Commercial Crew Program

The Commercial Crew Program facilitates and oversees the development of safe, reliable, and cost-effective crew transportation systems by commercial companies to carry NASA astronauts to and from the International Space Station (ISS). The program is a multi-phase effort that started in 2010. During the current phase, the program is working with two contractors—Boeing and SpaceX—that will design, develop, test, and operate the crew transportation systems. Once NASA determines the systems meet its standards for human spaceflight—a process called certification—the companies will fly up to six crewed missions to ISS.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Kennedy Space Center**

Commercial Partners: **Boeing, SpaceX, Blue Origin,[a] Sierra Nevada Corporation[a]**

Launch Location: **Boeing-Cape Canaveral Air Force Station, FL; SpaceX-Kennedy Space Center, FL**

Launch Vehicle: **Boeing-Atlas V; SpaceX-Falcon 9**

Requirement Derived from: **NASA Strategic Plan**

Budget Portfolio: **Space Operations, Space Transportation**

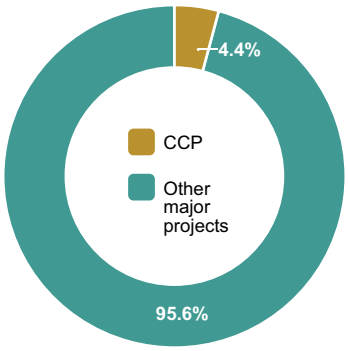
[a]Blue Origin and Sierra Nevada Corporation do not have contracts for the current phase and therefore were not included in this assessment.

PROJECT SUMMARY

Both of the Commercial Crew Program's contractors have made progress developing their crew transportation systems, but continue to have aggressive development schedules. All test flights have slipped to 2018 and the final certification reviews have slipped to early 2019. Both contractors continue to work through design issues for their crew transportation systems. SpaceX is finalizing the design for its launch vehicle, Falcon 9, which will be needed to support crewed flights. Boeing is analyzing the design of the forward heat shield to determine if its expected performance may damage the spacecraft during re-entry. The Commercial Crew Program is the first NASA program that the agency will evaluate against a loss of crew requirement, a key safety metric. Program officials said that if the contractors cannot meet the loss of crew requirement specified in the contracts, NASA could still certify their systems by employing operational mitigations.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



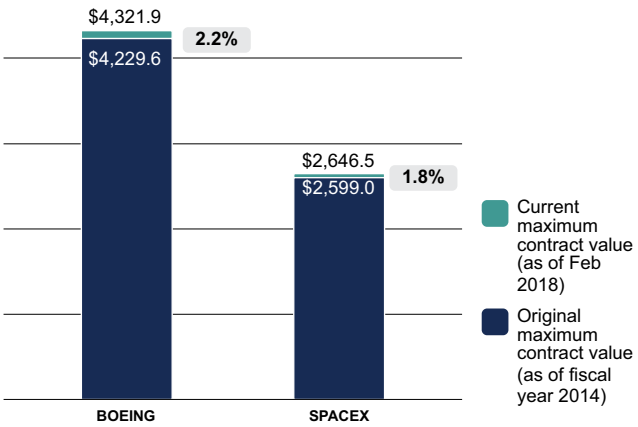
ESTIMATED FUNDING NEEDED[b]

then-year dollars in millions

[b]Includes costs to fund the contracts.

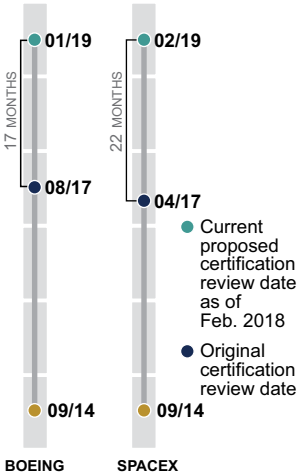
COST PERFORMANCE[c]

then-year dollars in millions



[c]Includes contract costs for development, operations, and special studies.

SCHEDULE PERFORMANCE



Cost and Schedule Status

Both of the Commercial Crew Program's contractors have made progress developing their crew transportation systems, but delays persist as the contractors have had difficulty executing aggressive schedules. The contractors were originally required to provide NASA all the evidence it needed to certify that their systems met its requirements by 2017. In January 2018, we found the contractors' test flights have slipped to 2018 and the final certification reviews have slipped to early 2019.[d] This represents a delay of 17 months for Boeing and 22 months for SpaceX from initial schedules. The Commercial Crew Program is tracking risks that both contractors could experience additional schedule delays and its schedule risk analysis indicates that certification is likely to slip until late 2019 for SpaceX and early 2020 for Boeing.

Design

SpaceX must close several of the program's top risks related to its upgraded launch vehicle design, the Falcon 9 Block 5, before it can be certified for human spaceflight. This includes SpaceX's redesign of the composite overwrap pressure vessel. SpaceX officials stated the new design aims to eliminate risks identified in the older design, which was involved in an anomaly that caused a mishap in September 2016. Separately, SpaceX officials told us that the Block 5 design also includes design changes to address cracks in the turbine of its engine identified during development testing. NASA program officials told us that they had informed SpaceX that the cracks were an unacceptable risk for human spaceflight. SpaceX officials told us that they have made design changes, captured in this Block 5 upgrade, that did not result in any cracking during initial life testing. However, this risk will not be closed until SpaceX successfully completes qualification testing in accordance with NASA's standards without any cracks. SpaceX officials stated they expect this testing to be completed in first quarter calendar year 2018.

Boeing is also mitigating several risks in order to certify its system including challenges related to the performance of its abort system and a component of its parachute system. Boeing is addressing a risk that its abort system may not meet the program's requirement to have sufficient control of the vehicle through an abort. In some abort scenarios, Boeing has found that the spacecraft may tumble, which could pose a threat to the crew's safety. To validate the effectiveness of its abort system, Boeing has conducted extensive wind tunnel testing and plans to complete a pad abort test in April 2018. Boeing is also addressing a risk that during re-entry to the Earth's atmosphere, a portion of the spacecraft's forward heat shield, which protects the parachutes during re-entry, may reconnect and damage the parachute system. NASA's independent analysis indicates that this may occur if both parachutes that pull the forward heat shield away from the spacecraft deploy as expected. Boeing's analysis indicates the risk exists only if one of two parachutes does not deploy as expected. If the program determines this risk is unacceptable, Boeing would need to redesign the parachute system, which the program estimates could result in at least a 6-month delay.

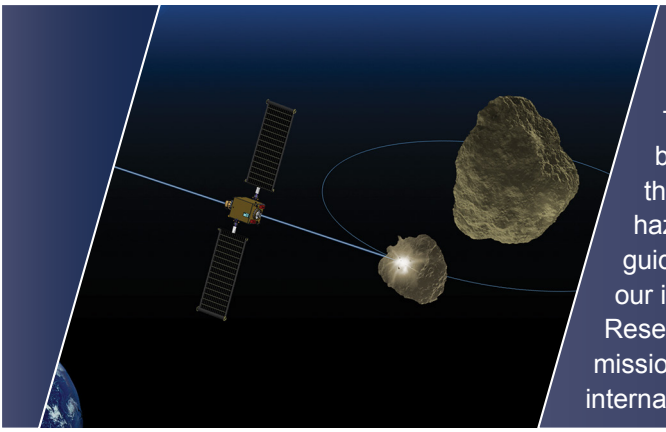
Other Issues to Be Monitored

The ability to meet one of the crew safety requirements, which stems from agency policy, is one of the program's top risks. NASA established the "loss of crew" requirement as one way to measure the safety of a crew transportation system, with the intent to minimize the probability of death or permanent disability to one or more crew members. Under the current contracts, the loss of crew requirement is 1 in 270, meaning that the contractors' systems must carry no more than a 1 in 270 probability of incurring loss of crew. Program officials told us that Commercial Crew is the first NASA program that the agency will evaluate against a loss of crew requirement. They said that if the contractors cannot meet the loss of crew requirement, there are several actions the Commercial Crew Program could take to help meet it. Program officials stated, however, these actions may not be enough to completely close the gap. The program has reported it is exploring options, such as on-orbit inspections of the spacecraft. Additionally, program officials told us that one of their greatest upcoming challenges will be to complete two oversight activities—conducting phased safety reviews and verifying that contractors meet requirements—concurrently. For example, the program originally planned to complete phase two of the safety review process in early 2016, but as of October 2017, neither contractor had completed this phase—the program had approved 90 percent of Boeing's phase two reports and 70 percent of SpaceX's.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, program officials stated that NASA's Commercial Crew Program and private industry partners, Boeing and SpaceX, continue to develop the systems that will return human spaceflight to the United States. Both commercial partners are undertaking considerable amounts of testing in 2018 to prove space system designs and the ability to meet NASA's safety and mission requirements for crew flights to the ISS.

[d] GAO-18-317T.



Double Asteroid Redirection Test

The DART project plans to travel to the near-Earth asteroid Didymos, a binary system, and impact the smaller of the two bodies. NASA will assess the deflection result of the impact for potential future use on other potentially hazardous near-Earth objects. The project responds to near-Earth object guidance by the Office of Science and Technology Policy to better understand our impact mitigation posture, and to recommendations by the National Research Council Committee to conduct a test of a kinetic impactor. The DART mission is part of the Asteroid Impact and Deflection Assessment, which is an international collaboration with the European Space Agency.

