Asteroid Redirect Robotic Mission

Project Challenges
- Funding
- Technology
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partners: **NASA Science Mission Directorate, and NASA Space Technology Mission Directorate, Glenn Research Center, Goddard Space Flight Center, Langley Research Center**

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

Mission Duration: **TBD**

Requirement derived from: **U.S. Space Policy**

NASA 2014 Strategic Plan Alignment: **Strategic Objective 1.1 Develop evolving exploration**

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

Preliminary estimate of Project Life Cycle Cost[a]

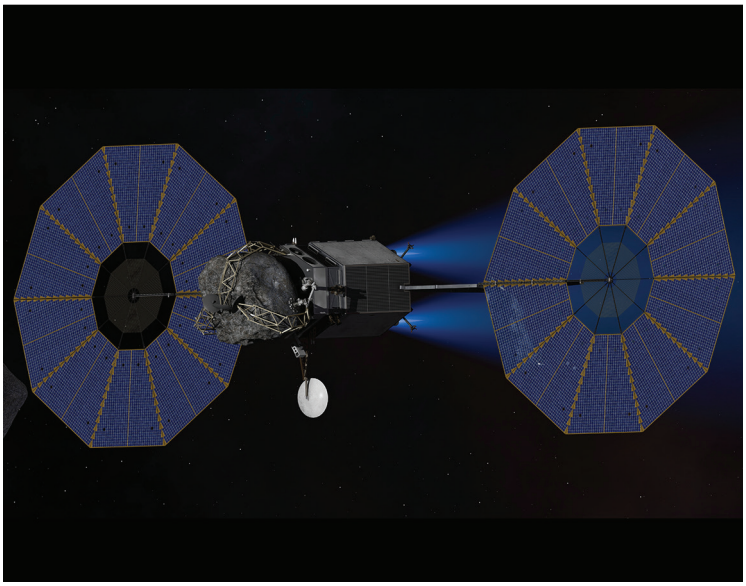
$1.72 BILLION

Latest: **February 2016**

[a]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 Asteroid Redirect Robotic Mission (ARRM) aims to retrieve a boulder from a selected asteroid and place it into lunar orbit for future human exploration. ARRM and the planned followed-on crewed mission to the boulder are capability demonstration missions, which are primarily designed to develop systems and provide the types of operational experiences required for future human and robotic exploration of Mars. ARRM will demonstrate technologies important for longer-duration, deep-space missions, such as advanced solar electric propulsion (SEP). The mission will also demonstrate an asteroid deflection technique by gravitationally altering the asteroid's trajectory.



Source: NASA/AMA Studios. | GAO-16-309SP

PROJECT SUMMARY

The ARRM project plans to leverage technologies from development efforts managed and funded by multiple NASA directorates, which could pose challenges for the project. The project's cost and schedule estimates assume that the agency will sufficiently fund these efforts. The Space Technology Mission Directorate is responsible for advanced SEP development, which contains some of the project's most significant risks. NASA has developed and tested prototypes of major SEP components, but there is limited time to complete their development, due in part to the project's launch window. NASA is also studying options for the ARRM spacecraft design and awarded four early design study contracts in January 2016 that will inform the spacecraft development contract.

12/20 Projected launch readiness date

07/19 System integration review

08/18 Critical design review

Implementation

04/17 - 06/17 Project confirmation

04/17 Preliminary design review

02/16 Mission/ system definition review

12/15 **GAO review**

Formulation

04/15 Formulation start

Asteroid Redirect Robotic Mission

Cost and Schedule Status

The ARRM project entered the concept and technology development phase in April 2015. The project has set an initial development cost cap of $1.25 billion, not including a launch vehicle or mission operations, and a launch readiness date of December 31, 2020.

Funding

The ARRM project is dependent on development efforts from multiple NASA directorates and the project's cost and schedule estimates assume that the agency will sufficiently fund these efforts. The Human Exploration and Operations Mission Directorate is the lead for the effort, but the Space Technology Mission Directorate will provide technology in key areas. The project plans to leverage high-powered solar electric propulsion (SEP) technologies currently being funded and developed by the Space Technology Mission Directorate. Between fiscal years 2015 and 2019, the Space Technology Mission Directorate plans to spend $230 million to develop SEP technologies. The ARRM project also plans to leverage advanced controls, sensors, and robotics technologies from the Space Technology Mission Directorate's Restore-L satellite servicing mission, but as a result of the Consolidated Appropriations Act, 2016, funding for Restore-L cannot be used to support activities solely needed for ARRM. The project assumes that approximately $50 to $60 million of the planned funding between fiscal years 2015 and 2019 for maturing Restore-L technologies will also support ARRM's development.

Technology

NASA has developed and tested prototypes of major components that could be used on the advanced SEP system, but it remains a source of cost and schedule risk for the project. SEP uses energy from the sun to accelerate propellant to produce a more fuel efficient thrust, which could benefit longer missions because it requires less propellant and reduces spacecraft mass. Among the potential SEP-related risks for the project is it has limited time to develop the system's component technologies, such as the power processing unit and solar array hardware. Development time is limited, in part, due the mission's December 2020 target launch readiness date.

Design

The ARRM project is studying options for the spacecraft design, and hopes to achieve cost savings and reduce risk by building on a commercially available spacecraft. The project awarded four early design study contracts in January 2016 to inform the spacecraft development contract.

The ARRM project has noted that if new crew safe requirements or requirements to support the follow-on Asteroid Redirect Crewed Mission, planned for 2025, are added to the project, then development costs could significantly increase. One of the key design assumptions for ARRM is that its Asteroid Redirect Vehicle will be "crew safe," but not "human rated." ARRM will carry hardware to make it possible for the Orion Multi-Purpose Crew Vehicle to dock with the ARRM vehicle after it brings the captured boulder into lunar orbit and for astronauts to conduct a study of the captured boulder outside the vehicle. If this follow-on crewed mission requires the ARRM Asteroid Redirect Vehicle to meet human-rated systems standards, such as resistance to cracking, then the vehicle would require design changes and additional testing.

Other Issues to Be Monitored

NASA has taken steps to address potential management and funding complexities that could affect the execution of ARRM. In November 2015, the heads of the human exploration and space technology mission directorates signed a memorandum of agreement defining the programmatic relationship between the two directorates for ARRM development. The project also plans to use a streamlined process for upcoming key decision point reviews.

Project Office Comments

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

Commercial Crew Program

DRAFT FOUO/Proprietary

Project Challenges
- Schedule
- Design (new)
- Launch (new)
- Funding

PROJECT ESSENTIALS

NASA Center Lead: **Kennedy Space Center**

Partners: **Boeing, SpaceX Blue Origin,* Sierra Nevada Corporation***

Launch Location: **Boeing-Cape Canaveral AFS, FL; SpaceX-Kennedy Space Center, FL**
Launch Vehicle: **Boeing-Atlas V; SpaceX-Falcon 9**

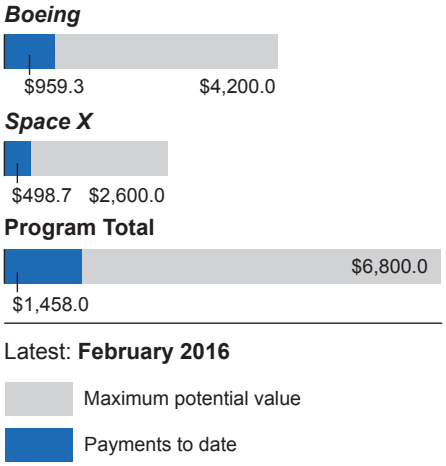
Requirement derived from: **NASA Strategic Plan**

NASA 2014 Strategic Plan Alignment: **Strategic Objective 1.3 Foster the commercialization of space transportation**

**Blue Origin and Sierra Nevada Corporation are CCP partners, but they do not have contracts with NASA for the Transportation Capabilities phase and therefore were not included in this assessment.*

TRANSPORTATION CAPABILITIES PHASE CONTRACTS

Then year dollars in millions



Latest: **February 2016**

Maximum potential value

Payments to date

The purpose of the Commercial Crew Program is to facilitate the development of safe, reliable, and cost-effective crew transportation systems (CTS) to carry NASA astronauts and cargo to and from the International Space Station (ISS). The Commercial Crew Program is a multi-phase effort that started in 2010 to stimulate private-sector interest in providing commercial human space transportation capabilities. The current Transportation Capabilities phase is intended to result in the final certification of CTSs for crewed flights. In September 2014, NASA awarded firm-fixed price contracts to Boeing and SpaceX for the design, development, test, and operation of CTSs; a minimum of two, but up to six crewed missions to ISS; and special studies, tests, and analysis.

Source: United Launch Alliance (left); Space Exploration Technologies (right). | GAO-16-309SP

PROJECT SUMMARY

The Commercial Crew Program is working to an aggressive schedule to certify Boeing and SpaceX CTSs by the end of 2017, at which point they could be used for crewed flights to and from ISS. To meet this schedule, Boeing and SpaceX are concurrently developing, testing, and producing their vehicles—a high risk strategy that could lead to costly modifications to systems already being built and delays if problems are identified during testing. In addition, the program is concerned that certification could be delayed, in part, because of a lack of design maturity in the companies' crew vehicles. Both companies held critical design reviews in 2015 and each had several key crew vehicle subsystems designs that were not yet mature. The program put Boeing and SpaceX on contract in 2015 for their first post-certification missions. The companies will need to complete the certification process before these flights.

2017/2018 Missions

2017 Final certification

12/15 GAO review

11/15 SpaceX authority to proceed with first post-certification mission

05/15 Boeing authority to proceed with first post-certification mission

09/14 Transportation capabilities phase contract awards

2012 – 2014 Integrated capabilities phase

2010 – 2012 Development phase

Commercial Crew Program

DRAFT FOUO/Proprietary

Cost and Schedule Status

NASA held an agency review in October 2015 to establish cost and schedule baselines for the Commercial Crew Program, but it has not yet finalized its decisions from the review, including the amount of cost and schedule reserves it will hold for risk mitigation activities.

Schedule

The Commercial Crew Program is working to an aggressive schedule to certify Boeing and SpaceX's CTSs by the end of 2017. To meet this schedule, Boeing and SpaceX are concurrently developing, testing, and producing their vehicles. Overlaps between these activities increase the risk that problems identified during development or testing could lead to costly modifications to systems already being built and schedule delays. The program ordered the first post-certification missions from the companies in 2015 before they completed development or tested their CTSs. These orders are made two to three years prior to actual mission dates in order to provide time for each company to manufacture and assemble the launch vehicle and spacecraft.

Boeing and SpaceX have yet to complete the majority of their critical test events and there is little time between test events for the companies to learn from them and make changes. Both companies plan to complete their uncrewed and crewed demonstration missions that are intended to test key system capabilities including their ability to launch, dock with the International Space Station (ISS), and return to Earth in 2017 and there are only about 4 months between each of these demonstrations. The companies will need to successfully complete these demonstrations and the certification process before they can fly post-certification missions. NASA extended its contract with the Russian Federal Space Agency to procure additional seats on the Soyuz vehicle through 2018 to ensure that it has access to ISS if delays occur.

Design

The Commercial Crew Program is monitoring several design-related issues that could delay final CTS certification, including the maturity of Boeing and SpaceX's current designs and the ability of the companies to meet NASA requirements and standards. Both Boeing and SpaceX held critical design reviews in 2015, but will not complete design activities until later than planned. Boeing held a critical design review in March 2015 for its CTS, which includes the Starliner crew vehicle, Atlas V launch vehicle, and ground systems, and a follow-on review in May 2015 that focused on the design of the launch vehicle and launch site. SpaceX held the first part of a multi-part critical design review in October 2015, which focused on the design of its launch vehicle—an upgraded version of the Falcon 9—and uncrewed ground systems, and the second part in December 2015, which focused on the Crew Dragon capsule and mission operations. An additional critical design review is planned to be completed by August 2016 for any remaining Dragon component or subsystem designs, including an updated seat design, and the crewed ground systems.

The program is tracking risks related to the design maturity of both companies' crew vehicles because they have several key subsystem designs that are not yet mature. For example, Boeing does not plan to complete the final lower-level component

design reviews for crew life support systems until May 2016 and SpaceX does not plan to completely mature its Dragon seat designs until spring 2016. Our best practice work shows that having a stable design prior to hardware fabrication can reduce the risk of rework efforts that could result in cost increases and schedule delays. For the parts of the CTS designs that are mature, the program is using a design change control process to assess the potential effects of proposed design changes on safety, and to approve or disapprove the companies' proposed changes.

Both companies have requested variances, or permission from the program to deviate from certain NASA requirements and design standards. If the program does not approve some of these variances, it could force the companies to make design changes, which could have cost and schedule implications. For example, Boeing requested variances for aspects of both the Starliner and Atlas V designs that do not meet fault tolerance requirements, which are requirements related to the ability of a system to continue operating should a component error or failure occur. SpaceX has requested a variance to use commercial-off-the shelf parts in certain applications rather than parts that have gone through special testing to be considered "space-rated." SpaceX officials said that they have used this approach and proven that it is reliable for multiple short-duration cargo missions. Overall, the program is taking several steps to mitigate these types of issues, including accommodating the companies' specific ways of doing business, limiting changes to requirements that might lead to design changes, and actively engaging with the companies on requested variances.

The Commercial Crew Program is also concerned that it may fall short of meeting the program's loss of crew requirement based on the current CTS designs. The program's loss of crew requirement is 1 in 270, which is a measure of how likely there will be loss of crew on a given mission. This is an increase in the requirement from the end of the Space Shuttle program, which was about 1 in 90. Boeing and SpaceX are responsible for meeting a loss of crew requirement of 1 in 200, and the program is responsible for closing the gap between that requirement and the one for the program. The program conducted assessments of each company's designs in order to meet the overall requirement and determined that it would be challenging without additional spacecraft modifications to protect against micrometeoroid and orbital debris. The companies would need to make these design changes soon, as they are both moving into manufacturing their systems. The program has established a team to develop a plan to close the requirements gap.

