013 with NASA project managers to determine to what extent these metrics are used to manage projects. Factors such as where a project was in its lifecycle or whether or not a project was heavily based on heritage technologies influenced how projects tracked the design metrics. Other factors, such as whether or not a metric is one of the National Aeronautics and Space Administration's (NASA) technical leading indicators, also influenced how a metric was tracked.[1]

- **Level of funding reserves and schedule margin at various points in the development life cycle.** All projects reported using this metric to track cost and schedule reserves at least monthly, with some projects reporting that they track this metric weekly. NASA policy requires that projects maintain cost and schedule margins and monitor the status of these margins through the use of a Technical, Schedule, and Cost Control Plan, which documents how the program plans to report on technical, schedule, and cost status. Some centers provide additional guidance on cost and schedule reserves and on the frequency of reporting reserves. Solar Probe Plus—managed by the Applied Physics Laboratory, which project officials stated did not have institutional guidelines on reserves—also reported tracking this metric.

- **Percentage of verification and validation plans complete at the preliminary design review and the critical design review.** Use of this metric varied by project as well as where the project was in the development life cycle. For example, projects that had not completed a preliminary design review did not discuss the use of the verification and validation plans metric. However, project officials that had completed the preliminary design review milestone told us that they used or had used the verification and validation metric. Among projects that had completed the critical design review milestone, a

[1]In 2012, NASA established three technical leading indicators to assess design maturity. The indicators are (1) the percentage of actual mass margin versus planned mass margin, (2) the percentage of actual power margin versus planned power margin, and (3) the percentage of overdue requests for action. Mass is a measurement of how much matter is in an object. It is related to an object's weight, which is mathematically equal to mass multiplied by acceleration due to gravity. Margin is the spare amount of mass or power allowed or given for contingencies or special situations. A request for action is a formal written request sponsored by the review panel asking for additional information or action by the project team. It is generally developed as a result of insufficient safety, technical, or programmatic information being available at the time of the review.

majority of project officials told us that they monitored verification and validation plans monthly to assist in tracking the completion of verification and validation events and activities. While projects are not required to use verification trends, they are one of NASA's recommended programmatic and technical leading indicators.[2]

- **Definition of the project's top level requirements, that define mission success criteria and are imposed by NASA, to requirements at the sub-system level by the time of the preliminary design review.** All projects reported using this metric; projects that have not yet held a preliminary design review reported that they are working to define requirements, which entails generating drafts of requirements for discussion and review or finalizing requirements—depending on the project's phase. Projects in formulation also work to flow requirements down from one level to the next in order to satisfy requirements and mission needs. NASA policy provides that a successful preliminary design review is demonstrated by, among other things, finalization of all "top level" requirements.[3]
- **Maturity of critical technologies to technology readiness level (TRL) 6 by preliminary design review.** NASA policy is to have new technologies developed to an "adequate state" by preliminary design review, and projects reported that they had followed or were currently following this metric for both critical and heritage technologies. For example, Surface Water and Ocean Topography, a project in formulation with four critical technologies, reports tracking technology development through burndown charts to TRL 6 and aims to have all technologies to a TRL 6 seven months prior to preliminary design review. The project also reports TRL status in its monthly status

[2]According to the NASA Space Flight Program and Project Management Handbook, in addition to the three required programmatic and technical leading indicators, NASA also recommends the use of additional recommended programmatic and technical leading indicators. NASA's full list of recommended programmatic and technical leading indicators is designed to assess project design stability and maturity at key points in a project's life cycle. NASA has designed these leading indicators to objectively assess design stability and minimize costly changes late in development. The indicators cover nine areas, in addition to allowing for project specific indicators as needed. These areas are (1) Requirement Trends, (2) Interface Trends, (3) Verification Trends, (4) Software Unique Trends, (5) Problem Report/Discrepancy Report Trends, (6) Manufacturing Trends, (7) Cost Trends, (8) Schedule Trends, and (9) Staffing Trends.

[3]NPR 7123.1B Appendix G, Table G-6 (Apr. 18, 2013).

reports along with any revisions to the projected technology maturity date and the reason for the revision.