Source: Johns Hopkins University/Applied Physics Lab. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Marshall Space Flight Center**

International Partner: **European Space Agency**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **22 months**

Requirement Derived from: **NASA Authorization Act of 2008 and implementing guidance**

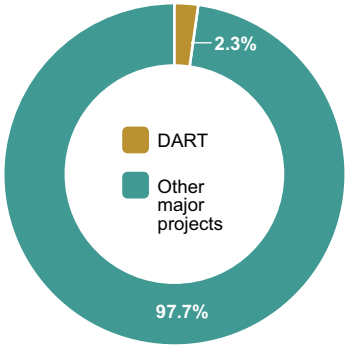
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The DART project is working toward preliminary design review and project confirmation, but funding uncertainty and technology maturity of its propulsion system may change the project's schedule. This uncertainty could trigger a re-evaluation of life-cycle costs and overall schedule heading to preliminary design review and project confirmation. Further, DART's planned electric propulsion thruster is facing development delays, particularly in its propulsion power systems. The project is looking at possible schedule delays should thruster issues persist. DART was also intended to be one of two spacecraft to be sent to the Didymos binary asteroid system—along with a spacecraft produced and launched by the European Space Agency. The European spacecraft did not receive necessary funding for 2017 and may be canceled. The DART project is assessing the effect on collected science data of losing proximate observation and is in the early stages of considering various alternatives.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



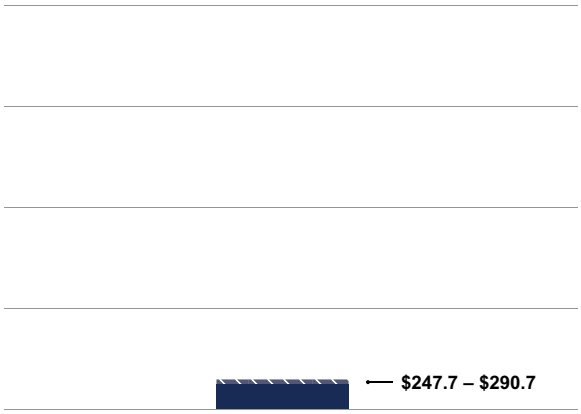
TOTAL FUNDED TO DATE

then-year dollars in millions

$22.5

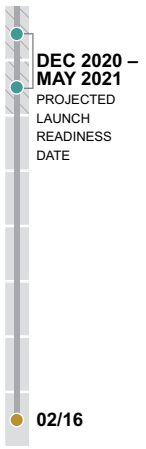
PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE



LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

The DART project entered the preliminary design and technology completion phase in June 2017 with the agency acknowledging that uncertain funding may affect the project's schedule. This could trigger a re-evaluation of life-cycle costs and overall schedule heading to preliminary design review and project confirmation—which the project has delayed by 2 months and 1 month, respectively. DART's planned launch readiness date range is December 2020 – May 2021, with impact of the asteroid occurring in 2022. Project officials told us that if they receive less funding than planned, there is another launch opportunity 2 years later and they are currently studying the effects on the mission if it is delayed to this date. Officials also noted a delayed launch window would likely increase total costs in exchange for lower annual costs.

Technology

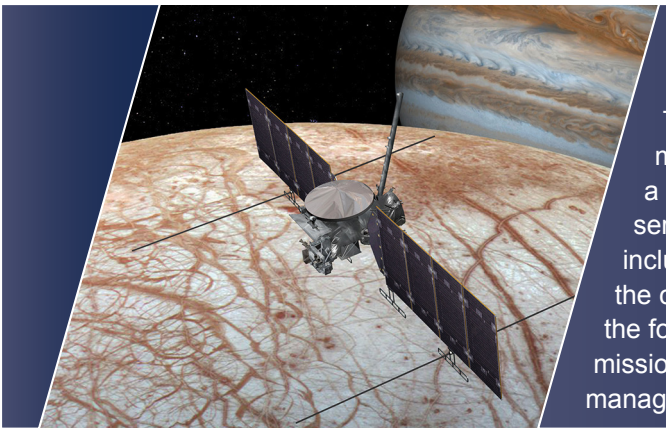
DART's propulsion system includes technologies that remain immature and may delay the mission preliminary design review and potentially the project's launch date. The DART project is working with NASA's Evolutionary Xenon Thruster-Commercial (NEXT-C)—a project managed at Glenn Research Center under the Discovery Program—to provide in-space electric propulsion for the mission. The DART mission will be the first time this technology will fly operationally and, if successful, will serve as qualification for future deep space missions. However, first-time production of this system—DART's critical path and top risk—is proving challenging. The NEXT-C thruster's power processing unit, which provides necessary voltages to the thruster, is the technical risk keeping the thruster from maturing. The project has delayed the mission preliminary design review by 2 months in part to allow more time to mature the NEXT-C technology. In addition, the program is carrying a risk to its launch readiness date dependent upon the NEXT-C meeting delivery and design targets.

Developmental Partner

The DART project's science collection may be less than originally planned due to the European Space Agency not funding DART's sister project, the Asteroid Impact Monitor (AIM) project. DART was designed to work with AIM as part of the collaborative Asteroid Impact & Deflection Assessment. Per the mission plan, as the DART spacecraft impacts the smaller of the Didymos binary asteroids, the AIM spacecraft would collect impact data along with Earth-based observatories. However, the AIM project did not receive necessary funding at the European Space Agency's ministerial meeting in December 2016. Losing AIM will reduce the amount of science data collected on the impact and the asteroids themselves. While the project believes that it can still meet its objectives of characterizing the results of the DART impact on the Didymos system, the project is performing planning and analysis leading up to preliminary design review to determine how effective the Earth-based observatories will be at determining the results of the impact event. As a result of the potential loss of science data, NASA is considering possible alternatives that could provide imagery and data related to the impact.

PROJECT OFFICE COMMENTS

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



Europa Clipper

The Europa Clipper mission aims to investigate whether the Jupiter moon could harbor conditions suitable for life. The project plans to launch a spacecraft in the 2020s, place it in orbit around Jupiter, and conduct a series of investigatory flybys of Europa. The mission's planned objectives include characterizing Europa's ice shell and any subsurface water, analyzing the composition and chemistry of its surface and ionosphere, understanding the formation of its surface features, and surveying sites for a potential landed mission. We did not assess the proposed Europa lander mission, which NASA is managing as a separate project in pre-formulation.

Source: Europa Project Personnel, California Institute of Technology, Jet Propulsion Laboratory. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

International Partner: **None**

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

Launch Vehicle: **TBD**

Mission Duration: **3 year science mission**

Requirement Derived from: **2011 Planetary Science Decadal Survey**

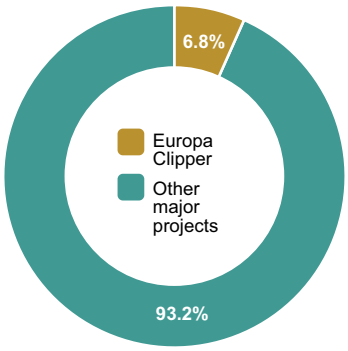
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The Europa Clipper project plans to hold its preliminary design review in August 2018 and its confirmation review in October 2018 on schedule, at which point the project will establish its cost and schedule baselines. The project implemented a process to manage instrument costs with options to descope an instrument entirely or in part but has not descoped any instruments to date. The project continues to work toward a June 2022 launch but the availability of a qualified and well-understood launch vehicle could affect that schedule. The project is maintaining compatibility with multiple launch vehicles as it awaits NASA's selection. The project is evaluating design options that may affect the mass and power needed to operate the spacecraft and its 10 instruments. The project has experienced workforce shortages since October 2016, but has seen recent improvements. The project is currently holding cost reserves consistent with Jet Propulsion Laboratory (JPL) policy, but is not meeting JPL's schedule reserve requirement due to technical issues with solar array development.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

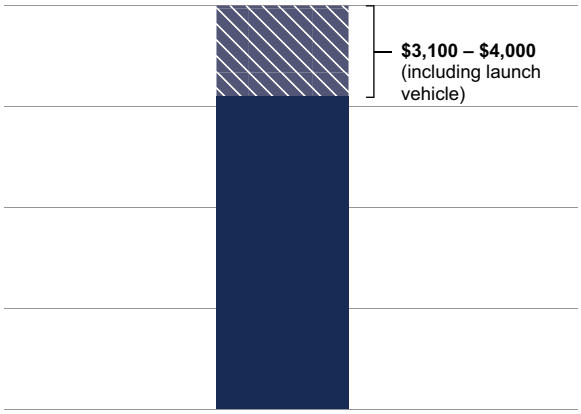


TOTAL FUNDED TO DATE

then-year dollars in millions

PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE

LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

In February 2017, NASA approved the Europa Clipper project to proceed with preliminary design and technology completion, but the project's independent review board highlighted that the complexity and scope of the current 10 instruments may cause cost and schedule growth. In response, the project proposed and NASA approved a process to manage instrument costs with options to descope an instrument entirely or in part to prevent cost growth. For example, if an instrument exceeds its development cost by 20 percent, the project would propose a descope option to NASA that brings instrument cost below that threshold. NASA has not descoped any instruments to date.