Launch

The Commercial Crew Program is working to address a number of launch vehicle issues that will need to be resolved prior to certifying that the vehicles are safe to transport crew.

- Boeing's selected launch vehicle, the Atlas V, is being modified by adding a new emergency detection system and a second engine to its upper stage, so that it can be certified for human spaceflight and meet fault tolerance requirements. However, based on the number of variances the launch vehicle provider has submitted for the new upper stage configuration, the program is concerned that the modified Atlas V could increase the level of risk on the program.

- SpaceX's launch vehicle, the Falcon 9, has been upgraded to improve its performance by increasing engine thrust and using densified propellants. Among the risks associated with the upgraded vehicle is SpaceX's planned concept of operations for launching using densified propellants. SpaceX plans to load crew into the Dragon and then fuel the rocket to keep the densified propellants chilled. The program has reported that loading the crew prior to the propellant is a potential safety risk. SpaceX stated that its approach will improve safety by minimizing personnel exposure to a fueled rocket. It has also identified safety and hazard controls to mitigate any risks associated with this approach. In December 2015, SpaceX launched the upgraded Falcon 9 for the first time and successfully landed its first stage on land.

Commercial Crew Program

Funding

One of the Commercial Crew Program's top risks during 2015 was funding uncertainty, but this appears to have been alleviated with the passage of the Consolidated Appropriations Act, 2016. In the Act, the program received funding in the amount requested by NASA. According to NASA, one of the reasons for the funding uncertainty was confusion over the way NASA is financing the contracts. The design, development, test, and evaluation activities in the contract that culminate in certification are fixed-price. The program uses performance-based payments, also referred to as milestone payments, to finance Boeing and SpaceX, and they are only paid after the successful completion of a milestone. The program designated five mandatory milestones, such as the certification review, and the companies developed a set of interim milestones. Under a fixed-price contract with performance-based financing payments, the contractors' incurred costs are irrelevant, and the milestone payments help finance the contract through development to completion. For example, the companies might use milestone payments received for completing the critical design review milestones to purchase hardware for test articles. Moving forward, if the program receives inadequate funding to finance planned contract work, it could be required to renegotiate the contract, which may result in price increases and schedule delays.

Project Office Comments

In commenting on a draft of this assessment, Commercial Crew Program officials stated that having at least two companies developing different crew transportation systems provides benefits in redundancy, innovation, and cost effectiveness. They also stated that the program was not funded at the levels requested in the President's Budget Request during fiscal years 2011-2015, which were critical years of design and development. They emphasized that adequate and timely funding and maintaining competition between the two companies are essential to ensuring program performance. Commercial Crew Program, Boeing and SpaceX officials provided technical comments, which were incorporated as appropriate.

Europa

Project Challenges
- Funding
- Design
- Launch
- Technology

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partner: **TBD**

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

Mission Duration: **3 years science mission**

Requirement derived from: **2010 Decadal Survey**

NASA 2014 Strategic Plan Alignment: **Strategic Objective 1.5 Understand the solar system**

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

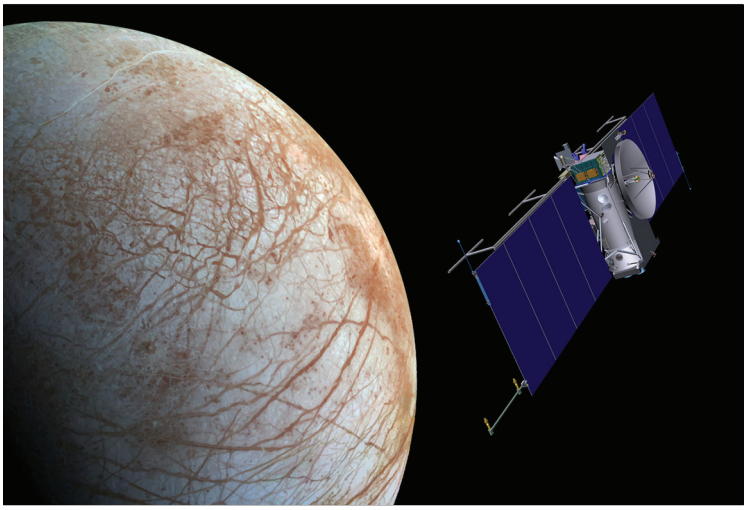
Preliminary Estimate of Project Life Cycle Cost[a]

[a]*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[b]: **July 2022**

[b]*The launch schedule is for planning purposes and could change as the project explores design options, such as incorporating a lander.*

The Europa mission aims to investigate whether the Jupiter moon could harbor conditions suitable for life. The project plans to launch the spacecraft in the 2020s, put it in orbit around Jupiter, and conduct a series of 45 investigatory flybys of Europa. The mission currently has four planned science objectives: (1) characterize Europa's ice shell and any subsurface water, (2) understand the habitability of Europa's ocean by analyzing its composition and chemistry, (3) understand the formation of surface features, and (4) characterize scientifically compelling sites for a potential future landed mission.



Source: Europa Project Personnel, California Institute of Technology, Jet Propulsion Laboratory
GAO-16-309SP

PROJECT SUMMARY

The Europa project has developed its mission profile and selected its science instruments, but it is still evaluating possible launch dates, launch vehicles, and additional payloads, all of which can have an effect on the project's cost, schedule, and risk. The project is working to a July 2022 launch readiness date that is contingent upon the project continuing to be appropriated more funding than requested by NASA, as it has for the past 4 years. However, the project is currently reassessing its plans after the Consolidated Appropriations Act, 2016 required it to incorporate a Europa lander, which would require significant design changes and increase the project's costs and development schedule. The Act also requires the Europa project to use the Space Launch System (SLS), which could have cost, schedule, and risk implications. SLS offers a shorter travel time to Jupiter than other launch vehicles, but it poses other risks since it may still be in development at Europa's preliminary design review—the point when projects prefer to select a launch vehicle.

07/22 Projected launch readiness date

07/20 System integration review

05/19 Critical design review

Implementation

05/18 Project confirmation

03/18 Preliminary design review

06/16 System requirements/ mission definition review

12/15 GAO review

Formulation

06/15 Formulation start

Europa

Cost and Schedule Status

The Europa project entered the concept and technology development phase in June 2015. It plans to enter the preliminary design and technology completion phase in July 2016, at which point it will establish a range of the expected cost and schedule for the project. The project developed its current plan before the Consolidated Appropriations Act, 2016 required Europa to fly an orbiter with a lander.

Funding

The Europa project is currently working to a July 2022 launch readiness date that is contingent upon the project receiving a higher level of funding than requested by NASA. The project was appropriated more funding than the agency requested for the past 4 years. For instance, in fiscal year 2016, the project was appropriated $175 million, which was $145 million more than NASA requested. However, even with this level of funding, it is unclear whether the 2022 launch date is still feasible given the direction to include a lander as part of the project.

Design

NASA may have to make significant changes to its planned design concept. The Consolidated Appropriations Act, 2016 requires Europa to fly an orbiter with a lander. The project is currently assessing how it will incorporate this into its current mission concept. Project officials previously stated that a lander would require significant design changes and increase the project's costs and development schedule. The project has set aside 250 kilograms of mass for payload options, such as a potential life detection instrument or a free-flying component to investigate plumes emitted from Europa's surface. Project officials have stated that a lander cannot be accommodated within this 250 kilogram limit.

Launch

The choice of launch vehicle could have cost, schedule, and risk implications for Europa. The project was maintaining compatibility with both evolved expendable launch vehicle variants, such as the Delta IV, Atlas V, and Falcon Heavy, and NASA's SLS; however, the recently enacted Consolidated Appropriations Act, 2016 requires the Europa project to launch on an SLS. Project officials said they view SLS as the best option because it offers a shorter travel time to Jupiter. However, it involves other risks. SLS will likely still be in development when Europa holds its planned preliminary design review in March 2018. The preliminary design review is the point when projects usually prefer to select a launch vehicle because it can affect the design of the spacecraft. Project officials previously said they would be willing to delay launch vehicle selection and maintain spacecraft compatibility with both launch vehicle options for 8 months until the SLS's committed launch readiness date of November 2018.

Technology

According to project officials, the Europa project's nine planned science instruments have been used in prior versions on other missions, but additional development will be required to ensure that they are adequately protected from Jupiter's harsh radiation environment. The damaging effect of Jupiter's harsh radiation environment on flight systems is the project's top risk. To mitigate this risk, the project is testing parts, modeling the spacecraft exterior, and reviewing radiation survivability approaches.

Project Office Comments

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

Exploration Ground Systems

Project Challenges
- Design
- Schedule

PROJECT ESSENTIALS

NASA Center Lead: **Kennedy Space Center**

Partners: **Ames Research Center, Johnson Space Center, Langley Research Center, and Marshall Space Flight Center**

Requirement derived from: **NASA Authorization Act of 2010**

NASA 2014 Strategic Plan Alignment: **Strategic Objective 1.1 Develop evolving exploration systems and capabilities**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Hensel Phelps Construction**

Contractor Activity: **Install work platforms for Space Launch System in Vehicle Assembly Building High Bay 3**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **March 2014**
Initial Value of Contract: **$99.6 million**
Current Value: **$124.7 million**

The Exploration Ground Systems (EGS) program is modernizing and upgrading infrastructure at the Kennedy Space Center and developing software needed to integrate, process, and launch the Space Launch System (SLS) and the Orion Multi-Purpose Crew Vehicle (Orion). The EGS program includes several major construction and facilities projects involving the Mobile Launcher, Crawler Transporter, Vehicle Assembly Building (VAB), and launch pad, all of which need to be complete before the first uncrewed exploration mission (EM-1) using the SLS and Orion vehicles.

Source: NASA. | GAO-16-309SP

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

$2,812.9		0.0% CHANGE
$2,812.9		

Formulation Cost

$969.4		-0.4% CHANGE
$965.8		

Development Cost

$1,843.5		0.2% CHANGE
$1,847.1		

Operations Cost

N/A		0% CHANGE
N/A		

Launch Schedule

11 2018 — 11 2018 | **0 months** CHANGE

Baseline FY 2014 | Latest Est. Feb 2016

PROJECT SUMMARY

The EGS program held its critical design review in December 2015, but several technical issues are putting pressure on the program's overall schedule. In an assessment prior to that review, NASA indicated that all EGS systems were mature with the exception of two software development efforts. The program is tracking these software development efforts as well as modifications to the building where SLS is assembled as top program risks. The EGS program is also tracking multiple risks related to the interdependencies between the Orion, SLS, and EGS programs. For example, EGS is working with SLS to resolve a problem identified with the connections between EGS support infrastructure and the SLS upper stage. Those issues, if not addressed, could affect EGS's ability to meet its November 2018 launch readiness date.

Implementation
- **11/18** Committed launch readiness date
- **07/16** System integration review
- **12/15** **GAO review**
- **12/15** Critical design review

Formulation
- **05/14** Project confirmation
- **03/14** Preliminary design review
- **08/12** Mission/system definition review
- **02/12** Formulation start

Exploration Ground Systems

Cost and Schedule Status

The EGS program held its critical design review in December 2015. Technical issues with the VAB, Mobile Launcher, verification and validation testing, the Ground Flight Application Software (GFAS), and the Spaceport Command and Control System (SCCS) have increased schedule risk.

Design and Schedule

Prior to the EGS program's critical design review, NASA indicated that all major EGS sub-systems were mature, with the exception of two software systems known as SCCS and GFAS, which have experienced development delays. The EGS program is concerned that delays in SCCS software development could affect the launch date for the first uncrewed exploration mission. The program is developing two software systems concurrently—the SCCS to operate and monitor ground equipment needed to launch and communicate with the integrated SLS and Orion vehicles, and GFAS to interface with flight systems and ground crews. SCCS development is behind its planned software release schedule. Program officials attributed the delays to workforce limitations—in both the number of staff and level of expertise. According to officials, the program has hired additional staff for SCCS and will be adding staff to GFAS in 2016 to help resolve this issue. In addition, the program is tracking a risk that development of GFAS could be delayed and costs could increase because it is dependent in part on SCCS development progress. GFAS must function within an operating structure defined by SCCS. Program officials expect the added workforce and, for GFAS, a schedule replan, to reduce the risk to both software programs.

Construction and safety issues associated with modifications to the VAB—the Apollo-era building where all parts of SLS will be assembled together—are also a top program risk. For example, according to EGS officials, the program has experienced challenges with the construction of new platforms in the VAB to accommodate SLS because the design of the platforms had to be modified to resolve issues discovered during hardware testing. Further, parts of the VAB do not meet national fire safety standards. Program officials said they are addressing the compliance issues in accordance with agency policy and procedures. The program estimates that if the platform design challenges continue, they may delay the completion of the VAB and result in a cost increase.

Other Issues to be Monitored

The EGS program is also tracking multiple risks related to the interdependencies between the Orion, SLS, and EGS programs. NASA is developing the three programs separately, but plans for them to function together in order to launch SLS and Orion. While the program has made progress on the major equipment and facilities modernization initiatives, EGS officials said ongoing issues may affect the design and installation of systems that interact directly with the Orion and SLS vehicles. For example, recent modeling showed that the connection that supplies power, fuel, and cooling connectivity between the SLS upper stage and the mobile launcher may apply more force than anticipated while moving away from the upper stage during launch. As a result, the EGS program is redesigning the connection. The mobile launcher is currently driving the project's overall schedule, so any issues it encounters have the potential to affect the program's ability to meet its November 2018 launch readiness date.