- **Percentage of actual mass margin versus planned mass margin over time.** All projects track the percentage of actual mass margin versus planned mass margin over time as it is one of NASA's three technical leading indicators required by NASA policy.[4] NASA Procedural Requirements 7123.1B state that projects should define, track, and actively manage mass margins, assessing them periodically and at major project milestone reviews. Projects reported that they track this metric in accordance with institutional requirements. Some centers provide additional guidance for mass margins including frequency of reporting and the percentage of mass margin required at various points in project development, with required margins ranging from 30 to 0 percent, depending on where a project is in the development cycle. Reporting is project- specific with the projects we talked to tracking this metric weekly, monthly, or quarterly. However, the Mars 2020 and Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) project officials stated that they are less concerned with this metric because their projects are based heavily on previous missions. As a result, these projects mainly comprise parts that have previously been built and tested and, according to project officials, therefore have less uncertainty with regard to mass because the potential for design changes is lower. InSight project managers stated that the project has been working to obtain a requirements waiver, as the project mass margins do not meet institutional requirements. The Jet Propulsion Laboratory —which is the lead NASA center for Mars 2020 and InSight—allows projects to apply for waivers in specific circumstances; however, the center can also require projects to carry additional margin.

[4] The mass of the Space Network Ground Segment Sustainment project is not monitored because the project is a ground system sustainment effort.

Appendix VII: Comments from the National Aeronautics and Space Administration

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

March 9, 2015

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) appreciate the opportunity to comment on the Government Accountability Office (GAO) draft report entitled "NASA: Assessments of Selected Large-Scale Projects" (GAO-15-320SP). 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. 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 year, including our successful launch of two science projects in 2014 and early 2015, as well as the Orion Exploration Test Flight-1 (EFT-1). On July 2, 2014, NASA launched the Orbiting Carbon Observatory-2 (OCO-2), the first mission to collect space-based measurements of atmospheric carbon dioxide with the precision, resolution and coverage needed to characterize its sources and sinks and quantify their variability over the seasonal cycle. The first global map of carbon dioxide was released in December 2014 and showed several hot spots in the Southern Hemisphere that could be caused by land use changes and agricultural fires. As the mission continues, the additional data will help scientists understand how carbon dioxide is distributed, both geographically and seasonally. On December 5, 2014, NASA completed the first test flight of the Orion crew vehicle, including a successful high speed reentry through the atmosphere. The EFT-1 mission of Orion was nearly flawless and the information from the test flight gives us increasing confidence in the systems we are designing to send the next generation on to Mars. On January 31, 2015, NASA launched the Soil Moisture Active Passive (SMAP) mission, which will produce global maps of soil moisture, which will aid in understanding the global water and carbon cycles. On-orbit checkout is scheduled to continue through April, at which point SMAP will begin its primary science operations. NASA also expects to launch the Magnetospheric Multiscale (MMS) mission later this month. The four MMS spacecraft will use Earth's magnetosphere as a laboratory to study the microphysics of three fundamental plasma processes: magnetic reconnection, energetic particle acceleration, and turbulence.

While NASA acknowledges that SMAP is the only project this audit cycle that launched within its original cost and schedule baseline, we believe a broader context is needed to put the OCO-2 and MMS performance in perspective. Both of these projects experienced situations outside of their control, as detailed in the individual project assessments. OCO-2 was rebaselined to accommodate a late change in launch vehicle and ultimately was launched well within the new cost and schedule baseline. MMS experienced a modest cost increase that required a replan, but was still manifested to launch within the Agency Baseline Commitment for schedule.

NASA agrees with the GAO's assessment that there are several large, complex projects comprising the majority of the available budget over the next several years and that issues with any one of these projects could have large ramifications across the portfolio. As we have previously discussed with the GAO, NASA has learned from the issues associated with JWST and the project is making excellent progress against its new baseline and continues to meet its annually-established milestones. Similarly, Orion and SLS are making excellent progress, and we look forward to bringing Orion to confirmation later this year. Once Orion has completed that milestone, NASA will fully assess the integrated path forward for Orion, SLS, and the Exploration Ground System.