The project is currently holding cost reserves consistent with JPL policy, but is not meeting JPL's schedule reserve requirement due to technical issues with solar array development. In March 2017, the project discovered that the materials it planned to use on its solar arrays did not meet requirements under low temperatures. As a result, the project changed the materials it plans to use and is exploring using a different vendor for the solar arrays. Project officials said the technical issues and the project's actions to mitigate them delayed delivery of the solar arrays 3 months beyond the project's baseline need date. However, project officials said the baseline need date was earlier than the actual need date for solar array integration. As a result, the project is reassessing the integration and test flow and may be able to recover some schedule reserves.

The project plans to hold its preliminary design review in August 2018 and its confirmation review in October 2018 on schedule, at which point the project will establish its cost and schedule baseline.

Launch

The Europa Clipper project continues to work toward a June 2022 launch, but the availability of a qualified and well-understood launch vehicle could affect that schedule. Project officials stated that the project needs to select a launch vehicle by the end of 2018 to maintain a 2022 launch date. The project is maintaining compatibility with multiple launch vehicles such as the Delta IV Heavy, Falcon Heavy, and NASA's Space Launch System (SLS); however, each of the launch vehicles under consideration has trade-offs that affect development. The Consolidated Appropriations Act, 2016 requires the project to use SLS; however, recent SLS schedule delays could result in a delay to Europa Clipper's planned June 2022 launch readiness date unless NASA adjusts its current plans for SLS and the associated ground systems. Project officials support using SLS as the launch vehicle, even if it delays the planned launch, because SLS allows a direct flight to Jupiter. This path could reduce the travel time by approximately 4.5 years compared to other launch vehicle options.

Technology and Design

The project is currently meeting JPL mass and power margin requirements, but is evaluating design options that may affect the mass and power needed to operate the spacecraft and its 10 instruments. For example, accommodation of the ice-penetrating radar has been difficult because it requires a higher-than-expected amount of power that could lead to design trades. To mitigate this risk, the project is conducting additional testing of the instrument to evaluate compatibility at lower levels of power. The project is also evaluating design options for its solar arrays, which project officials said will increase available power but may also increase mass.

Other Issues to Be Monitored

The project experienced workforce shortages at JPL in several key areas since October 2016. The project has revised staffing plans several times, but the project continues to face workforce shortages even with NASA headquarters involvement. As of January 2018, project officials reported that improvements have been seen in addressing workforce shortages. Other JPL projects have experienced workforce issues as well, which NASA attributes to the amount of work the laboratory is managing.

PROJECT OFFICE COMMENTS

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

Exploration Ground Systems

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 Orion Multi-Purpose Crew Vehicle (Orion). The EGS program consists of several major construction and facilities projects including the Mobile Launcher (pictured to the left), Crawler Transporter, Vehicle Assembly Building, and launch pad, all of which need to be complete before the first uncrewed exploration mission using the SLS and Orion vehicles.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Kennedy Space Center**

International Partner: **None**

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

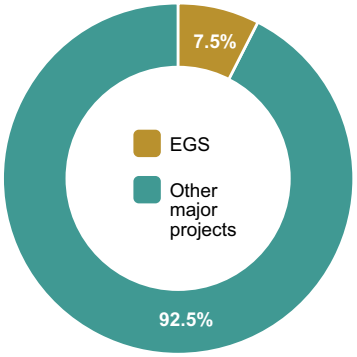
Budget Portfolio: **Exploration, Exploration Systems Development**

PROJECT SUMMARY

In December 2017, NASA announced a new schedule and cost estimate for the EGS program, after determining that the November 2018 launch readiness date for Exploration Mission-1 (EM-1) was no longer feasible. NASA is now planning to a launch readiness date of December 2019, with 6 months of schedule reserve to a June 2020 date. The life-cycle cost estimate for EGS is approximately $3.1 billion to the December 2019 date and $3.2 billion to June 2020. The program's schedule is currently driven by its two major software development efforts, both of which are undergoing technical challenges. For example, the ground control system is in the process of transitioning to a new contractor and is undergoing organizational changes. In addition, while the program has made progress with major projects such as the Vehicle Assembly Building and Launch Pad 39B, the Mobile Launcher is continuing to have technical challenges. Fifteen percent of the Mobile Launcher's accessories and umbilicals still have to complete testing, and there are emerging concerns about the structural integrity of the Mobile Launcher's base.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

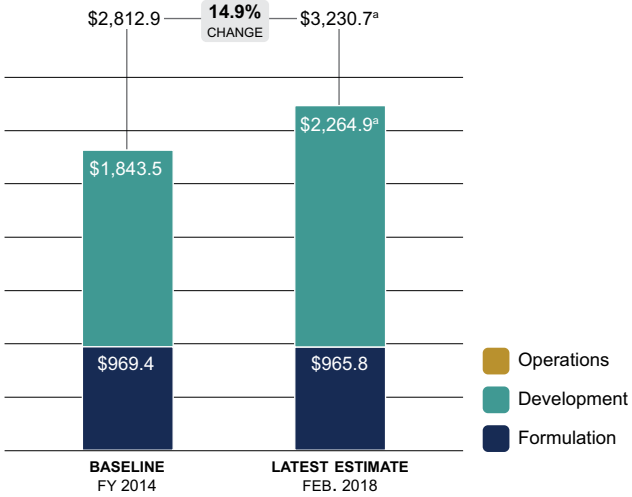


ESTIMATED FUNDING NEEDED

then-year dollars in millions

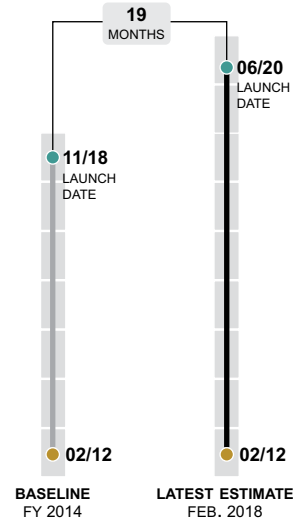
COST PERFORMANCE

then-year dollars in millions



[a]Assumes June 2020 launch date.

SCHEDULE PERFORMANCE



Cost and Schedule Status

In December 2017, NASA announced a new schedule and cost estimate for the EGS program, after determining that the November 2018 launch readiness date for Exploration Mission-1 (EM-1) was no longer feasible. In April 2017, we found that the date was likely unachievable for all three human spaceflight programs—EGS, the Space Launch System, and the Orion Multi-Purpose Crew Vehicle—due to technical challenges continuing to cause schedule delays and the programs having little to no schedule reserve to the EM-1 date, meaning they would have to complete all remaining work with little margin for error for unexpected challenges that could arise.[b] The new launch readiness date for EM-1 is now December 2019, but NASA has allocated 6 months of schedule reserve to June 2020 for possible manufacturing and production schedule risks. This represents a delay of 13-19 months for EM-1. The life-cycle cost estimate for EGS is approximately $3.1 billion to the December 2019 date and $3.2 billion to June 2020, or 11.8 to 14.9 percent above the project's committed baseline.

Technology

EGS's two major software development efforts—Spaceport Command and Control System (SCCS), which will operate and monitor ground equipment, and Ground Flight Application Software (GFAS), which will interface with flight systems and ground crews—are the program's primary schedule drivers, and the program has recently restructured the organization of the SCCS in order to address gaps in systems engineering processes, among other concerns. EGS's other major software development effort, GFAS, continues to face challenges due to late deliveries from the SLS and Orion programs and delays in SCCS; however, program officials stated they have been heavily focused on resolving SCCS challenges. According to program officials, increased processing needs combined with unplanned rework led to higher complexity in the SCCS system. This complexity in turn led to a program review of SCCS, which found gaps in the system development process and in SCCS's organizational structures. As a result of these issues, EGS is restructuring the Systems Engineering and Integration organization, augmenting hardware, and hiring more staff. Program officials noted that a challenge in this restructuring is hiring because NASA is competing for software developers with the local aerospace economy. The program is also executing a pre-planned transition that moves SCCS under the same contractor as GFAS and will shift the SCCS development structure to smaller deliverables that can be released more often. A senior NASA official said that EGS's software development is a top issue leading up to EM-1, and that as a result, the EGS Associate Program Manager was temporarily reassigned to exclusively manage enhancements to the EGS software development effort.