Project Office Comments

In commenting on a draft of this assessment, EGS program officials emphasized that the program is holding sufficient schedule reserve to cover potential GFAS and VAB delays. They also stated that multiple integrated technical task teams and programmatic working groups exist to facilitate integration among SLS, Orion, EGS, and the enterprise. The program officials also provided technical comments, which were incorporated as appropriate.

Gravity Recovery and Climate Experiment Follow-On

Project Challenges
- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partner: **German Research Centre for Geosciences (Germany)**

Launch Location: **Yasny, Russia**
Launch Vehicle: **Dnepr**

Mission Duration: **5 years**

Requirement derived from:
NASA 2010 Climate Plan

NASA 2014 Strategic Plan Alignment: **Strategic Objective 2.2 Understand our home planet**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Airbus Defence and Space**

Contractor Activity: **Satellite buses**

Type of Contract: **Firm-Fixed-Price**
Date of Award: **January 2012**
Initial Value of Contract: **$118.4 million**
Current Value: **$124.3 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$431.9
$431.9
0.0% CHANGE

Formulation Cost
$107.4
$107.4
0.0% CHANGE

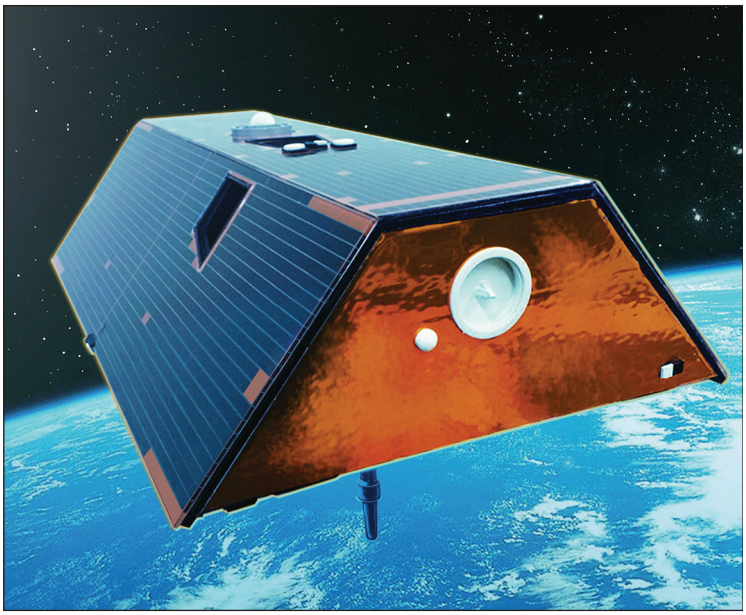
Development Cost
$264.0
$263.4
-0.2% CHANGE

Operations Cost
$60.5
$61.1
1.0% CHANGE

Launch Schedule
02 2018 — 02 2018
0 months CHANGE

Baseline FY 2014
Latest Est. Feb 2016

The Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) will continue and expand upon the 2002 GRACE mission, which remains in operation. It will provide high-resolution models of Earth's gravity field and insight into water movement on and beneath the Earth's surface over a 5-year period. These models will provide rates of ground water depletion and polar ice melt and enable improved planning for droughts and floods. The system operates as an observatory with instruments working concurrently within its two spacecraft. GRACE-FO is a collaborative effort with the German Research Centre for Geosciences (GFZ).



Source: NASA/JPL Caltech. | GAO-16-309SP

PROJECT SUMMARY

The GRACE-FO project successfully completed its critical design review and system integration review in 2015 and remains on track to launch 6 months early in August 2017. The project completed its critical design review with a mature design, which was largely based on heritage technology used in GRACE. The project continues to track risks related to its Russian launch vehicle and launch site. It is working with GFZ to develop alternative launch service options in the event that political or other risks affect the availability of the Dnepr launch vehicle. The project is also tracking a health risk for staff at its new launch site in Yasny, Russia, which is near an asbestos mine. The launch site changed from its original site in Kazakhstan to Yasny for technical reasons. The project will have to manage potential staffing challenges, since some personnel are not willing to travel to the new site.

02/18 Committed launch readiness date

08/17 Manifested launch readiness date

12/15 GAO review

07/15 System Integration review

02/15 Critical design review

Implementation

02/14 Project confirmation

01/14 Preliminary design review

07/12 Mission/ system definition review

01/12 Formulation start

Formulation

Gravity Recovery and Climate Experiment Follow-On

Cost and Schedule Status

The GRACE-FO project successfully completed its critical design review and system integration review in 2015. The project began assembly, test, and launch operations in August 2015, and remains on track to launch 6 months early in August 2017. The project continues to hold cost and schedule reserves consistent with the amount required by NASA center and Jet Propulsion Laboratory policy.

Technology and Design

The GRACE-FO project completed its critical design review in February 2015 with a mature design, which can help reduce risk in subsequent phases of a project. The design of GRACE-FO is largely based on the original GRACE spacecraft and uses updated heritage technology. Utilizing heritage technologies and designs on projects can help to reduce risk and control costs when they are used for similar purposes in similar environments. The project does not have any new critical technologies, but it will include a Laser Ranging Interferometer instrument, which is expected to measure the range between the two spacecraft with more precision than the heritage technology, as a technology demonstration. The flight models of this instrument were delivered in September 2015 for test and integration in Germany.

Development Partner

The GRACE-FO project continues to track risks related to its Russian launch vehicle and launch site. The project office is working with GFZ to mitigate potential risks associated with its launch vehicle, Dnepr, which is contributed by GFZ. NASA and GFZ are developing alternative launch service options in the event that political or other risks affect the availability of the launch vehicle. The launch vehicle is manufactured by Kosmotras, a Russian firm, in conjunction with the Ukrainian firm Yuzhnoye. According to the project office, the firms' working relationship has not been affected by the unrest between the two countries.

The GRACE-FO project office is also tracking potential health risks and staffing challenges associated with its new launch site in Yasny, Russia. The Yasny launch site is a few miles from an active, open-air asbestos mine. GRACE-FO was originally supposed to launch from the Baikonur Cosmodrome in Kazakhstan. However, due to technical reasons, the project's launch site was changed to Yasny in February 2015. Although staff exposure to asbestos at the site is expected to be minimal, the project plans to test asbestos levels at the site and limit staff exposure time in the lead up to launch. The project will also have to manage potential staffing challenges, since some personnel are not willing to travel to the new site.

Delays in receiving clearances from the Russian Ministry of Defense for the project to access the Yasny launch site are affecting the project's schedule for several launch-related milestones, including asbestos testing and the launch vehicle's critical design review, which was originally planned for June 2015. The project did not receive the clearances in October 2015 as expected and these milestones will be completed at least 7 months later than planned.

Project Office Comments

In commenting on a draft of this assessment, GRACE-FO project officials noted that the project continues to have excellent coordination among participants with a focus on risk mitigation and is working to resolve issues related to the delays in obtaining launch site clearances. The project continues to have a close partnership with GFZ for the launch service, mission and ground operations planning activities, and the development of the German elements of the Laser Ranging Interferometer. Project officials also stated that the spacecraft and instruments are proceeding well with minimal risk. All NASA instrument components have been delivered to Germany in preparation for spacecraft integration and the remaining flight instrument components are expected to be delivered in January 2016. Project officials also provided technical comments, which were incorporated as appropriate.

Ice, Cloud, and Land Elevation Satellite-2

Project Challenges
- Technology
- Schedule

Previously Reported Challenges
- Parts
- Design
- Funding
- Launch
- Workforce

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **None**

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

Mission Duration: **3 years**

Requirement derived from:
2007 Earth Science Decadal Survey

NASA 2014 Strategic Plan Alignment:
Strategic Objective 2.2 Understand our home planet

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: **$177.1 million**

PROJECT PERFORMANCE

Then year dollars in millions

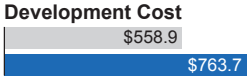
Total Project Cost

23.6% CHANGE

Formulation Cost

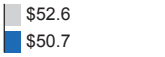
0.1% CHANGE

Development Cost



36.6% CHANGE

Operations Cost



-3.6% CHANGE

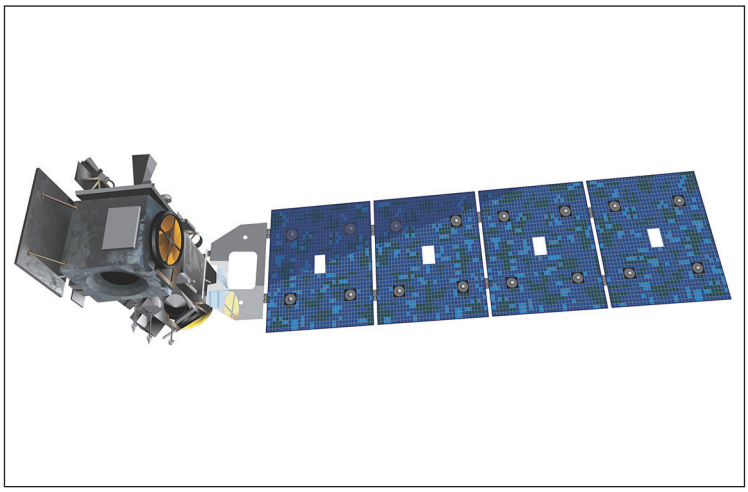
Launch Schedule

05 2017 — 06 2018

13 months CHANGE

Baseline FY 2013 | Latest Est. Feb 2016

NASA's Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) is a follow-on mission to ICESat designed to measure changes in polar ice-sheet mass and elevation. These measurements will provide a better understanding of the mechanisms that drive these changes and their associated effect on global sea level. ICESat-2 will use a pulsing multi-beam laser instrument to take measurements. The instrument will also have a high-pulse repetition rate, which allows the satellite to make more frequent measurements and provide better elevation estimates than ICESat over high slope and rough areas.



Source: Orbital Sciences Corporation. | GAO-16-309SP

PROJECT SUMMARY

The ICESat-2 project plans to begin system-level integration and testing in November 2016, but continues to face schedule risks related to its only instrument, the Advanced Topographic Laser Altimeter System (ATLAS). Since its May 2014 re-baseline, the project has used 5 of its 10 months of schedule reserve to address ATLAS technical challenges and late component deliveries. The project is tracking several risks that could result in the use of additional reserves. For example, an ATLAS flight laser and mirrors in the telescope alignment monitoring system might need to be replaced with spares, which could result in additional ATLAS schedule delays. The ICESat-2 project completed its spacecraft segment in February 2015 and is conducting risk reduction activities while it waits to be integrated with ATLAS.

Implementation

- **06/18** Committed launch readiness date
- **10/17** Manifested launch readiness date
- **10/16** System integration review
- **12/15** GAO review
- **05/14** Project rebaseline
- **02/14** Critical design review

Formulation

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

Ice, Cloud, and Land Elevation Satellite-2

Cost and Schedule Status

The ICESat-2 project plans to begin system-level integration and testing in November 2016, but continues to face schedule risks related to its only instrument, ATLAS. The project was re-baselined in May 2014. Since the re-baseline, the project used 5 of its 10 months of schedule reserve to address ATLAS technical challenges and late component deliveries. The project's rate of using schedule reserves decreased in 2015 and it continues to hold cost and schedule reserves consistent with the amount required by center policy.

Technology and Schedule

The ICESat-2 project achieved several important milestones with the ATLAS instrument in 2015, but continuing technical issues pose a schedule risk for the project. In July 2015, the project integrated and aligned the instrument's two lasers and test fired them for the first time. Project officials said integrating the lasers was especially difficult because they have to perfectly align with the receiver to collect science data. All of the major ATLAS subsystems were also delivered for integration and testing, which is underway and scheduled to end in July 2016.

The ICESat-2 project has used 5 of the 8 months of schedule reserve specifically held for ATLAS and is tracking risks that could consume the rest. If those risks materialize, system-level integration and testing could be delayed. In the last year, the project used 1 month of schedule reserve to address ATLAS technical issues during integration and test. Our prior work shows that it is during integration and test where problems are commonly found and schedules tend to slip. The project is tracking multiple risks that could result in the use of additional schedule reserves. For example, there is a risk that a crystal in the each of ATLAS's two lasers may become de-bonded from its mount, which would result in loss of laser function. If the project determines that the flight lasers are unacceptable to fly, it plans to replace one of them with a spare laser, which is currently being built. ICESat-2 only needs one laser for mission success. Replacing one of the lasers could result in a 2 month delay to ATLAS delivery. The project may also have to replace mirrors in the telescope alignment monitoring system because their coatings failed a damage resistance test. Replacing these mirrors with spares that have passed this test could result in a 1 month delay in the ATLAS integration and test schedule. In addition to those risks, the project is concerned that it may experience additional schedule delays if it identifies problems during its 5.5-month long ATLAS environmental testing. This testing is scheduled to begin in February 2016 and must be successfully completed before the instrument's delivery for system-level integration and testing in November 2016. According to project officials, this environmental testing is sequential in nature and cannot be compressed. Consequently, the project will not be able to address problems by adjusting interim milestones in this test period.

The project has worked ahead in other areas to reduce its overall schedule risk. After the spacecraft segment was completed in February 2015, the project began conducting risk reduction activities with it while it waits to be integrated with ATLAS. For example, the project addressed an interference problem found in the spacecraft's solar array. The project also began conducting mission operations risk reduction testing using the spacecraft in October 2015.

Project Office Comments

In commenting on a draft of this assessment, ICESat-2 project officials noted the major ATLAS schedule risks identified in the assessment continue to be mitigated by the ATLAS team. The project plans to make a decision on whether it will replace one of the flight lasers due to crystal de-bonding risk in spring 2016. Project officials also reported that they plan to use up to 1 month of schedule reserves to replace mirrors in the telescope alignment monitoring system in January 2016, which will delay the start of ATLAS environmental testing. They said the project continues to work with the contractor responsible for system-level integration and testing to identify opportunities to recover schedule if ATLAS is delivered later than planned. Project officials also provided technical comments, which were incorporated as appropriate.