This year's report provided additional perspective on the GAO's continued inclusion of NASA on its High Risk List and the areas where the GAO believes NASA needs to make additional progress. NASA remains dedicated to continuous improvement of its acquisition management processes and performance, which we believe will lead to removal from the GAO's High Risk List. The GAO's 2015 High Risk Report identified NASA as the top-ranked Agency for meeting the most criteria for removal from the High Risk and we are in agreement as to the areas where additional effort is required. As highlighted in both the GAO's draft report and the High Risk Report, NASA continues to implement several initiatives to mitigate acquisition management risks and provide additional tools to the project management community to enable them to better assess risks. We are extremely pleased to see progress toward improving cost and schedule performance, but acknowledge that there continues to be areas for improvement as evidenced by the need to rebaseline Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) and Space Network Ground Segment Sustainment (SGSS) shortly after both projects were confirmed.

One area of improvement identified by the GAO is related to the use of the Joint Cost and Schedule Confidence Level (JCL). As part of NASA's continuous improvement in cost estimating policies and processes, NASA instituted this policy in 2009 to increase the likelihood of project success at the specified funding level. Implementation of the JCL process closely followed the adoption of a policy that requires projects to be budgeted at seventy percent confidence level of their estimated cost. 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. While the policy has been in place for several years, NASA continues to implement and improve the use of the JCL process and provide additional tools and capabilities to project management personnel. For example, an update to the Cost

Estimating Handbook was recently released and provides specific JCL guidance in a dedicated appendix. NASA is also using the lessons learned from past JCL analyses to improve how these calculations are done for newer projects. This includes providing tailored guidance to individual projects as they go through confirmation, as well as changing the discussion surrounding JCLs to focus more on the risks and general applicability of the JCL analysis given project-specific considerations.

The GAO also specifically mentions earned value management (EVM) as important to understanding project performance during development. NASA is continuing to implement changes in response to the GAO's recommendations from its 2012 EVM audit. For example, over the past several years, NASA has rolled out an in-house EVM capability at all of the major spaceflight Centers. To date, this capability has been introduced at Marshall Space Flight Center, Goddard Space Flight Center, Kennedy Space Center, and, most recently, Johnson Space Center. NASA is also implementing several changes to strengthen the EVM community of practice and is providing additional training and tools to the NASA workforce to aid in the conduct of EVM analyses.

NASA has had numerous discussions with the GAO regarding the application of best practices and metrics to assess technological maturity and design stability. We appreciate the GAO's acknowledgement of the progress that has been made in adopting these metrics, as evidenced by the positive trends the GAO has observed. As the GAO notes, there are many indicators to measure a project's readiness as they move forward and NASA has provided projects with the flexibility to tailor their approach based on the metrics that make the most sense given where a project is in its lifecycle and any project-specific constraints or concerns. This approach is consistent with our policies and handbooks for program and project management.

In the area of technology development, NASA has transitioned to a strategy of maturing critical technology outside of a specific project. We believe that the current approach is better suited to NASA's efforts to take on more challenging missions in both human space flight and earth and space science. Work being done through the Space Technology Mission Directorate (STMD) encompasses a broad spectrum of technology readiness levels, and includes cross-cutting technologies that are broadly applicable across all NASA spaceflight mission areas and can be infused into NASA missions. For example, Mars 2020, a project added to the GAO's assessment this year, includes contributions not just from the Science Mission Directorate, but the Human Exploration and Operations Mission Directorate and STMD. In addition, the most recent Discovery program solicitation offered five new NASA-developed technologies for use by proposers. This approach has the potential to enable principal investigators to include new critical technologies in missions at lower cost risk than that incurred when the mission undertakes the technology maturation.

Finally, NASA would like to thank the GAO for continuing to consider and incorporate 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 jointly to address any questions and appreciates the ongoing dialog with the GAO on this critical subject. If you have any questions or require additional information, please contact Ellen Gertsen at (202) 358-0812.

Sincerely,

Robert M. Lightfoot
Associate Administrator

Appendix VIII: 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; Kathryn M. Buchinger; Lisa L. Fisher; Laura Greifner; Kristine R. Hassinger; Charlotte E. Hinkle; Ramzi N. Nemo; Kenneth E. Patton; Carrie W. Rogers; Roxanna T. Sun; Tonya Woodbury; and Kristin Van Wychen made key contributions to this report.

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