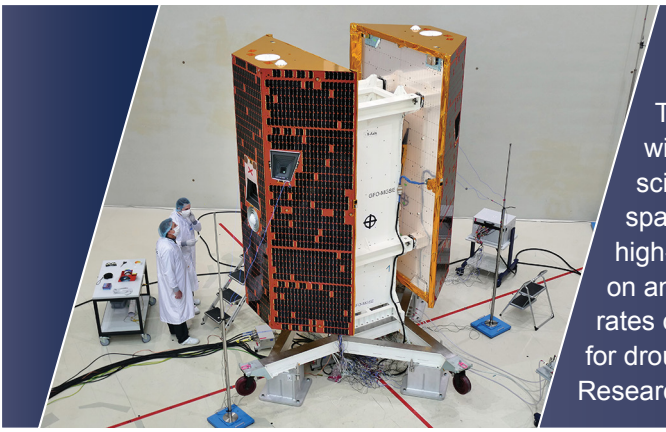
Design

The EGS program has made progress on several projects, including the Vehicle Assembly Building and Launch Pad 39B, but technical challenges continue with the Mobile Launcher. The Mobile Launcher supports the assembly, testing, and servicing of the SLS rocket and provides the platform on which SLS and Orion will launch. The program has started verification and validation activities for the Mobile Launcher, while ground support equipment and umbilical installation projects are still underway. For example, 15 percent of the Mobile Launcher's umbilicals and launch accessories still have to complete testing. Program officials previously said this concurrency increases risk because of uncertainties regarding how systems not yet installed may affect the systems already installed. In November 2017, EGS reported that loads models have indicated low stress margins in critical locations in the Mobile Launcher base. The program attributed this issue to an error in their model. The program is currently designing structural reinforcements for the base of the Mobile Launcher and hydraulics pedestals for the launch pad. Program officials stated this approach could be completed within the program's existing schedule.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, EGS program officials said the vast majority of EGS development and production content is on track for EM-1 and work is proceeding for the first flight of crew on Exploration Mission-2. In addition, officials said EGS has strengthened its ground software development plans to reflect expected deliveries from other programs. Program officials also provided technical comments, which were incorporated as appropriate.

[b] GAO-17-414.



Source: Airbus Defense and Space. | GAO-18-280SP

Gravity Recovery and Climate Experiment Follow-On

The Gravity Recovery and Climate Experiment Follow-On (GRACE-FO) will continue and expand upon the 2002 GRACE mission, which ended science operations in October 2017. The system, which consists of two spacecraft working together to obtain scientific measurements, will provide high-resolution models of Earth's gravity field and insight into water movement on and beneath the Earth's surface for up to 5 years. These models will provide rates of ground water depletion and polar ice melt and enable improved planning for droughts and floods. GRACE-FO is a collaborative effort with the German Research Centre for Geosciences (GFZ).

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

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

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **Falcon 9**

Mission Duration: **5 years**

Requirement Derived from: **NASA 2010 Climate Plan**

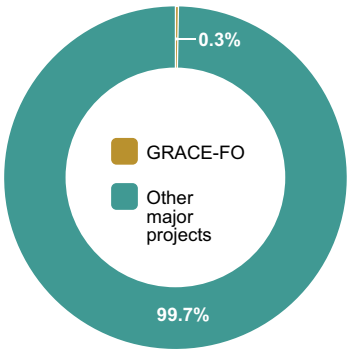
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The GRACE-FO project plans to launch in May 2018, 3 months later than its committed launch readiness date of February 2018, but within its committed cost baseline. Delays to the project's launch readiness date, which over time have accumulated to 9 months of delays, are related to the project's launch vehicle arrangement. First, GFZ—NASA's partner on the project, which is responsible for the launch vehicle—reported that it was notified by the Russian Federal Space Agency that the Dnepr launch vehicle was no longer available. Subsequently, GFZ arranged to launch the two GRACE-FO spacecraft, along with commercial satellites, on a SpaceX Falcon 9. But the project experienced subsequent delays after SpaceX experienced an anomaly on a launch pad that resulted in delays to the launch schedule. The project used the extra time created by the launch delays to conduct additional risk reduction activities during system-level integration and test.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

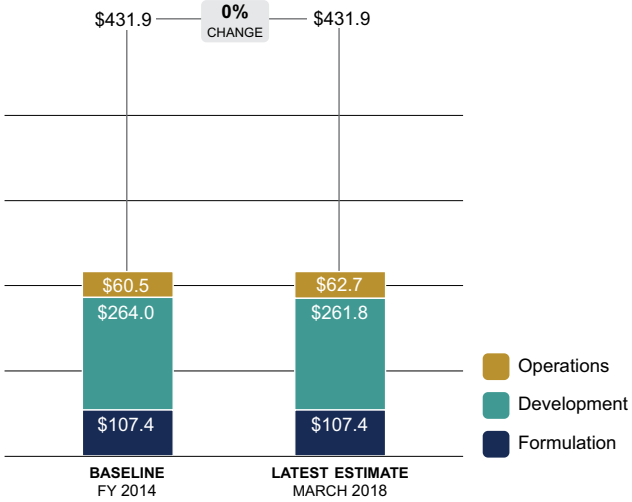


ESTIMATED FUNDING NEEDED

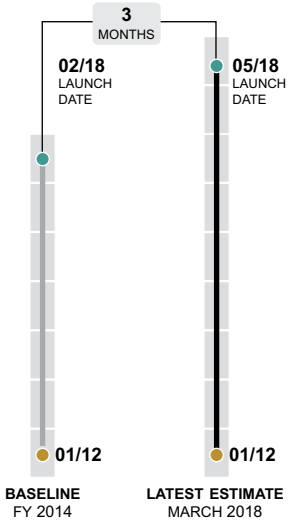
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The GRACE-FO project plans to launch in May 2018, 3 months later than its committed launch readiness date of February 2018, due to delays related to its launch vehicle arrangement. The project expects to launch within its cost baseline and plans to use its remaining project-held reserves to cover costs through May 2018. The project completed system-level testing on both spacecraft in November 2017 and shipped GRACE-FO to Vandenberg Air Force Base in California for pre-launch activities in December 2017.

Launch and Development Partner

The GRACE-FO project previously planned to launch early in August 2017, but delays related to its launch vehicle arrangement resulted in a 9-month delay to its launch readiness date. The launch vehicle is the responsibility of NASA's partner on the project—GFZ. An initial delay of 4 months occurred when the project changed its launch vehicle after GFZ reported that it was notified by the Russian Federal Space Agency that the Dnepr launch vehicle was no longer available. GFZ, in June 2016, arranged to launch the two GRACE-FO spacecraft, along with commercial satellites, on a SpaceX Falcon 9. SpaceX then experienced an anomaly on a launch pad in September 2016 that resulted in delays to the launch schedule as SpaceX investigated the source of the anomaly. In July 2017, a new 30-day launch readiness window from March to April 2018 was negotiated, resulting in an additional 4 months of delays for the project. In March 2018, the launch was delayed an additional month to May 2018 due to launch range availability.

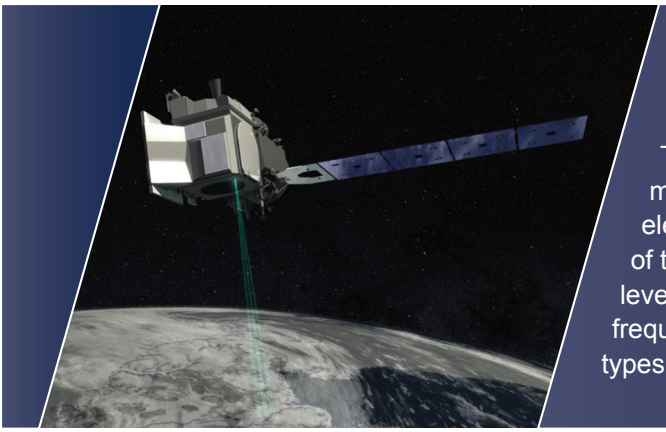
Integration and Test

The project used the extra time in the schedule due to launch delays to conduct additional risk reduction activities during system-level integration and test. For example, the project identified a design issue with its global positioning system antenna during testing. With the extra time, it replaced the antennas on both spacecraft to resolve the issue. In addition, the project identified a manufacturing issue with one of the two cavities that stabilizes the laser of its Laser Ranging Interferometer (LRI), which is contributed by GFZ. LRI is a technology demonstration that performs the same ranging measurements of GRACE-FO's microwave instrument but with greater precision and is not needed to meet the mission's science requirements. With the extra time, the project was able to replace and reintegrate the cavity with the spacecraft.

In addition, the project is investigating the shifting of an optical system component of LRI during system-level environmental testing in August 2017. The project is investigating the cause, but anticipates the shift is likely due to the expansion of adhesive bonds between the optical components when exposed to temperature and humidity. The project conducted additional tests using spare flight hardware in a vacuum, which removes humidity, to understand future alignment performance in a space-like environment. The project expects that it will be able to use the component as-is because tests indicate there is sufficient performance margin even with the shifting, that exposure to the vacuum of space will reduce the shifting, and it can make operational adjustments to further improve performance, if needed.