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

Project Challenges
- Technology
- Development partner (new)
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partners: **Centre National d'Etudes Spatiales (France) and German Aerospace Center (Germany)**

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

Mission Duration: **29 months**

Requirement derived from:
2010 Decadal Survey

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.5 Understand the solar system

CONTRACT INFORMATION

Current highest value contract

Contractor: **Lockheed Martin Corporation**

Contractor Activity: **Spacecraft development**

Type of Contract: **Fixed Fee and Cost-Plus-Award-Fee**
Date of Award: **October 2012**
Initial Value of Contract: **$199.2 million**
Current Value: **$226.2 million**

PROJECT PERFORMANCE

Then year dollars in millions

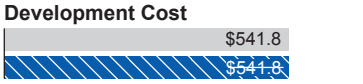
Total Project Cost

~~0.0%~~ CHANGE

Formulation Cost

~~0.0%~~ CHANGE

Development Cost



~~0.0%~~ CHANGE

Operations Cost

~~0.0%~~ CHANGE

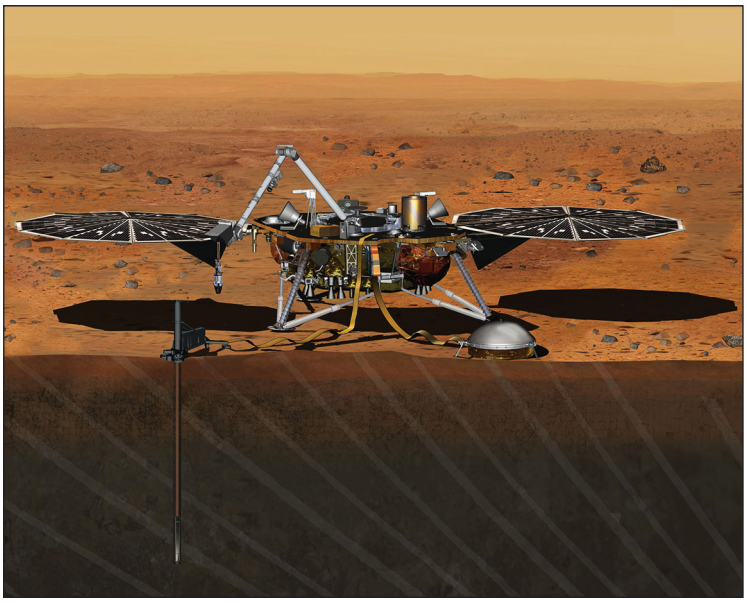
Launch Schedule[a]

~~0 months~~ CHANGE

Baseline FY 2014 | Latest Est.[a] Feb 2016

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

The Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport (InSight) is a Mars lander with two primary objectives. It is intended to further understanding of the formation and evolution of terrestrial planets by determining Mars's size, its composition, and the 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. It will also determine the present level of tectonic activity and the meteorite impact rate on Mars. InSight is based on the Phoenix lander design. Phoenix successfully landed on Mars in 2008.



Source: © California Institute of Technology. | GAO-16-309SP

PROJECT SUMMARY

The InSight project will not launch in March 2016 as planned due to technical issues with the Seismic Experiment for Interior Structure (SEIS) instrument, which is critical to achieving the project's science objectives. The project will not meet its committed launch date and must wait 26 months before another planetary launch opportunity is available. The instrument, which was already 11 months behind schedule and was rapidly consuming the project's remaining schedule margin, experienced numerous vacuum seal leaks in its sphere enclosure during instrument-level testing and efforts to repair it were unsuccessful. In December 2015, NASA managers decided to suspend the March 2016 launch, citing insufficient time to resolve the leak and complete testing required to ensure a successful mission. NASA is currently assessing the effects of the launch delay and the project's options going forward.

03/16 Launch readiness date (under review)

03/16 Committed launch readiness date

12/15 GAO review

02/15 System integration review

Implementation

05/14 Critical design review

03/14 Project confirmation

10/13 Preliminary design review

Formulation

07/12 Formulation start

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

Cost and Schedule Status

NASA will not launch InSight in March 2016 as planned due to technical issues with the Seismic Experiment for Interior Structure (SEIS) instrument. The project will not meet its committed launch date and must wait 26 months before another launch opportunity is available. NASA is currently assessing the effect of the SEIS issues and launch delays and whether or not to continue the project. If the project is not terminated, the launch delay will likely increase project costs.

Technology and Development Partner

In December 2015, NASA cancelled its planned March 2016 InSight launch because of recurring problems with the SEIS, its primary payload science instrument. SEIS, a seismometer contributed by the French Space Agency, the Centre National d'Etudes Spatiales (CNES), is critical for meeting three of the project's six top level mission requirements, and contributes to the other three. SEIS experienced numerous vacuum seal leaks in its sphere enclosure during instrument-level testing. The instrument, which was already 11 months behind schedule and was rapidly consuming the project's remaining schedule margin, requires a vacuum seal around its three main sensors in order to make accurate seismic measurements on Mars. In December 2015, the project made a targeted repair to the sphere, but in subsequent testing in extreme cold temperatures designed to replicate the Martian environment, SEIS again failed to hold a vacuum. In December 2015, NASA managers decided to suspend the March 2016 launch, citing insufficient time to resolve the leak and complete testing required to ensure a successful mission. The next available launch window is 26 months from the original planned launch date. A CNES official stated that CNES is working to address SEIS sphere problems. The InSight spacecraft, which was delivered to the launch site in mid-December 2015, will be returned to the contractor for storage while NASA decides the future of the project.

Funding

Prior to the launch delay, InSight project's cost estimates for the operations phase had increased and the project will need to use cost reserves to cover the associated costs. NASA officials stated that estimated operations cost have grown as the project has gained a better understanding of what it will take to safely deploy InSight's instruments on the ground with less risk. Project officials stated that they lacked a good understanding of the post-launch resources needed for deployment earlier in the project's life cycle. The project expects to use a combination of NASA headquarters-held cost reserves and the remaining project-held cost reserves to cover these additional costs.

Project Office Comments

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

Ionospheric Connection

Project Challenges
- Technology
- Contractor

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **University of California, Berkeley**

Launch Location:
Kwajalein (Marshall Islands)
Launch Vehicle: **Pegasus**

Mission Duration: **2 years**

Requirement derived from:
2013-2022 Decadal Survey; Heliophysics Division 2009 Roadmap

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.4 Understand the Sun

CONTRACT INFORMATION

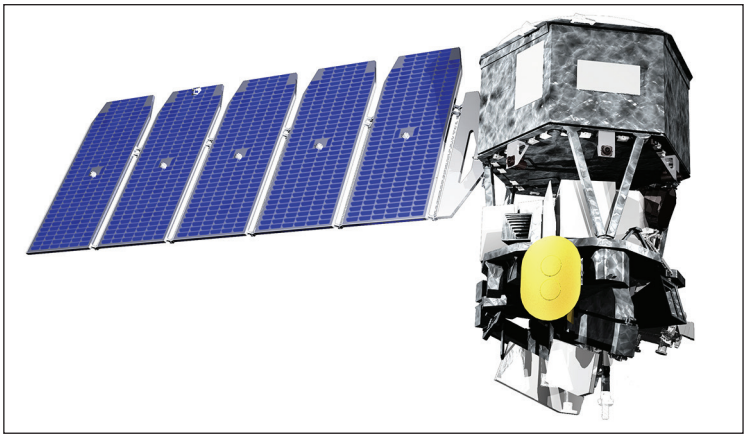
Current highest value contract

Contractor: **University of California, Berkeley**

Contractor Activity: **Project management, mission systems engineering, and mission operations**

Type of Contract: **Cost-No-Fee**
Date of Award: **January 2012**
Initial Value of Contract: **$138.5 million**
Current Value: **$139.1 million**

The Ionospheric Connection (ICON) observatory will orbit Earth to explore its ionosphere—the boundary region between Earth and space where ionized plasma and neutral gas collide and react. Its four instruments will provide a combination of direct measurements and remote sensing to further understanding of Earth's upper atmosphere, the Earth-Sun connection, and the ways in which Earth weather drives space weather.



Source: © University of California, Berkeley. | GAO-16-309SP

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost
$252.7
$252.7
0.0% CHANGE

Formulation Cost
$42.4
$42.4
1.0% CHANGE

Development Cost
$196.0
$195.8
-0.1% CHANGE

Operations Cost
$14.3
$14.5
1.4% CHANGE

Launch Schedule
10 2017 — 10 2017
0 months CHANGE

Baseline FY 2015 | Latest Est. Feb 2016

PROJECT SUMMARY

The ICON project held a successful critical design review in April 2015 with a mature design, and project data indicates it has performed well against its cost and schedule baselines. The project expects a number of schedule delays related to the production and delivery of three of its four payload instruments, but these delays are not expected to negatively affect the project's overall schedule. All four instruments are scheduled to be delivered by February 2016 for payload integration and testing.

Implementation
- **10/17** Committed launch readiness date
- **06/17** Targeted launch readiness date
- **06/16** System integration review
- **12/15 GAO review**
- **04/15** Critical design review

Formulation
- **10/14** Project confirmation
- **07/14** Preliminary design review
- **01/14** Mission/system definition review
- **09/11** Formulation start

Ionospheric Connection

Cost and Schedule Status

The ICON project held a successful critical design review in April 2015 with a mature design and the project plans to complete payload and spacecraft integration and testing by its planned systems integration review in June 2016. The project is currently holding cost and schedule reserves at the amount required by center policy. During ICON's confirmation review in October 2014, the project's targeted launch readiness date was set for June 2017—4 months later than previously anticipated. The new launch readiness date was set, in part, to allow the project to add instrument hardware to improve the reliability of scientific measurements, and to increase the overlap with other similar NASA missions to optimize data collection. Project officials stated that the added 4 months will also provide more time to address technical risks.

Technology

The project has experienced several technical issues that could delay spacecraft and payload integration and testing, but have not negatively affected the project's overall schedule. For example, one of ICON's contractors reported component failures and production problems that delayed testing of the integration master avionics unit, which is the spacecraft's electronics control system. The unit was delivered for integration with the spacecraft in November 2015. Additionally, technical problems with the Far Ultraviolet (FUV) instrument have delayed its delivery to payload integration and testing by two months to February 2016. As a result, the FUV is now driving the project's schedule. The project lost three weeks of schedule margin due to problems with the equipment that supports FUV calibration. The FUV flight detector, which is part of the instrument's flight cameras, also experienced a high voltage discharge during testing which is expected to further contribute to delays. The project plans to change the sequence of tasks performed during payload integration and testing to minimize the use of schedule reserve due to the late FUV delivery.

Contractor

The project experienced a schedule delay in 2015 with what project officials described as its most complex instrument, the Michelson Interferometer for Global High-Resolution Thermospheric Imaging (MIGHTI). The delay was due to a change in the subcontractor providing engineering support to the Naval Research Laboratory, which is responsible for developing MIGHTI. After the change, it took 2 to 3 weeks to transition key MIGHTI support personnel to the new subcontract. Project officials stated that they are working to recover lost schedule reserves by developing a fully integrated MIGHTI test model that will go through qualification testing. Project officials anticipate that this testing will help them discover problems early and reduce risk later in development. MIGHTI is scheduled to be delivered to payload integration and testing by late January 2016.

Project Office Comments

In commenting on a draft of this assessment, ICON project officials said the project continues to progress toward system integration. All instruments are in the final stages of environmental testing and on schedule to be delivered in February 2016; spacecraft hardware is on schedule to be delivered after completion of component level environmental testing; and ground segment equipment needed to test the spacecraft has been delivered and integrated at the contractor's facility. Project officials also reported that there are no known technical risks at this time for the spacecraft, payload, or ground segment components and that it has sufficient margins to achieve its planned launch date. Project officials also provided technical comments, which were incorporated as appropriate.

James Webb Space Telescope

Project Challenges

- Schedule
- Design
- Manufacturing
- Contractor (new)

Previously Reported Challenges

- Design/Technology
- Test and Integration
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partners: **European Space Agency, Canadian Space Agency (Canada)**

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

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

Requirement derived from:
2001 Astrophysics Decadal Survey

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.6 Search for life and understand the universe

CONTRACT INFORMATION

Current highest value contract

Contractor: **Northrop Grumman Aerospace Systems**

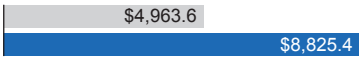
Contractor Activity: **Spacecraft development and other components**

Type of Contract: **Cost-Plus-Award-Fee/ Incentive-Fee**
Date of Award: **2002**
Initial Value of Contract: **$824.6 million**
Current Value: **$3,598.0 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost



77.8% CHANGE

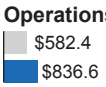
Formulation Cost

0.0% CHANGE

Development Cost

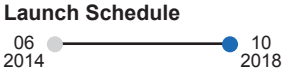
139.8% CHANGE

Operations Cost



43.6% CHANGE

Launch Schedule



52 months CHANGE

Baseline FY 2009 | Latest Est. Feb 2016

The James Webb Space Telescope (JWST) is a large, infrared-optimized space telescope designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems. It will also help further the search for Earth-like planets. JWST will have a large primary mirror composed of 18 smaller mirrors and a sunshield the size of a tennis court. Both the mirror and sunshield are folded for launch and open once JWST is in space. JWST will reside in an orbit about 1 million miles from the Earth.

Source: NASA. | GAO-16-309SP

PROJECT SUMMARY

The JWST project continues to meet its cost and schedule commitments, but technical challenges have reduced overall project schedule reserves. The project is still holding schedule reserves above the project's plan and NASA center requirements, but it must complete five major integration and test events, three of which have not yet begun. Integration and test is when problems are often identified and schedules tend to slip. In addition, all JWST elements and major subsystems remain within weeks of driving the project's overall schedule. As a result, the use of additional reserve on any element or major subsystem may further reduce the overall project schedule reserve and require the project to prioritize mitigating some issues over others. The cryocooler—a driver of cost and schedule issues for the project—was delivered by the responsible subcontractor in July 2015—approximately 18 months later than planned. It remains a schedule risk as it begins testing.

10/18 Committed launch readiness date

07/17 System integration review

12/15 GAO review

Implementation

09/11 Project rebaseline

03/10 Critical design review

07/08 Project confirmation

03/08 Preliminary design review

01/06 Mission/ system definition review

Formulation

03/99 Formulation start

James Webb Space Telescope

Cost and Schedule Status

The JWST project continues to operate within its 2011 cost and schedule baseline. The project currently holds almost 9 months of schedule reserve, which is above the project's plan and center requirements.

Schedule

The JWST project is currently on schedule, but in December 2015, we found that the project continues to face schedule risks. Before launch, the project must complete five major integration and test events, three of which have not yet begun. Integration and test is when problems are often identified and schedules tend to slip. In addition, all JWST elements and major subsystems remain within weeks of becoming the critical path, which drives the project's overall schedule. As a result, the use of additional reserve on any element or major subsystem may reduce the overall project schedule reserve and require the project to prioritize mitigating some issues over others.

Design and Manufacturing

The project consumed about 2 months of schedule reserve in 2015 addressing design and manufacturing issues. For example, the instrument suite's heat straps—flexible straps that conduct energy and heat away from the instruments—did not perform as expected in testing and had to be redesigned and reinstalled. In addition, the majority of the 76 cryogenic harnesses that connect to mirrors on the Optical Telescope Element were damaged because the supplier used inappropriate tooling and required repairs or replacement. The sunshield also experienced various manufacturing problems, such as damage to a section of the multi-segmented mid-boom assembly, and the project will need to use additional schedule reserves to remanufacture the damaged piece. Finally, the cryocooler experienced technical challenges that used schedule reserve and delayed its delivery. The cryocooler was delivered by the responsible subcontractor in July 2015—approximately 18 months later than planned—and it remains a schedule risk as it begins testing.

Contractor

In December 2015, we reported that the primary threat to JWST meeting its long-term cost commitment was the prime contractor. For the past 20 months, Northrop Grumman's actual workforce exceeded its projections. The prime contractor needed a larger workforce than planned due to unexpected technical issues—primarily related to the spacecraft and sunshield development—and additional work requested by NASA.

Other Issues to be Monitored

The JWST project continues to meet its cost commitments, but unreliable contractor performance data may pose a risk to project management. To help manage the project and account for new risks, project officials conducted a cost risk analysis of the prime contractor in 2014. A cost risk analysis uses information about cost drivers, technical risks, and schedule to determine the reliability of a program's cost estimate. In December 2015, we found the analysis substantially met best practices, but officials do not plan to periodically update it. Instead, the project is using a risk-adjusted analysis to update and inform its cost position, but this analysis is based on contractor-provided performance data that contained anomalies that render the data unreliable. NASA agreed with our recommendation to improve the reliability of this data by requiring contractors to identify, explain, and document all anomalies.

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 on Track but May Benefit from Improved Contractor Data to Better Understand Costs*, GAO-16-112 (Washington, D.C.: Dec. 17, 2015).

Mars 2020

Project Challenges
- Technology maturity (new)
- Design

Previously Reported Challenges
- Funding

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partners: **NASA Human Exploration and Operations Mission Directorate, NASA Space Technology Mission Directorate, U.S. Department of Energy, Centre National d'Etudes Spatiales (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

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.5 Understand the solar system

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: **$7.5 million**
Current Value: **$7.7 million**

PROJECT PERFORMANCE

Then year dollars

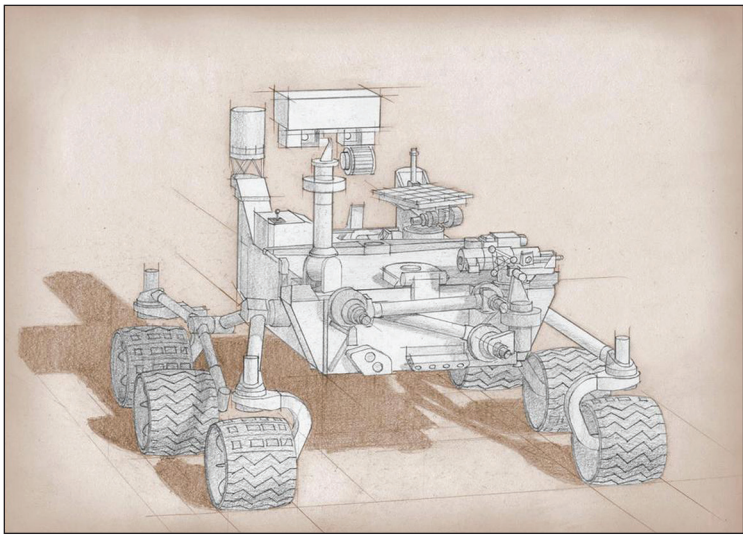
Preliminary Estimate of Project Life Cycle Cost*:

Latest: **February 2016** **$2.168 – $2.351** 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: **July 2020**

Mars 2020 is part of the Mars Exploration program, which seeks to further understand whether Mars was, is, or can be a habitable planet. Its rover and science instruments will systematically explore Mars by conducting geological assessments, searching for signs of ancient life, determining potential environmental habitability, and preparing well-documented soil or rock samples for potential future return to Earth. The rover may also include a technology demonstration instrument designed to covert carbon dioxide into oxygen. 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.



Source: NASA/JPL Caltech. | GAO-16-309SP

PROJECT SUMMARY

The Mars 2020 project delayed its preliminary design review by 2 months to February 2016 to allow the project more time to develop some of its new instruments. The project's confirmation review, or Key Decision Point C, was also delayed. In preparation for the preliminary design review, the project continued to mature its seven critical technologies, but at the time of our review, several had not yet reached the level of maturity recommended by best practices for preliminary design. The project has identified several design and mass-related issues that pose cost and schedule risks for the project. For example, the overall mass of the rover could exceed the MSL design, rover wheel redesigns to improve performance could add mass, and design changes to the spacecraft might be needed to integrate terrain relative navigation (TRN) technology, which could help ensure a successful landing near science targets.

07/20 Projected launch readiness date

11/17 System integration review

11/16 Critical design review

Implementation

03/16 Project confirmation

02/16 Preliminary design review

12/15 GAO review

10/14 System requirements/ mission definition review

Formulation

11/13 Formulation start

Mars 2020

Cost and Schedule Status

The Mars 2020 project delayed its preliminary design review by 2 months to February 2016, in part to allow for more time to develop of some of its new instruments. The project also delayed its project confirmation, or Key Decision Point C, by 3 months to March 2016, at which point it will establish its cost and schedule baselines. Schedule is a key driver for Mars 2020. If the project misses its 2020 launch window, it must wait 26 months before another launch opportunity is available.

Technology Maturity

The Mars 2020 project is continuing to mature its seven critical technologies, but several have not yet reached the level of maturity—technology readiness level 6—recommended for preliminary design. Maturing critical technologies to this level is a best practice, which helps minimize risks for space systems entering product development. Of the project's seven critical technologies, the least mature is part of a technology demonstration instrument that is designed to convert carbon dioxide to oxygen. If the instrument does not work as intended, it can be removed from the project because it is not needed to achieve any of the primary science objectives.

Design

The Mars 2020 project has identified several design and mass-related issues that pose cost and schedule risks for the project. The project is tracking a risk that increases to the combined mass of the rover, payload, and sampling system could exceed the project's mass allocations and loads capability. A project official said the project has partly mitigated the risk by determining that it could increase its landing mass and permit up to 70 kilograms beyond the MSL rover's 980 kilogram mass. However, new risks continue to emerge. For example, the project is monitoring the mass and volume of the turret for the rover's robotic arm. The design of the turret is important because it affects the functionality of two instruments and parts of the sampling and caching system that will take samples of the Martian surface. Due to the turret's location, it also affects the balance and mobility of the rover. Mass growth in any of the turret's components has the potential to impact the robotic arm design and increase overall rover mass, necessitating further redesign. In addition, the project is tracking a risk that the rover's sampling and caching system may be late to assembly and testing. For example, the project noted that increases in the mass or volume of subcomponents could lead to hardware redesigns and development delays. The project plans to continue tracking this risk until after its critical design review, planned for November 2016.

The project is also considering design changes that could result in mass increases. For example, the project is considering a redesign of the Mars 2020 rover wheels to prevent similar damage to MSL's wheels caused by sharp rocks on the Martian terrain. We reported in 2015 that because the project is based heavily on the MSL design, any changes to the existing design could affect the project's ability to control cost and schedule. The wheel redesign would also likely introduce additional mass and complicate the project's overall rover mass concerns.

Further, the project might need to make design changes to the spacecraft to integrate terrain relative navigation (TRN) technology, which would better ensure a successful landing near science targets. The project held a landing site workshop in August 2015, and subsequently announced that access to most of the top eight sites requires TRN. Project officials estimated that it will cost $30 to $50 million to integrate TRN technology into Mars 2020. The project anticipates making a final decision on TRN prior to project confirmation.

Project Office Comments

In commenting on a draft of this assessment, Mars 2020 project officials noted that the project plans to mature all of its critical technologies prior to the preliminary design review in February 2016. The project also continues to proceed with heritage builds, which have gone well to date, and reports that the wheel redesign should not negatively affect mass. The Mars Program has identified funding for TRN that would eliminate any need for additional project development funds should it be added to the mission. Project officials also provided technical comments, which were incorporated as appropriate.

NASA ISRO – Synthetic Aperture Radar

Project Challenges
- Technology maturity
- Design (new)
- Development partner

PROJECT ESSENTIALS

NASA Center Lead: **Jet Propulsion Laboratory**

Partner: **Indian Space Research Organisation (India)**

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

Mission Duration: **3 years**

Requirement derived from: **National Research Council Decadal Survey**

NASA 2014 Strategic Plan Alignment: **Strategic Objective 2.2 Understand our home planet**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Northrop Grumman Aerospace Systems**

Contractor Activity: **Radar antenna reflector development**

Type of Contract: **Cost-Plus-Fixed-Fee and Cost-Plus-Incentive-Fee**
Date of Award: **October 2015**
Initial Value of Contract: **$28.3 million**
Current Value: **$8.14 million**

PROJECT PERFORMANCE

Then year dollars

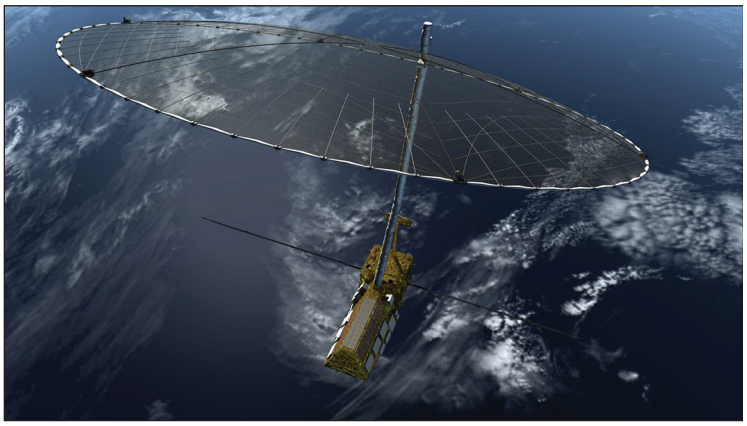
Preliminary Estimate of Project Life Cycle Cost*:

Latest: **February 2016** **$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 Indian Space Research Organisation (ISRO) - Synthetic Aperture Radar (NISAR) is being designed to study the solid Earth, ice masses, and ecosystems and 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 use advanced radar imaging to construct large-scale data sets of the earth's movements. NISAR represents the first major aerospace science partnership between NASA and ISRO.



Source: © 2014 California Institute of Technology/Jet Propulsion Laboratory. | GAO-16-309SP

PROJECT SUMMARY

The NISAR project continues to mature its critical technologies and expects to demonstrate they are at the level of maturity recommended by best practices by its preliminary design review, scheduled for June 2016. Maturing technologies to this level helps reduce risk for projects entering development. The project is currently not meeting its mass margin requirements, but expects to have a better mass estimate after it finalizes the selection of key hardware vendors. The project is also tracking risks related to its radar development, the differences in NASA and ISRO project management processes, and the viability of the ISRO-contributed launch vehicle. The project plans to hold its confirmation review, or Key Decision Point C, in September 2016—at which point the project will establish its cost and schedule baselines.

Implementation
- **12/20** Projected launch readiness date
- **02/19** System integration review
- **01/18** Critical design review

Formulation
- **09/16** Project confirmation
- **06/16** Preliminary design review
- **12/15** GAO review
- **12/14** Mission definition/ system requirements review
- **03/14** Formulation start

NASA ISRO – Synthetic Aperture Radar

Cost and Schedule Status

The NISAR project plans to hold its preliminary design review early in late June 2016 and its confirmation review, or Key Decision Point C, on schedule in September 2016—at which point the project will establish its cost and schedule baselines.

Technology Maturity

The NISAR project is continuing to mature its three critical technologies and, according to a project official, expects them to reach a technology readiness level 6 by its planned June 2016 preliminary design review. Maturing critical technologies to this level is a best practice, which helps minimize risks for space systems entering product development. We reported in 2015 that 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.