PROJECT OFFICE COMMENTS

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



Ice, Cloud, and Land Elevation Satellite-2

The Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) is a follow-on mission to ICESat that will measure changes in polar ice-sheet mass and elevation. The measurements will provide researchers a better understanding of the mechanisms that drive polar ice changes and their effect on global sea level. ICESat-2's upgraded laser instrument will allow the satellite to make more frequent measurements and provide better elevation estimates over certain types of terrain than ICESat.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **Delta II**

Mission Duration: **3 years**

Requirement Derived from: **2007 Earth Science Decadal Survey**

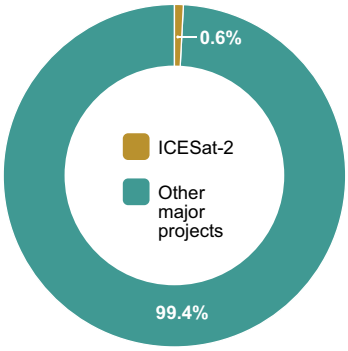
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The project will miss its rebaselined committed launch date but does not expect the cost to exceed the rebaseline because it has sufficient cost reserves to cover the delay. The project will miss its committed launch readiness date of June 2018 due to issues with its sole instrument—the Advanced Topographic Laser Altimeter System (ATLAS). In July 2016, the ICESat-2 project encountered problems with the flight lasers developed for ATLAS that caused NASA to delay the launch date to October 2018, which is 17 months beyond the original baseline and 4 months beyond the rebaselined date set in 2014. The project held its system integration review and began system-level integration and test in August 2017. The two repaired lasers that will fly on the ATLAS instrument were shipped back to Goddard Space Flight Center, completed flight acceptance testing, and are integrated onto the instrument. The project entered the system assembly and testing phase in October 2017.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

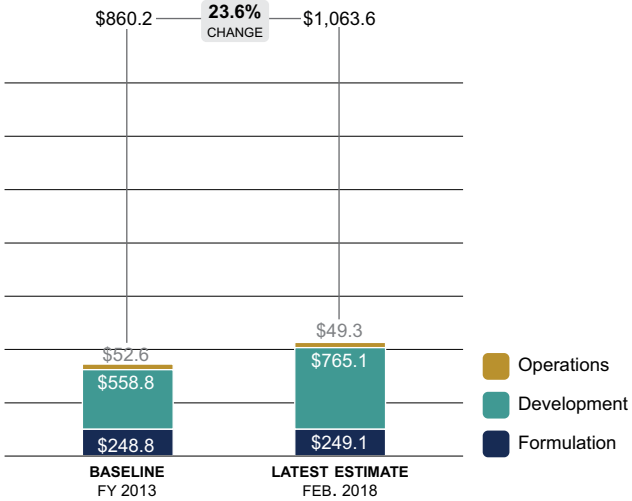


ESTIMATED FUNDING NEEDED

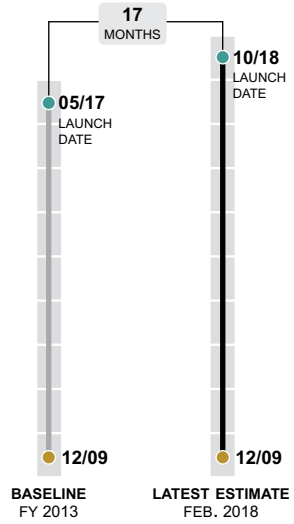
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The project will miss its rebaselined committed launch date but does not expect the cost to exceed the rebaseline because it has sufficient cost reserves to cover the delay. The ICESat-2 project is proceeding to integration and test after problems with lasers within the primary instrument—the Advanced Topographic Laser Altimeter System (ATLAS)—caused NASA to delay the launch readiness date from June 2018 to October 2018. This represents a 17-month delay beyond the original baseline and a 4-month delay beyond the rebaselined date set in 2014. However, the project is working to an earlier, September 2018 launch readiness date. The project completed a cost and schedule replan in October 2017, which required a large portion of remaining headquarters-held cost reserves, but did not take the project over its baseline commitment of $1,063.5 million.[a] The project is holding cost and schedule reserves at the level required by NASA center policy, but the project will need to realign funding planned for system integration and testing to address a shortfall in cost reserves for the operations phase. The project held its system integration review in August 2017 and received approval to enter the system assembly and testing phase in October 2017.

Technology and Design

Over numerous years, the ICESat-2 project has addressed issues with its flight lasers, and continues to mitigate the risk that they might fail again in the future. During ATLAS environmental testing in 2016, the project determined two of its three lasers needed repairs due to cracked crystal. The remaining laser did not require rework and continued to operate—completing over 2,300 hours of runtime. Subsequently, the project found that components on a test model—similar to the laser that did not need repairs—cracked while in storage. Project officials were unable to identify a single root cause of the cracking but determined this was an indication that the unrepaired laser could fail. ICESat-2 only needs one laser for mission success, but will carry a second for redundancy. In July 2017, following the completion of a trade study to determine which two of its three flight lasers should fly on ATLAS, NASA decided to use the two lasers that were repaired for flight. Officials said this decision was due to uncertainty in the reliability of the unrepaired laser and that the repaired lasers fully address the factors that contributed to the fractures. Since being repaired, together these lasers have completed a total of over 1,200 hours of runtime and have performed to requirements. Flying the two repaired lasers does not affect the project's plans to launch in September 2018. However, the project is carrying multiple risks to account for the potential that the repaired lasers could still fail at various points in time. For example, the project is carrying two risks that weigh the effect of the lasers failing on the ground during integration and test or failing while on orbit. If a laser fails during integration and test, it would take 5 weeks to replace it with a spare.

Integration and Test

The ICESat-2 project is proceeding through integration and test now that the ATLAS flight lasers are integrated onto the instrument and undergoing performance testing. The project held its system integration review and began system-level integration and test in August 2017. The two repaired lasers that will fly on the ATLAS instrument were shipped back to Goddard Space Flight Center and completed flight acceptance testing. On one of the repaired lasers, which was fully integrated onto the optical bench, the project observed an unusual pattern in its optical components during initial performance testing, and ATLAS officials have convened a review board to investigate the cause of this issue. The other repaired laser, which performed as expected during acceptance testing, began integration in September 2017 and is now undergoing performance testing.

[a]This total baseline cost differs from the total cost outlined in the table above due to an increase in project labor during the formulation phase. This increase is not related to the ATLAS instrument.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, ICESat-2 officials stated that during initial ATLAS testing, flight laser two exhibited an anomalous laser behavior. Project officials stated the laser was transported back to the contractor for cleaning and testing, which revealed comparable results to previous tests. The laser was returned to NASA and is performing normally. Project officials also provided technical comments, which were incorporated as appropriate.

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport

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-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

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

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **Atlas V**

Mission Duration: **29 months**

Requirement Derived from: **2011 Planetary Science Decadal Survey**

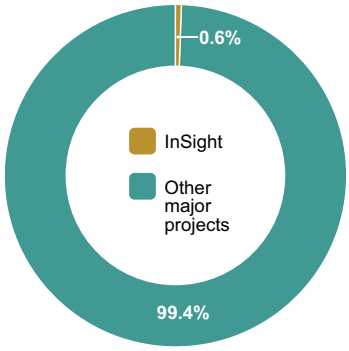
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The InSight project is on track to meet its revised cost and schedule agreement after technical issues with its primary instrument—the Seismic Experiment for Interior Structure (SEIS)—caused it to miss the previously planned launch date of March 2016. The project is holding cost and schedule reserves consistent with the level required by Jet Propulsion Laboratory policy. NASA redesigned the SEIS container and integrated it on the lander in August 2017. The project continues to track a risk that sensors within the SEIS will not function as intended, which would affect the project's ability to meet science requirements. To increase confidence that the sensors will perform, the project is completing tests to confirm the sensors' ability to survive for the mission's duration. The project also used the additional time from the launch delay to redesign the wiring within the HP3—a German-contributed instrument that drills into the Martian surface to collect temperature data—to address an anomaly found in testing.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

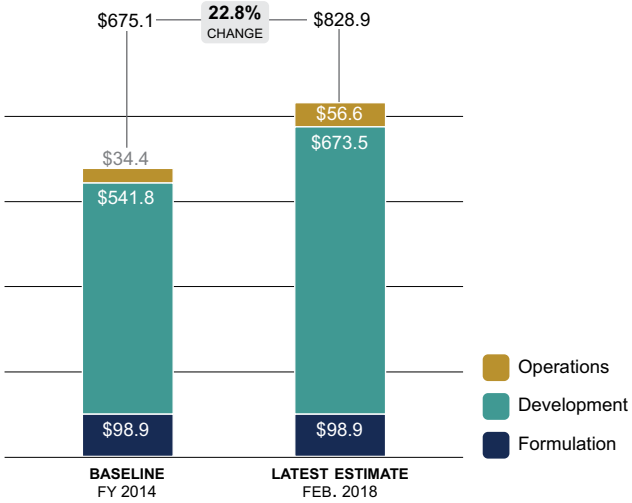


ESTIMATED FUNDING NEEDED

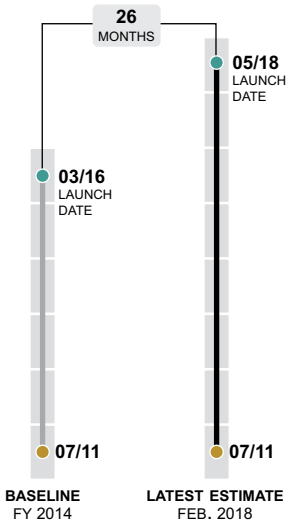
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The InSight project is on track to meet its revised cost and schedule agreement approved by NASA in August 2016 after the project missed its previously planned launch date. The InSight project missed its original launch date due to technical issues with the Seismic Experiment for Interior Structure (SEIS) instrument—the project's primary instrument and a contribution from the Centre National d'Etudes Spatiales (CNES)—which increased costs by almost $154 million and delayed the launch by 26 months. The project delivered the InSight spacecraft to the launch site in February 2018 before its planned launch in May 2018. The project is holding cost and schedule reserves consistent with the level required by Jet Propulsion Laboratory policy.