One of the critical technologies currently being matured is the reflector boom. The boom assembly will be used to deploy a 12-meter radar reflector as part of the instrument antenna that will be used to transmit and receive the separate feeds from the L- and S-band radars. The reflector boom will be built in-house at the Jet Propulsion Laboratory based on lessons learned from the recently launched Soil Moisture Active and Passive (SMAP) project. SMAP encountered several design issues with its reflector boom assembly, which was built by a contractor. Project officials stated that the boom assembly will be developed concurrently with the Surface Water and Ocean Topography (SWOT) project to achieve cost savings. The requirements for the boom will be based on SWOT requirements since those are more stringent.

Design

The NISAR project does not meet NASA's mass margin requirements for its current phase of development, but expects to be in compliance by the preliminary design review. Officials stated that they expect to have a better mass estimate after the selection of key hardware vendors. The project also plans to complete instrument structure mass optimization efforts in December 2015. If needed, the project has contingencies available to reduce mass, such as eliminating system redundancies.

Development Partner

Because the NISAR project is the first major partnership between NASA and ISRO, the project is tracking a risk that differences in NASA and ISRO project management processes could negatively affect cost and schedule. The project is managing this risk by working with ISRO to understand process differences and expectations for deliverables. The project expects this issue to remain a cost and schedule risk until the system integration review in February 2019.

In addition, the project continues to monitor a risk regarding the reliability of the ISRO-contributed Geosynchronous Satellite Launch Vehicle (GSLV) Mark II because it has not yet met NASA-ISRO agreed-upon criteria for its use on NISAR. For example, the GSLV Mark II must have three successful launches prior to NISAR's planned launch date in 2020. According to project officials, the first GSLV Mark II launch was unsuccessful. However, as of September 2015, it has had two consecutive successful launches, with its most recent launch in August 2015 a success. If ISRO cannot achieve the agreed-upon criteria, the project could be delayed by 2 years and costs could grow by approximately $20 to $30 million.

Project Office Comments

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

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

Project Challenges

- Technology (new)
- Development Partner

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **Canadian Space Agency (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**

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.5 Understand the solar system

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: **$342.4 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

-5.7% CHANGE

Formulation Cost

0.0% CHANGE

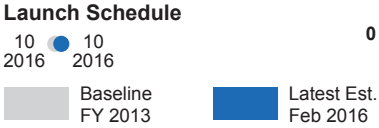
Development Cost

-10.0% CHANGE

Operations Cost

7.1% CHANGE

Launch Schedule



0 months CHANGE

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 help explain our solar system's formation and how life began. The OSIRIS-REx mission has five science objectives: (1) return and analyze a sample from an asteroid, (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: NASA. | GAO-16-309SP

PROJECT SUMMARY

The OSIRIS-REx project expects to be ready to launch on schedule in September 2016 and complete development under its committed cost. As of December 2015, all of the project's payload instruments have been delivered for integration and testing, but technical challenges have delayed the delivery of a flight navigation system until April 2016. The project plans to ship the fully integrated and tested spacecraft to the launch site in May 2016. Because OSIRIS-REx has a 39-day planetary launch window that begins September 3, 2016, maintaining the project's schedule is especially important to meeting the planned launch date. The project has the required level of schedule margin for this stage of the project.

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

Cost and Schedule Status

The OSIRIS-REx project expects to be ready to launch on schedule in September 2016 and complete development under its committed cost. As of December 2015, all of OSIRIS-REx payload instruments have been delivered for integration and testing. The project plans to ship the fully integrated and tested spacecraft to the Cape Canaveral launch site in May 2016. According to project officials, maintaining the project's schedule is important because OSIRIS-REx has a 39-day planetary launch window, which begins on September 3, 2016. If the project misses this window, it will have to wait a year for another launch opportunity. The project currently meets the required level of schedule margin for this stage of the project.

Technology

The project has experienced technical challenges that have delayed the delivery of flight hardware and navigation systems, but it has been able use schedule reserves to prevent these delays from affecting the launch schedule. The project expects the spacecraft's guidance, navigation, and control light detection and ranging (GN&C LIDAR) instrument, which is critical to navigating the spacecraft around the target asteroid, to be delivered to integration and testing 14 months later than planned, due to a number of technical issues. For example, during system-level testing, the GN&C flight units experienced a leak in their laser enclosures, which led the project to implement an alternate design with a new vendor. The project expects the resealed GN&C LIDAR units to be delivered in April 2016. To avoid delaying spacecraft integration and testing, the project is using a mass model and a GN&C flight model without the repaired enclosure for spacecraft environmental testing. Project officials have determined the minimum level of GN&C LIDAR testing required in the event the test period must be shortened due to the late delivery. Project officials stated that the GN&C LIDAR will remain a source of technical and schedule risk even after it has been delivered to integration and testing. They said that GN&C LIDAR issues could increase project costs by as much as $1.8 million, but the project has cost reserves to address the issues, if needed. The project has developed a separate redundant system, called Natural Feature Tracking, to serve as a backup capability if the GN&C LIDAR does not successfully complete testing or fails during flight.

Development Partner

The OSIRIS-REx laser altimeter (OLA) instrument, a non-essential contribution from the Canadian Space Agency, was delivered 4 months behind schedule in late November 2015 and missed critical system-level testing, including mechanical testing. The project used a mass model for mechanical testing in order to reduce testing risks. OLA is a ranging instrument that will help create a high-resolution 3-dimensional model of the asteroid.

Other Issues to Be Monitored

The Science Processing and Operations Center (SPOC), which is responsible for processing data from OSIRIS-REx, has experienced schedule delays due to multiple issues, including design problems and poorly written software code. SPOC must be completed before launch. To maintain the project's schedule, it de-scoped initial SPOC software requirements and plans to deliver the first of four complete SPOC builds by December 2015, with subsequent software builds scheduled for delivery in the spring and summer of 2016. The project conducted three ground readiness tests in fall 2015 and plans to complete its final ground readiness tests by July 2016 to support launch.

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

Project Challenges
- Funding
- Design
- Development partner (new)

Previously Reported Challenges
- Schedule

PROJECT ESSENTIALS

NASA Center Lead: **Johnson Space Center**

Partner: **European Space Agency**

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

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

Requirement derived from:
NASA Authorization Act of 2010

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.1 Develop evolving exploration systems and capabilities

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: **$12.10 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 millions

Total Project Cost

Baseline	$11,283.5	0.0% CHANGE
Latest Est.	$11,284.0	

Formulation Cost

Baseline	$4,515.1	3.5% CHANGE
Latest Est.	$4,671.5	

Development Cost

Baseline	$6,768.4	-2.3% CHANGE
Latest Est.	$6,612.0	

Operations Cost

Baseline	N/A	0.0% CHANGE
Latest Est.	N/A	

Launch Schedule
- First non-crewed launch readiness date: **Sept 2018**
- First crewed launch readiness date: **no later than April 2023**

Baseline FY 2015 | Latest Est. Feb 2016

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. The Orion program is continuing to advance development of the human safety features, designs, and systems started under the Constellation program, which was cancelled in 2010. Orion is planned to launch atop NASA's Space Launch System (SLS). The current design of Orion consists of a crew module, service module, and launch abort system.

Source: NASA/Kennedy. | GAO-16-309SP

PROJECT SUMMARY

In September 2015, NASA established its cost and schedule baselines for the Orion program's first crewed mission with a life-cycle cost estimate of $11.3 billion and a launch readiness date of no later than April 2023. The program continues to work toward an internal launch readiness date of August 2021. NASA will not commit to an actual launch date for the first crewed mission until after the first uncrewed mission is complete. The baseline does not include a date for the first uncrewed mission, although the program is working to a launch readiness date of September 2018. The Orion program continues to make progress on development of the vehicle and in October 2015 completed the critical design review board associated with the first uncrewed mission; however, the program does not plan to close out the critical design review until a follow-on review is held in May 2016.

Implementation
- **04/23** First crewed launch readiness date
- **09/18** First non-crewed launch readiness date
- **12/15** GAO review
- **10/15** Critical design review

Formulation
- **09/15** Project confirmation
- **12/14** First exploration test flight
- **08/14** Orion preliminary design review
- **02/12** Orion formulation start
- **02/10** Orion cancelled under Constellatior Program
- **07/06** Formulation start under Constellatior program

Orion Multi-Purpose Crew Vehicle

Cost and Schedule Status

In September 2015, NASA established cost and schedule baselines for the Orion program's first crewed Exploration Mission (EM-2) with a life-cycle cost of $11.3 billion and a launch readiness date of no later than April 2023. This life-cycle cost estimate does not include production, operations, or sustainment of additional crew vehicles, despite NASA's plans to use and possibly enhance the vehicle after 2023. The baseline does not include a date for the first uncrewed Exploration Mission (EM-1), which is planned to demonstrate the spacecraft's system performance prior to EM-2. The program is working to a launch readiness date of September 2018 for EM-1. NASA has not yet determined actual launch dates for EM-1 or EM-2. It plans to establish an integrated launch date target for EM-1 after all three associated programs—Orion, SLS, and Ground Systems Development and Operations—reach a sufficient level of design maturity. NASA plans to identify a launch date target for EM-2 after EM-1 is complete.

Funding

The Orion program is working to an earlier internal launch readiness date of August 2021 for EM-2 that depends on the program being appropriated more funding than NASA requested in fiscal year 2016 and plans to request in fiscal years 2017 through 2021. While Congress has provided the program with more funding than NASA requested in fiscal years 2013 through 2015, it may be unrealistic for NASA to expect additional funding each year given the constrained fiscal environment.

Design

The Orion program continues to make progress on development of its vehicle, having completed the critical design review for EM-1 in October 2015. However, the program did not fully review the design for the European Service Module (ESM), which has its system-level critical design review scheduled for April 2016; the heat shield, which is being redesigned; key crew life support systems, which were deferred from EM-1 to EM-2; or the program's cost and schedule estimates to ensure they are credible and adequate resources exist to complete development. The Orion program plans to close out the EM-1 critical design review during a follow-on review in May 2016. The program will not assess the key crew life support systems and other unique crew capabilities that will first fly on EM-2 until the EM-2 critical design review currently planned for 2017.

The Orion program is redesigning its heat shield. During the first exploration test flight in December 2014, the vehicle flew with a monolithic heat shield design. However, NASA has determined that not all aspects of the monolithic design will meet the more stringent requirements for EM-1 and EM-2 when the vehicle will be exposed to a greater temperature variance and longer durations. The program has decided to use a block heatshield design for EM-1, where it will adhere approximately 300 blocks to the support structure and apply filler material to the gaps between blocks. However, this design also has some risk because of uncertainty about the ability to adhere the blocks to the support structure. To mitigate this risk, the program will continue to develop the monolithic design as well.

Development Partner

The European Space Agency has experienced design challenges with the ESM. Under a barter agreement signed in December 2012, the European Space Agency is to contribute portions of the Orion service module for EM-1. After delivery, NASA's prime contractor for Orion will be responsible for integrating the ESM with the remaining service module components. As a result of design challenges, several ESM subsystem preliminary design reviews were completed as much as 6 months later than planned, with the last completed in June 2015. Similarly, individual subsystem critical design reviews have been delayed by up to 5 months in 2015.

Project Office Comments

In commenting on a draft of this assessment, Orion program officials noted that NASA continues to direct the program to execute to the August 2021 launch readiness date, which the agency acknowledges is aggressive and carries risk including the uncertainty of annual funding. They added that NASA has quantified this risk through the establishment of the Agency Baseline Commitment that places the first crewed flight no later than April 2023. Program officials also provided technical comments, which were incorporated as appropriate.

Solar Probe Plus

Project Challenges
- Design
- Manufacturing (new)

Previously Reported Challenges
- Funding
- Parts/Test and Integration
- Launch
- 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
NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.4 Understand the Sun

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: **$729.1 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

Baseline	$1,553.4	0.0% CHANGE
Latest Est.	$1,553.4	

Formulation Cost

Baseline	$247.1	0.0% CHANGE
Latest Est.	$247.1	

Development Cost

Baseline	$1,055.7	-0.5% CHANGE
Latest Est.	$1,050.3	

Operations Cost

Baseline	$250.6	2.1% CHANGE
Latest Est.	$256.0	

Launch Schedule

08 2018 — 08 2018 **0 months** CHANGE

Baseline FY 2014 | Latest Est. Feb 2016

Solar Probe Plus (SPP) will be the first NASA mission to visit a star. Using the gravity of Venus, the spacecraft will orbit the Sun 24 times and gather information to increase knowledge about the solar wind, including its origin, acceleration, and how it is heated. SPP instruments will observe the generation and flow of solar winds from very close range and sample and take measurements of the Sun's outer atmosphere, or solar corona, where solar particles are energized. 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-16-309SP

PROJECT SUMMARY

The SPP project has encountered a series of design and manufacturing challenges, but it currently has adequate cost and schedule reserves to address them. The project held its critical design review in March 2015 with 34 percent of design drawings released, which is lower than recommended by best practices, to allow the project to begin the two-year process of building the flight cooling system and maintain its planetary launch window. At the review, the project released 100 percent of the drawings for the cooling system. The project has had to use cost and schedule reserves to address design and manufacturing issues. The project redesigned an instrument within its Solar Wind Electrons Alphas and Protons (SWEAP) instrument suite—which is key to meeting the project's science objectives. Further, the start of integration and test was put at risk because some of the spacecraft's panels were made too large, due to a design error.

Implementation
- **08/18** Committed launch readiness date
- **05/16** System integration review
- **12/15** GAO review
- **03/15** Critical design review

Formulation
- **03/14** Project confirmation
- **01/14** Preliminary design review
- **11/11** Mission/system definition review
- **11/09** Formulation start

Solar Probe Plus

Cost and Schedule Status

The SPP project held its critical design review in March 2015, as planned, but the start of system integration and test could be delayed due to design and manufacturing issues. The project plans to begin spacecraft integration and testing in June 2016 and system-level testing in March 2017. The project has used cost and schedule reserves to address design and manufacturing issues, but continues to hold reserves consistent with the amount required by center policy.

Design and Manufacturing

The SPP project has encountered a series of design and manufacturing challenges, but it currently has adequate cost and schedule reserves to address them. The project held its critical design review in March 2015 with only 34 percent of its design drawings released. According to best practices, releasing at least 90 percent of drawings by this review lowers the risk of subsequent cost growth and schedule delays. Project officials explained that they held the critical design review with a relatively low level of releasable drawings to allow the project to begin the 2-year process of building the flight cooling system and preserve its launch window. At the critical design review, the project released 100 percent of the drawings for this system. Maintaining the project's 2018 planetary launch window is important because the window only opens every 10 months and subsequent launch windows have longer mission durations and require more fuel. An SPP project official said the project expects to release the majority of the drawings by its May 2016 system integration review when the project must demonstrate that all system components are ready for integration.

The SPP project also had to address design issues with key instruments. First, part of the SWEAP payload, which is required to meet the project's top science objectives, had to be redesigned to better accommodate its launch environment. The SWEAP payload also experienced delays as a result of poor management by the responsible subcontractor. As a result of these issues, the project took over management of part of SWEAP and provided additional cost and schedule reserves to the SWEAP effort. The project also made changes to its antenna design following its critical design review to mitigate potential damage to the Fields instrument antenna and spacecraft during launch. Antenna damage could impede SPP's ability to meet its science objectives. The project is testing an updated design that provides a more effective way to secure the antennas to the spacecraft. The project expects to resolve this issue in July 2016, after its system integration review.

Design-related manufacturing issues have put the start of system integration and testing at risk. The project was unable to assemble the spacecraft structure on schedule because four of the eight spacecraft structural panels were too large and needed to be resized. The project completed the spacecraft structure in December 2015, but had to use schedule reserves to cover the five week period needed to fix the panels.

Issue Update

We previously reported that the SPP project changed its launch vehicle and as a result carried a design risk into critical design review. NASA has since awarded contracts for the launch vehicle and upper stage, which has enabled the project to begin to understand and address launch environment risks. For example, the project is working with the launch provider to mitigate the risk of increased vibration to the spacecraft when the spacecraft and the upper stage separate during launch. The project has benefitted from a decrease of more than $1 million in its expected launch vehicle costs. The exact amount will not be fully known until the project launches in 2018.

Project Office Comments

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

Space Launch System

Project Challenges
- Cost (new)
- Schedule
- Design (new)
- Contractor (new)

Previously Reported Challenges
- Funding
- Integration of Existing Hardware

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

NASA 2014 Strategic Plan Alignment:
Strategic Objective 1.1 Develop evolving exploration systems and capabilities

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: **$4.193 billion**

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

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

Baseline	$9,695.4	0.0% CHANGE
Latest Est.	$9,695.4	

Formulation Cost

Baseline	$2,674.0	0.0% CHANGE
Latest Est.	$2,674.0	

Development Cost

Baseline	$7,021.4	0.0% CHANGE
Latest Est.	$7,021.4	

Operations Cost

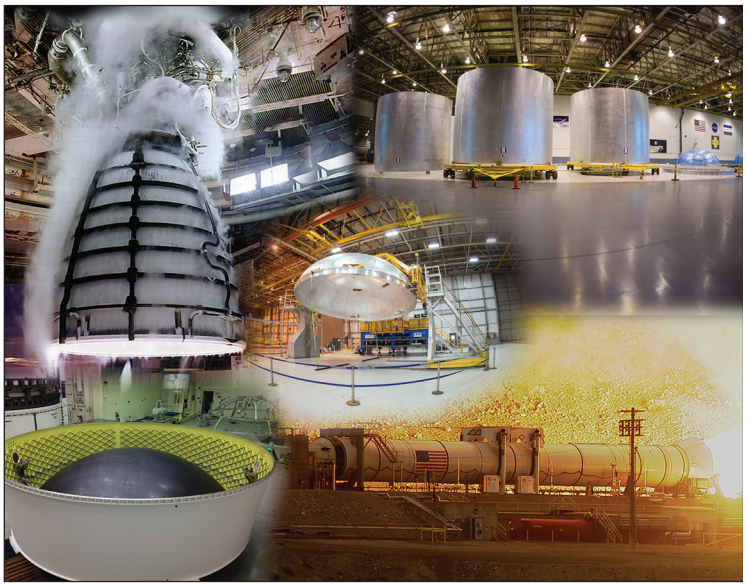
Baseline	N/A	0.0% CHANGE
Latest Est.	N/A	

Launch Schedule

11 2018 — 11 2018 **0 months** CHANGE

Baseline FY 2014 | Latest Est. Feb 2016

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-16-309SP

PROJECT SUMMARY

The SLS program completed its critical design review for the 70-metric ton launch vehicle's uncrewed first exploration mission (EM-1) in July 2015, but it is at risk of design changes due to problems and delays with a major subsystem—the interim cryogenic propulsion stage (ICPS). The SLS program plans to complete its assessment of the ICPS design at a design review planned for spring 2016. If new development issues arise, the program has limited cost and schedule reserves remaining to address them. A critical period also lies ahead as NASA responds to Congressional direction to not use funds to human-rate ICPS for carrying crew as originally planned for the second SLS exploration mission (EM-2) scheduled for 2021.

11/18 Committed launch readiness date

12/15 GAO review

Implementation

07/15 Critical design review

08/14 Project confirmation

07/13-09/13 Preliminary design review

Formulation

05/12 Mission/system design review

11/11 Formulation start

Space Launch System

Cost and Schedule Status

The SLS program's limited cost and schedule reserves place it at increased risk of exceeding its committed cost and schedule baseline. At its confirmation in August 2014, the program established its cost and schedule baseline for EM-1 at approximately $7 billon for development, with a launch readiness date of November 2018. The program's baseline cost includes reserves of less than 4 percent per year. Similarly, the SLS program has limited schedule reserves. The program has already allocated 7 of 11 months of schedule reserve to mitigate delays with the development of the core stage, the SLS's fuel tank and structural backbone. A major contributing factor in this delay was the need to repair incorrectly installed structural components within the core stage assembly facility. The program is tracking other threats to its schedule, including a risk regarding excessive hydrogen accumulating around the base of the vehicle during launch.

Design

Prior to the July 2015 critical design review for the SLS 70-metric ton vehicle, the SLS program had released nearly 90 percent of design drawings—a best practice—but it is at risk of design changes due to problems and delays with a major subsystem. The interim cryogenic propulsion stage (ICPS), which provides in-space propulsion for the SLS, did not have a stable design at the time of the SLS program's critical design review due in part to immature safety and reliability analysis and the discovery of potential ICPS vibration issues. The program also purposefully deferred portions of the ICPS critical design review until spring 2016, which is when the second phase of the spacecraft and payload integration and evolution critical design review is scheduled, because designs for new avionics and secondary payloads were not yet ready for review.

Contractor

The SLS program is renegotiating the core stage contract with Boeing. According to NASA officials, the contract is being modified, in part, to resolve differences between the program and contractor regarding the level of funding available to begin work on the exploration upper stage. Program officials anticipate the renegotiated contract will be finalized in early 2016, at which point the effect on the program's overall cost and schedule should be known.

Other Issues to be Monitored

The Joint Explanatory Report to the 2016 Consolidated Appropriations Act, while not law, prohibited the use of NASA funds to human-rate the ICPS. The SLS program had originally planned to use ICPS as the second stage propulsion system for both the EM-1 uncrewed and EM-2 crewed missions and then develop a new exploration upper stage for future missions. As part of the fiscal year 2016 NASA Exploration appropriation, Congress appropriated no less than $2 billion for SLS, of which no less than $85 million is to be for the development of a new upper stage.

Project Office Comments

In commenting on a draft of this assessment, SLS program officials stated that they had developed a solution to prevent excessive hydrogen from accumulating around the base of the launch vehicle by repositioning the hydrogen burn-off ignitors. They also stated that solutions have been identified for ICPS vibration issues. The ICPS plans to complete its design review of the avionics and secondary payloads in spring 2016. Program officials also provided technical comments, which were incorporated as appropriate.

[a]See GAO, *Space Launch System: Management Tools Should Better Track to Cost and Schedule Commitments to Adequately Monitor Increasing Risk.* GAO-15-596 (Washington, D.C.: July 16, 2015).

Space Network Ground Segment Sustainment

Project Challenges
- Contractor

Previously Reported Challenges
- Funding
- 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

NASA 2014 Strategic Plan Alignment: **Strategic Objective 3.2 Ensure sustainable technical capabilities for NASA's future missions**

CONTRACT INFORMATION

Current highest value contract

Contractor: **General Dynamics C4 Systems**

Contractor Activity: **Modernizing the ground system and network**

Type of Contract: **Cost-Plus-Award-Fee**
Date of Award: **June 2010**
Initial Value of Contract: **$626.0 million**
Current Value: **$952.6 million**

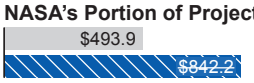
PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

~~40.0%~~ CHANGE

NASA's Portion of Project Cost

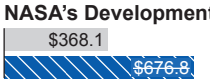


~~70.5%~~ CHANGE

NASA's Formulation Cost

~~31.5%~~ CHANGE

NASA's Development Cost



~~83.9%~~ CHANGE

Contribution from Other Users[a]

~~-0.8%~~ CHANGE

Completion schedule

06 2017 — ~~09 2019~~

~~27 months~~ CHANGE

Baseline FY 2013 | Latest Est.[b] Feb 2016

[a]*At its 2013 confirmation, SGSS expected approximately $368.7 million from other Space Network users. As of 2015, the actual amount received was $365.7 million.*

[b]*The project's latest cost and schedule estimates are currently under review.*

The Space Network Ground Segment Sustainment (SGSS) project plans to develop and deliver a new ground system for three Space Network sites—which provides essential communication and tracking services to NASA, other government agencies and commercial users. Existing ground systems, based on 1980s technology and software, are becoming increasingly obsolete and unsustainable. Updated systems, software, and equipment will allow the Space Network to continue to provide critical communications services to customer missions for the next several decades, while reducing operations and maintenance costs.

Source: NASA. | GAO-16-309SP

PROJECT SUMMARY

The SGSS project continues to experience contractor performance problems that could result in further cost and schedule increases. NASA approved a new baseline for the project in June 2015, which increased its estimated cost by $345 million and delayed its estimated completion by 27 months. The SGSS project has completed three of its five software increments. The SGSS contractor has fallen behind schedule on the fourth increment due to lower than expected levels of software development productivity. The fifth increment is also at risk. If the contractor continues to perform poorly, the Space Communications and Navigation (SCaN) program will consider reducing the scope of the project after the contractor delivers an initial capability in 2018 and trains NASA personnel how to install, operate, and maintain the system.

09/19 Final acceptance review

09/18 First operational readiness review

08/17 System integration review

12/15 GAO review

06/15 Project rebaseline

Implementation

06/13 Critical design review

04/13 Project confirmation

09/12 Preliminary design review

11/11 Mission/system definition review

Formulation

09/10 Formulation start

Space Network Ground Segment Sustainment

Cost and Schedule Status

NASA approved a new SGSS cost and schedule baseline in June 2015, but the contractor is falling behind its new schedule. The cost overruns that led to the new baseline were caused, in part, by overly optimistic contractor staffing estimates. NASA managers had noted concerns with contractor plans and staffing estimates in 2013 during project confirmation. The new baseline provides the SGSS project with over $65 million in cost reserves and 8 months of schedule margin. The project plans to complete software integration and testing by December 2016, but this schedule is at risk.

Contractor

The SGSS project continues to experience contractor performance problems that could result in further cost increases and schedule delays in its software development effort. The SGSS project is comprised of five software increments, with each successive increment building upon the prior increments. The first three increments are complete, and the final two, which contain the project's management and control software, are in development. At the project's June 2015 rebaseline review, the standing review board warned that the contractor's estimates for the new baseline underrepresented the complexity of the final two increments and the aggressiveness of the schedule. As of December 2015, the completion of the fourth increment was at least 5.5 weeks behind the contractor's schedule, and the project is concerned that additional delays may occur. The project also estimated that costs could increase by as much as $6.6 million over several fiscal years due to the schedule delays. The project expects to use project-held cost and schedule reserves to address the schedule delays and cost increases. The schedule and cost of the fifth software increment is also a project risk because the contractor might need more staff and time than estimated to complete it due to lower than expected levels of software development productivity. The backlog of defects to be addressed by the fifth increment also continues to increase.

SCaN has recently taken several steps to improve contractor oversight in response to standing review board recommendations. For example, the project developed metrics to help track contractor performance in software development. We have reported that metrics, such as measuring changes in the expected amount of software code that needs to be developed, provide useful insight to software development activities and progress, and identify areas for improvement.

If the contractor continues to perform poorly, SCaN may reduce the scope of the project. SCaN is considering terminating the project after an initial capability is delivered and the project holds its operational readiness review in September 2018. SCaN would terminate the project at this point because the contractor would have delivered the hardware, antenna modifications, and software needed to enable the full range of SGSS capabilities and Space Network staff would have been trained on how to take over installation, operations, and maintenance of the system. NASA would still have to finish installation work across the three Space Network sites and complete the transition to SGSS. According to NASA officials, this transition would occur incrementally as funding became available. The SGSS project is to complete a detailed transition plan before entering the system integration, test, and deployment phase in 2017.