Integration and Test and Development Partner

The InSight project has resolved technical issues that necessitated a SEIS redesign, but is working to mitigate a risk on a key SEIS component that could affect SEIS's performance in operations. After discovering vacuum seal leaks that prevented the SEIS container from sealing properly and ultimately caused the launch delay, the project restructured SEIS responsibilities with NASA redesigning the SEIS container and CNES conducting integration and test. In March 2017, CNES confirmed that the redesign of the SEIS container was successful after completing a leak test, and integrated the SEIS with the lander in August 2017. The project is tracking a risk related to a potential failure of a Very Broad Band (VBB) sensor—a key SEIS component that will be used to measure seismic activity—in operations. The project has requested and received a significant number of VBB waivers. For example, the project requested and received approval to proceed with an oxidized part on several VBBs. The waivers individually have a low risk of causing a VBB failure, but together present a more moderate risk of a failure. More than one VBB failure would prevent the project from meeting its science requirements, according to officials. The project is completing tests to confirm the sensors' ability to survive for the mission's duration, which should provide increased confidence in the VBBs.

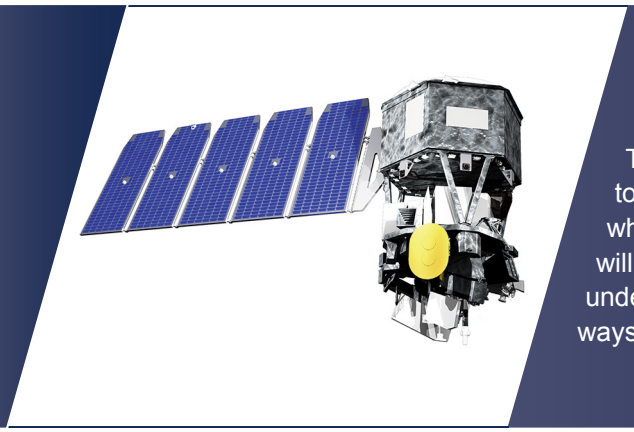
Because the project had additional time in its schedule due to the launch delay, it redesigned the Heat Flow and Physical Properties Probe (HP3)—a contributed instrument that will drill into the Martian surface to take temperature measurements—to resolve anomalies that occurred late in testing and to improve performance. These anomalies included damaged internal wiring caused by shocks generated by the hammering mechanism. The project completed a HP3 trade study, which evaluated whether or not to fly the redesigned HP3 or proceed with the original design, and determined the redesigned HP3 represented the lower risk option for the mission. The project integrated the redesigned HP3 in October 2017 prior to system-level testing. The HP3 is not needed for the project to meet its level 1 science requirements.

Design

The InSight project was tracking a risk related to its parachute that could have consumed approximately 27 percent of its cost reserves, but in October 2017 the project made the decision to use the existing parachute design that removed that risk. According to officials, the InSight project uses the same manufacturer for nylon in its parachute as the Mars 2020 project—another project that will land on Mars—originally planned to use. Mars 2020 discovered a potential problem with the strength of its parachute fabric as the fabric was degrading upon exposure to high heat during a planetary protection activity. As a result, the InSight project was concurrently building a parachute with new nylon material as well as a parachute using existing material. However, the project decided to abandon building a parachute using new material when it was determined that the new nylon material did not meet specifications, the vendor could not meet the required schedule in order to make the risk reduction option viable, and, according to officials, expert reviews rated the existing parachute as acceptable to fly. The Advanced Supersonic Parachute Inflation Research Experiment successfully completed a test in October 2017 that provided the project with additional support for their decision to use the parachute using original material.

PROJECT OFFICE COMMENTS

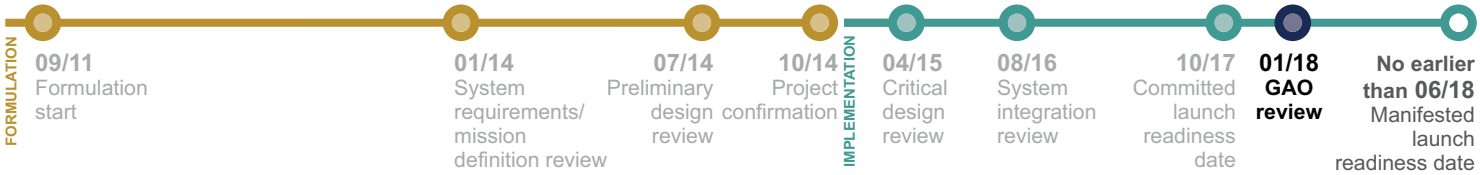
InSight project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate



Ionospheric Connection Explorer

The Ionospheric Connection Explorer (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 make direct measurements and use remote sensing to further researchers' 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-18-280SP



PROJECT INFORMATION

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

International Partner: **Centre Spatial de Liege Université de Liège (Belgium)**

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

Launch Vehicle: **Pegasus**

Mission Duration: **2 years**

Requirement Derived from: **2010 Science Mission Directorate Science Plan and 2009 Heliophysics Roadmap Team Report to the NASA Advisory Council**

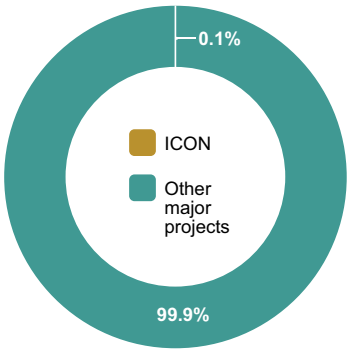
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The ICON project has missed its committed launch readiness date of October 2017 and both the project's schedule and costs are under review. Delays to the project's launch readiness date are related to problems with ICON's launch vehicle. The project experienced a 6-month delay due to a transport incident with a launch vehicle segment and launch range conflicts. In September 2017, an anomaly found in testing of the launch vehicle bolt cutter assemblies resulted in additional delays, but the magnitude of these delays is unknown while an investigation of the anomaly is underway. In February 2018, NASA determined the project will launch no earlier than June 2018, but this date is still under review. The ICON project completed its system-level integration and test activities in April 2017 as planned, but has not shipped the spacecraft to the launch site due to the launch delay.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

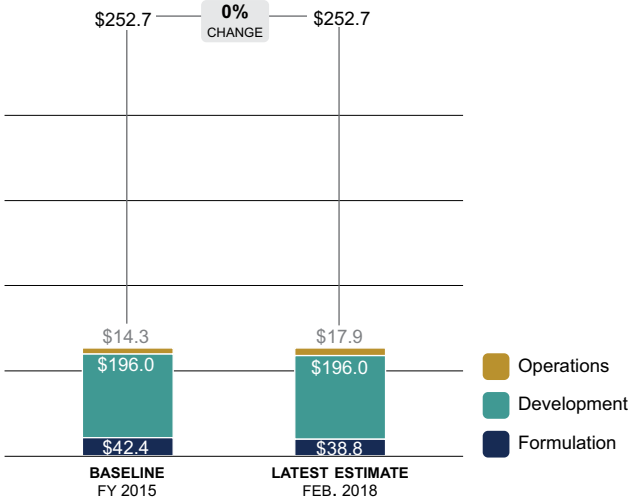


ESTIMATED FUNDING NEEDED

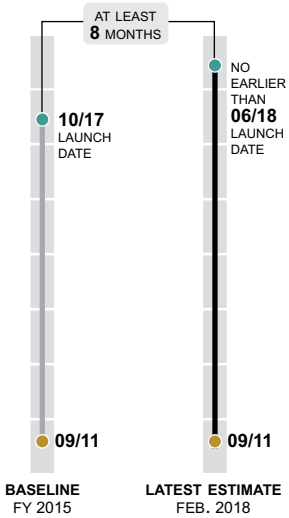
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The ICON project has missed its committed launch readiness date of October 2017 and both the project's schedule and costs are under review. The project completed its system-level integration and test activities in April 2017 as planned, but has not shipped the spacecraft to the launch site due to ongoing delays related to the launch vehicle. According to officials, the project received $7.8 million of headquarters-held reserves to cover initial delays, but it cannot determine whether it will exceed its cost baseline until NASA and the launch vehicle provider set a new launch date. Project officials said they need about $1 million a month for ICON to remain in storage.