Project Office Comments

In commenting on a draft of this assessment, SGSS project and SCaN officials reported that the project has sufficient project- and headquarters-held cost and schedule reserves to cover contractor schedule and cost expansion. They noted that the project has partially mitigated the effect of contractor performance problems, including by simplifying the design and automating testing. In addition, the officials stated that the project is working to deliver full scope of capabilities at all three sites by September 2019. Project officials also provided technical comments, which were incorporated as appropriate.

Surface Water and Ocean Topography

Project Challenges
- Technology maturity (new)
- Design (new)
- Development partner

PROJECT ESSENTIALS

NASA Center Lead:
Jet Propulsion Laboratory

Partners: **Centre National d'Etudes Spatiales (France), Canadian Space Agency (Canada), United Kingdom Space Agency (United Kingdom)**

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

Mission Duration: **3 years**

Requirement derived from:
2007 Decadal Survey

NASA 2014 Strategic Plan Alignment: **Strategic Objective 2.2 Understand our home planet**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Airbus Defence and Space**

Contractor Activity: **Gyroscope development**

Type of Contract: **Firm-Fixed Price**
Date of Award: **November 2015**
Initial Value of Contract: **$3.7 million**
Current Value: **$3.7 million**

PROJECT PERFORMANCE

Then year dollars

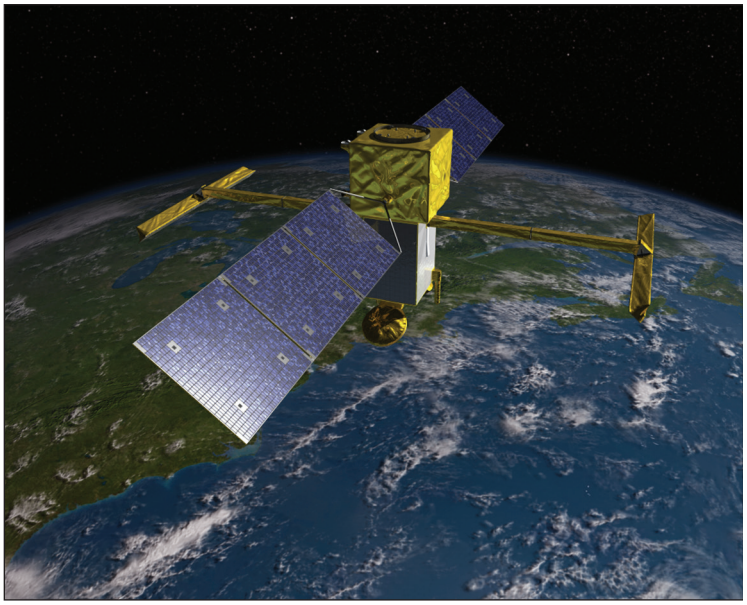
Preliminary estimate of Project Life Cycle Cost*

Latest: **February 2016** **$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) will use its wide-swath radar 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 and variations in ocean currents, which will help improve weather and climate predictions. SWOT is a joint project between NASA and the French Space Agency—the Centre National d'Etudes Spatiales (CNES).



Source: NASA/JPL – Caltech (artist depiction). | GAO-16-309SP

PROJECT SUMMARY

The SWOT preliminary design review has been delayed by several months to March or April 2016 to allow the project time to study ways to enhance reliability after another NASA mission with a radar instrument experienced a failure after launch. The project's confirmation review, or Key Decision Point C, has also been delayed. In preparation for the preliminary design review, the project matured three of its four critical technologies to the level of maturity recommended by best practices and is in the process of confirming the maturity of the fourth technology, which is contributed by CNES. The SWOT project is also addressing potential payload mass issues in the lead-up to the design review. Project officials stated that potential changes to the payload design to reduce mass could require the project to use some of its cost reserves.

10/20 Projected launch readiness date

01/19 System integration review

06/17 Critical design review

Implementation

05/16 Project confirmatior

04/16 Preliminary design review

12/15 GAO review

05/14 Mission/ system definition review

Formulation

11/12 Formulation start

Surface Water and Ocean Topography

Cost and Schedule Status

The SWOT preliminary design review has been delayed by several months to late March or early April 2016. The project delayed the design review so that it could study ways to enhance the reliability of the mission after the Soil Moisture Active and Passive (SMAP) mission's radar failed after launch. The project also delayed its confirmation review, or Key Decision Point C, to May 2016, at which point it will establish its cost and schedule baselines.

Technology Maturity and Development Partner

The project expects to mature all four critical of its technologies to a technology readiness level 6 in preparation for its preliminary design review. Maturing critical technologies to this level is a best practice, which helps minimize risks for space systems entering product development. The project has matured three out of its four critical technologies to a technology readiness level 6. These technologies are components of Ka-band Radar Interferometer (KaRIn) instrument, which is the project's most complicated and challenging development. According to the project, the fourth KaRIn component, the CNES-contributed radio frequency unit (RFU), was reported as technology readiness level 6 prior to the KaRIn instrument-level preliminary design review. The project plans to formally recognize the RFU as technology readiness level 6 after it receives additional test documentation from CNES. The project is also tracking a variety of KaRIn RFU-related risks including its aggressive schedule and limitations on its performance.

Design

The SWOT project is addressing potential mass issues in the lead-up to its preliminary design review. The project is tracking a risk that its payload mass could exceed its spacecraft allocation. If the payload mass exceeds its allocation, the spacecraft design would have to change or the payload mass would need to be reduced, which could have cost, schedule, or performance implications. The project's mass margin decreased to a level below NASA requirements after design updates to KaRIn in May and June 2015, but the margin has since improved. The project is currently conducting a mass scrub exercise, which gets triggered when margins become tight. Project officials stated that changes to the design to reduce payload mass could require the project to use some of its cost reserves.

Other Issues to Be Monitored

The project is concerned that an outage that occurred in July 2015 on the recently-launched SMAP mission could affect the development of SWOT's radar components and is taking steps to proactively address the issues. SMAP's radar experienced an anomaly that originated in the radar's high power amplifier, which boosts the power level of the radar's pulse to ensure accurate measurements. NASA made a final, unsuccessful attempt to power up the radar unit in August 2015, and decided to end attempts to recover SMAP's radar operations after exhausting options to recover the high power amplifier. The project is proactively monitoring and researching the SMAP anomaly because its findings may affect the SWOT design and implementation plans. The project has not yet identified any areas of commonality between SMAP and SWOT related to the anomaly that are a concern; however, the SMAP failure has caused the project to re-examine its own risk of experiencing a single point failure that could threaten the mission. As a result, the project is delaying its preliminary design review, so that it and CNES can study ways to enhance SWOT reliability without affecting cost, schedule, or partnership commitments.

Project Office Comments

In commenting on a draft of this assessment, SWOT project officials noted that the project continues to track mass and other key performance parameters in close coordination with CNES. Project officials stated that they employ a combination of techniques, such as redesigns and reassessing requirements, to maintain the appropriate technical margins at key milestones. They also reported that the enhanced reliability study is progressing well and expect to complete it in early February 2016. Project officials provided technical comments, which were incorporated as appropriate.

Transiting Exoplanet Survey Satellite

Project Challenges
- Schedule
- Contractor (new)
- Launch (new)

Previously Reported Challenges
- Design

PROJECT ESSENTIALS

NASA Center Lead:
Goddard Space Flight Center

Partner: **Massachusetts Institute of Technology, Principal Investigator**

Launch Location: **Cape Canaveral AFS, FL**
Launch Vehicle: **Upgraded Falcon 9**

Mission Duration: **2 years**

Requirement derived from:
2010 Decadal Survey

NASA 2014 Strategic Plan Alignment: **Strategic Objective 1.6 Search for life and understand the universe**

CONTRACT INFORMATION

Current highest value contract

Contractor: **Orbital ATK, Inc.**

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: **$73.0 million**

PROJECT PERFORMANCE

Then year dollars in millions

Total Project Cost

-7.1% CHANGE

Formulation Cost

0.0% CHANGE

Development Cost

-8.3% CHANGE

Operations Cost

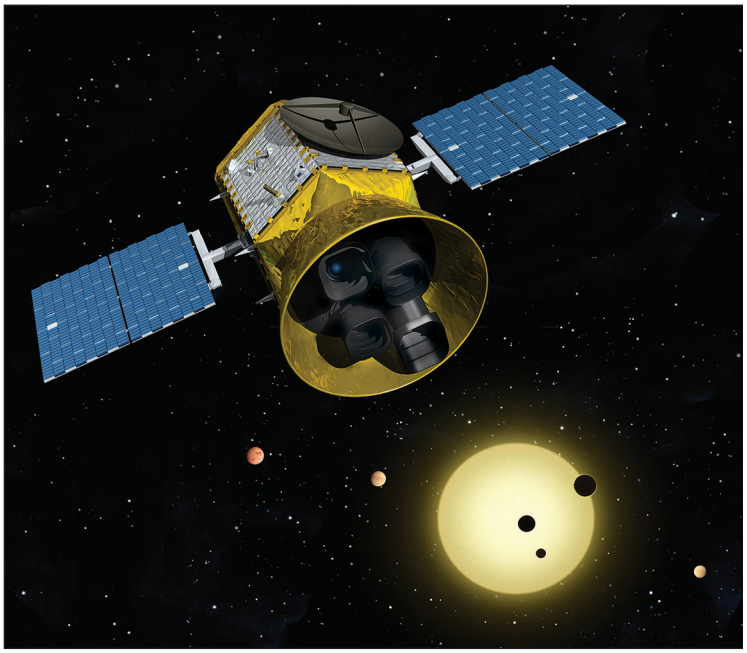
0.4% CHANGE

Launch Schedule

0 months CHANGE

Baseline FY 2015 | Latest Est. Feb 2016

The Transiting Exoplanet Survey Satellite (TESS) will use four identical, wide field-of-view cameras to conduct the first extensive survey of the sky from space. The mission's goal is to discover exoplanets—or planets in other solar systems—during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth. TESS aims to discover Earth-sized, rocky, and potentially habitable exoplanets, of which few are known. The mission plans to characterize the most favorable targets for detailed investigations by other missions, including the James Webb Space Telescope.



Source: NASA. | GAO-16-309SP

PROJECT SUMMARY

The TESS project continues to pursue an aggressive schedule, and as a result it has increased its risk of cost growth and schedule delays. The project is working towards an August 2017 launch date, which is 10 months before its committed launch date and 4 months before NASA's planned date. This schedule-driven approach has been evident in project execution. For example, the project held its critical design review in August 2015 before its instrument design was stable. Development delays and technical issues with the data handling unit (DHU), a primary component of the TESS instrument, pose a threat to the project schedule and have led the project to pursue a dual path for DHU development, which will increase project costs. The project is also tracking several launch-related risks stemming from a June 2015 Falcon 9 launch failure and unknowns related to the upgraded Falcon 9 that will be used for TESS.

06/18 Committed launch readiness date

12/17 NASA internal launch readiness date

08/17 Project launch readiness date

10/16 System integration review

12/15 GAO review

Implementation

08/15 Critical design review

10/14 Project confirmation

09/14 Preliminary design review

02/14 Mission system/ design review

04/13 Formulation start

Formulation

Transiting Exoplanet Survey Satellite

Cost and Schedule Status

The TESS project held its critical design review in August 2015, but did not successfully complete it because its instrument design was not stable. The project addressed the outstanding issues with its instrument design, including the cameras and data handling unit (DHU), at a separate technical review in December 2015. The start of system integration and test—planned for October 2016—could be delayed. The TESS project has used cost and schedule reserves to address DHU issues, but is currently holding reserves consistent with the amount required by center policy.

Schedule and Contractor

The TESS project continues to pursue an aggressive development schedule, and as a result has increased its risk of cost growth and schedule delays. The project is working towards an August 2017 launch, which is 10 months before its committed launch date and 4 months before NASA's planned launch date. To stay on schedule, the project held its critical design review before its instrument design was stable. The project released less than 90 percent of its design drawings by the review, which best practices show can increase the project's risk of cost growth and schedule delays.

Development delays with the DHU are threatening the project's schedule. The DHU provides power to TESS's cameras and serves as the instrument data storage and processing computer. The development of the DHU is behind schedule due to a series of technical issues related to its complex and compact design and contractor performance issues. As a result, the project has depleted the schedule margin for its instrument and could delay its system–level integration and test. The project has taken several steps to mitigate DHU-related risks. First, to maintain the August 2017 launch date, the project plans to begin system-level testing with the DHU's design model instead of the final flight unit. In addition, the project increased management and oversight of the DHU contractor. Finally, the project plans to award a contract for an alternative DHU. The project plans to pursue both DHU paths in the near-term, which will increase project costs by at least several million dollars.

Further delays to the TESS development are possible. The project is tracking a risk that it will not reach the level of maturity required to complete its systems integration review, planned for October 2016, which is required to begin the assembly, integration and test phase. Because the project did not complete its critical design review on schedule, the time between that milestone and the systems integration review has been compressed.

Launch

The TESS project is tracking several launch related risks. Subsequent to the project's selection of the Falcon 9 as its launch vehicle, SpaceX decided to phase out its existing Falcon 9 for an upgraded version that has yet to be flown. NASA will have to certify the upgraded Falcon 9, but it has not yet done so. A project official told us that if the certification process is delayed, it could result in a TESS launch delay. Further, the project is concerned that it does not know what effect the launch environment for this vehicle may have on its delicate science instrument. Project officials said that after its March 2016 launch vehicle preliminary design review, the project will better understand the upgraded Falcon 9 and will consider options, such as purchasing a "soft ride" to mitigate potential frequency and vibration during launch. The project also continues to monitor the accident investigation and corrective actions taken by SpaceX as a result of a June 2015 Falcon 9 launch failure, which involved the prior design, not the planned upgrade.

Project Office Comments

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