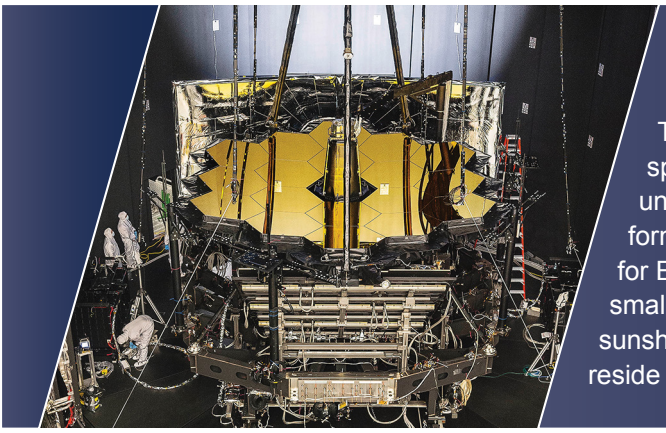
Launch

The ICON project had planned to launch early, in June 2017, but the project has experienced delays associated with its launch vehicle. In January 2017, two of the Pegasus launch vehicle's three stages were involved in a transport accident. The stages were subsequently returned to the launch vehicle contractor facility for inspection and testing, and no damage was found. The launch vehicle contractor then delivered the stages to Vandenberg Air Force Base for integration and testing activities. Due to conflicts at the launch vehicle range, the earliest available launch date was December 2017, which resulted in a 6-month launch delay from the planned June 2017 launch date.

In September 2017, however, an anomaly identified in bolt cutter assembly confidence testing—testing to show that the bolts that hold the launch vehicle and payload together will separate as planned during launch—resulted in additional delays, but the magnitude of the delay is unknown. One of nine bolt cutter assemblies failed to fracture a bolt during testing. As a result, NASA and the contractor halted testing and began an investigation of the anomaly, which is ongoing. NASA's Launch Services Program is working with the launch vehicle provider to identify the root cause of the anomaly, evaluate options to resolve the issue, and determine a new launch readiness date. In February 2018, NASA determined the project will launch no earlier than June 2018, but this date is still under review.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, ICON project officials stated that the project completed all observatory integration and test activities last year. As of January 2018, the observatory remains in the Orbital-ATK cleanroom in Gilbert, Arizona in a safe state—under continuous purge and performing periodic monitoring of the battery voltage—awaiting determination of a new launch date and shipment for launch vehicle integration. Project officials also provided technical comments, which were incorporated as appropriate.



James Webb Space Telescope

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-18-280SP

PROJECT INFORMATION

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

International Partners: **European Space Agency, Canadian Space Agency**

Launch Location: **Kourou, French Guiana**

Launch Vehicle: **Ariane 5**

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

Requirement Derived from: **2001 Astrophysics Decadal Survey**

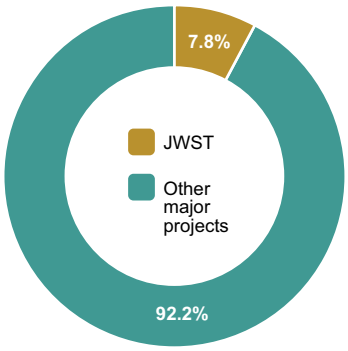
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

The JWST project delayed its planned launch readiness date by a total of at least 19 months from October 2018 to May 2020. In March 2018, NASA announced the most recent delay to approximately May 2020 based on a schedule analysis by its standing review board. This analysis showed that more time will be needed to integrate and test the telescope and spacecraft elements and conduct environmental testing. For several years, the observatory contractor has overestimated workforce reductions at the beginning of each fiscal year, but technical challenges have prevented the planned reductions and hindered JWST's ability to control costs. As a result, the observatory contractor has maintained higher workforce levels than expected, and may continue to do so in the coming months. Along with the latest launch delay, this puts the project at risk of exceeding its $8 billion congressional cost cap.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

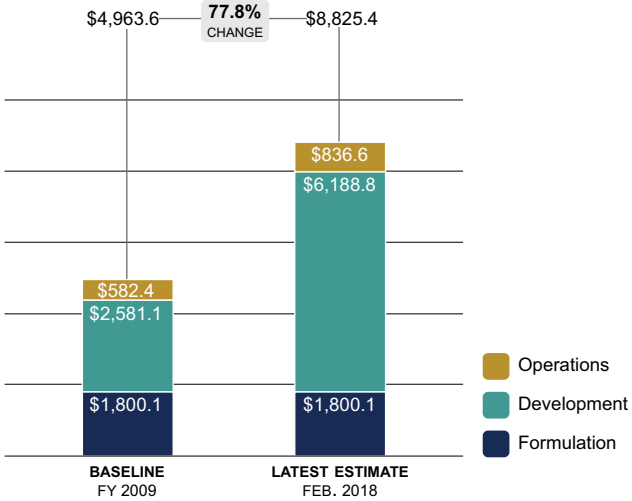


ESTIMATED FUNDING NEEDED

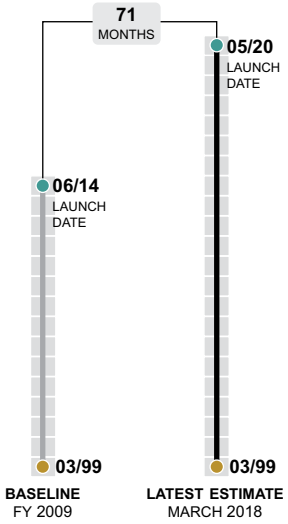
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The JWST project has delayed its planned launch readiness date by at least 19 months, from the committed October 2018 launch readiness date to approximately May 2020. NASA announced two delays for the project since we last reported in May 2017.[a] First, in September 2017, the project announced a delay of up to 8 months based on the results of a schedule risk assessment that showed various components of spacecraft element integration were taking longer to complete than expected. Prior to establishing the new launch window, the project used all remaining schedule reserves to address various technical issues, including a test anomaly on the telescope and sunshield hardware challenges. The new launch date included up to 4 months of new schedule reserves. However, by February 2018, the project had consumed the 4 months of reserves due to continuing challenges with spacecraft integration and test. Then, in March 2018, the JWST project announced an 11-month launch readiness delay to approximately May 2020 based on the results of a standing review board schedule analysis. According to the analysis, the previous launch date was not possible due to lessons learned during spacecraft element integration and test and propulsion system rework. The analysis further indicated that more time will be needed to integrate and test the telescope and spacecraft elements and conduct environmental testing.

Due to these challenges, the observatory contractor has maintained higher levels of workforce than expected, and may continue to do so in the coming months. As a result, the project is at risk of exceeding the $8 billion congressional cap for formulation and development costs established in 2011. An external independent review board will conduct a schedule analysis, with the results expected in May 2018, to be followed by the agency's final decision on JWST's launch date in June 2018 and a report to Congress in summer 2018. After the launch date is determined, NASA will update the project's cost estimate.

Integration and Test

The project and observatory contractor significantly underestimated the time required to complete integration and test work on the spacecraft element. Execution of spacecraft integration and test tasks was much slower than planned due to a variety of challenges including complexity of work and reach and access limitations on flight hardware. In addition, the observatory contractor has consumed several weeks of schedule reserves due to various workmanship errors, particularly with respect to the spacecraft propulsion systems. For example, an observatory contractor technician applied too much voltage and damaged components of the propulsion system, and reattaching the replacement components consumed 5 weeks of reserves. Also in May 2017, the observatory contractor discovered that valves in the thruster modules—which help control spacecraft on-orbit positioning—had been damaged by a cleaning solution and had to be refurbished. Reattaching the refurbished modules was expected to be complete by February 2018, but was delayed by one month when a technician applied too much voltage to one of the components in a recently refurbished thruster module.

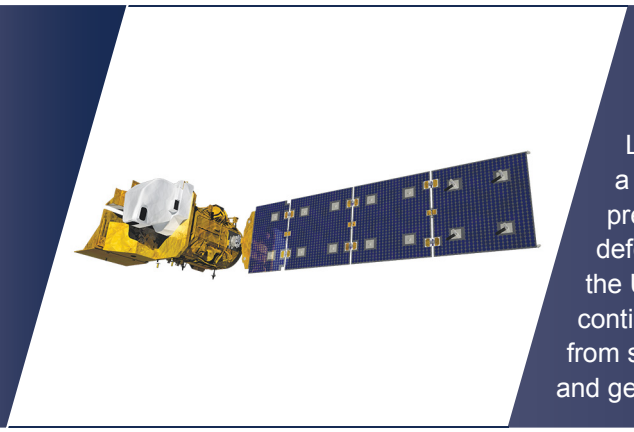
Contractor

The observatory contractor continued to maintain higher than planned workforce levels in the past year, and may continue to do so in the coming months. For several years, the observatory contractor has overestimated workforce reductions at the beginning of each fiscal year, but technical challenges have prevented the planned reductions and hindered JWST's ability to control costs. After completing negotiations on a cost overrun proposal in September 2017, driven by higher-than-planned workforce levels, the project is expected to issue a request for proposal from the observatory contractor in early 2018 for the costs for the remaining work through the new launch window. A cost overrun proposal seeks to increase the value of a cost-reimbursement contract when the total estimated cost is less than the contract's estimated cost to complete the performance of the contract.

PROJECT OFFICE COMMENTS

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

[a] GAO-17-303SP.



Landsat 9

Landsat 9 is the next satellite in the Landsat series Program, which provides a continuous space-based record of land surface observations to study, predict, and understand the consequences of land surface dynamics, such as deforestation. The program is a collaborative, joint mission between NASA and the U.S. Geological Survey. The Landsat data archive constitutes the longest continuous moderate-resolution record of the global land surface as viewed from space and is used by many fields, such as agriculture, mapping, forestry, and geology.

Source: Orbital ATK (artist rendering). | GAO-18-280SP

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **Atlas V**

Mission Duration: **5 years**

Requirement Derived from: **National Plan for Civil Earth Observations**

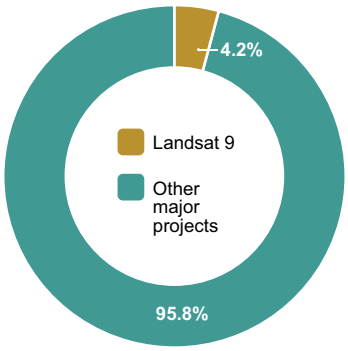
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The Landsat 9 project entered the implementation phase in December 2017 and formally established its cost and schedule baselines. The project is working to a launch readiness date of December 2020, 11 months earlier than its baselined launch date, in part to help meet a goal of the scientific community to maintain two Landsat satellites on-orbit simultaneously. As a result, the project is not holding schedule reserves at the level required by NASA center policy to address known and unknown risks. The project considers this schedule challenging, but achievable because of the high use of heritage technologies, mature instrument designs, and extensive use of hardware from the prior Landsat mission, Landsat 8. The project entered implementation with mature technologies and stable instrument designs. The project plans to hold its critical design review in April 2018. Our work on product development best practices shows that at least 90 percent of design drawings should be released by critical design review to lower the risk of subsequent cost and schedule growth. As of January 2018, the project had released about 64 percent of its design drawings. Prior to this review, the project will need to mature the design of its spacecraft.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

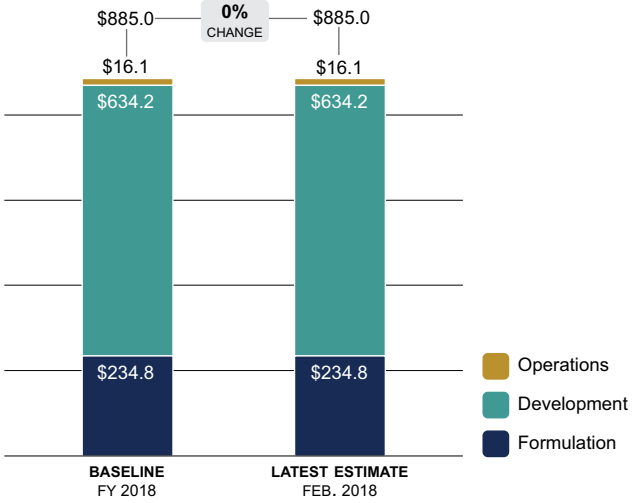


ESTIMATED FUNDING NEEDED

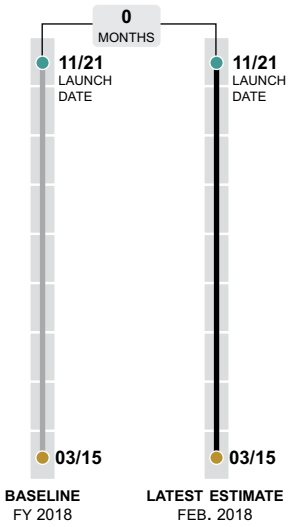
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The Landsat 9 project entered the implementation phase in December 2017 and formally established its cost and schedule baselines. The project set a baseline life-cycle cost of $885 million and a launch date of November 2021. However, the project is working toward a launch readiness date of December 2020 due to direction in the Explanatory Statement accompanying the Consolidated Appropriations Act, 2016. According to officials, this earlier launch date will help ensure that the Landsat program is able to maintain two Landsat satellites on-orbit simultaneously, which is a goal of the scientific community, but not a requirement for the program. NASA calculated the project's joint cost and schedule confidence level, the likelihood a project will meet its cost and schedule estimate, at 47 percent for the earlier December 2020 launch date. This is slightly lower than the 50 percent required by NASA policy. However, for the baselined launch date of November 2021, the joint cost and schedule confidence level is greater than 70 percent, which meets the requirement in NASA policy.

As a result of working to this earlier launch date, the project is holding schedule reserves below the level required by NASA center policy. This means the project would have less time to address known and unknown risks without affecting its December 2020 launch date. The project considers this schedule challenging, but achievable because of the high use of heritage technologies, mature instrument designs, and extensive use of hardware from the prior Landsat mission, Landsat 8. In addition, project officials said they have confidence that the project can meet this date because they have been executing to this aggressive schedule without needing any schedule reserves. The project is holding cost reserves at the level required by NASA center policy.

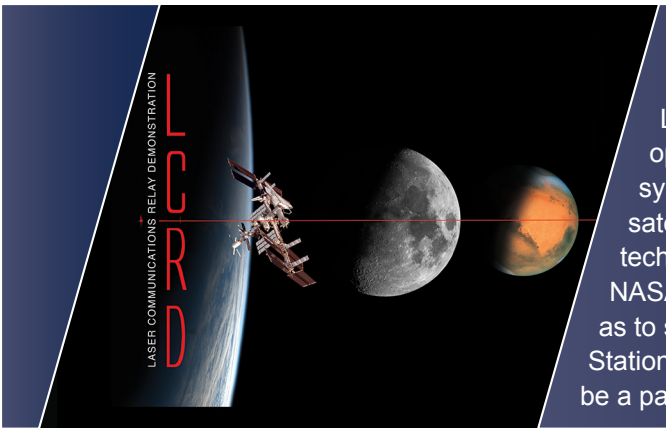
Technology and Design

The Landsat 9 project proceeded into implementation with mature technologies. The project held its preliminary design review in September 2017 with mature technologies and stable instrument designs due to high use of heritage technologies and designs from Landsat 8. 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. Specifically, Landsat 9's instruments—Thermal Infrared Sensor-2 and Operational Land Imager-2—are at a technology readiness level 9 and all components in the flight segments are above a technology readiness level 6. Maturing technologies to a technology readiness level 6 by preliminary design review is a best practice and helps minimize risks for space systems entering product development.

The project also proceeded into implementation with the designs of its two instruments stable. The project plans to hold its critical design review in April 2018. Our work on product development best practices shows that at least 90 percent of design drawings should be released by critical design review to lower the risk of subsequent cost and schedule growth. As of January 2018, the project had released about 64 percent of its design drawings. The project completed critical design reviews for its two instruments prior to mission preliminary design review due to the high level of heritage designs from Landsat 8, and has released over 90 percent of drawings for both. Most of the drawings that have not been released are for the spacecraft. The project's spacecraft also has a design similar to that of Landsat 8 and uses heritage components from other Earth-orbiting satellites. The project plans to hold its spacecraft critical design review in February 2018.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, Landsat 9 project officials stated that all project elements are successfully making progress and on track to support a December 2020 launch readiness date. Officials also provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Laser Communications Relay Demonstration

LCRD is a technology demonstration mission with the goal of advancing optical communication technology for use in deep space and near-Earth systems. LCRD will demonstrate bidirectional laser communications between a satellite and ground stations, develop operational procedures, and transfer the technology to industry for future use on commercial and government satellites. NASA anticipates using the technology as a next generation Earth relay as well as to support near-Earth and deep space science, such as the International Space Station and human spaceflight missions. The project is a mission partner and will be a payload on a U.S. Air Force Space Test Program satellite.

Source: Universities Space Research Association (USRA). | GAO-18-280SP

PROJECT INFORMATION

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

International Partners: **N/A**

Launch Location: **Cape Canaveral Air Force Station, FL**

Launch Vehicle: **Atlas V 551**

Mission Duration: **2+ years**

Requirement Derived from: **NASA Strategic Plan**

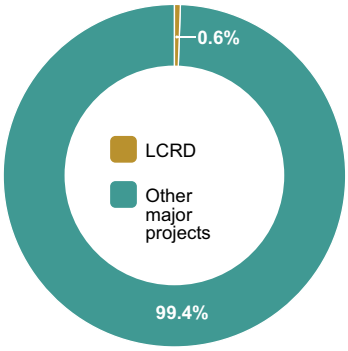
Budget Portfolio: **Space Technology, Research and Development**

PROJECT SUMMARY

The LCRD project established its cost and schedule baselines in April 2017 at a higher cost and later schedule than preliminary estimates due to funding, programmatic, and design changes made after preliminary design review in October 2013. The LCRD project has had to delay its schedule, change its host spacecraft, and adjust its design to accommodate scope changes as well as funding shortfalls in prior years. LCRD has also added a redundant communication capability that adds longevity but also cost and complexity to the spacecraft. In addition, multiple hardware components have been delivered late and are consuming project schedule reserves heading into integration and test.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

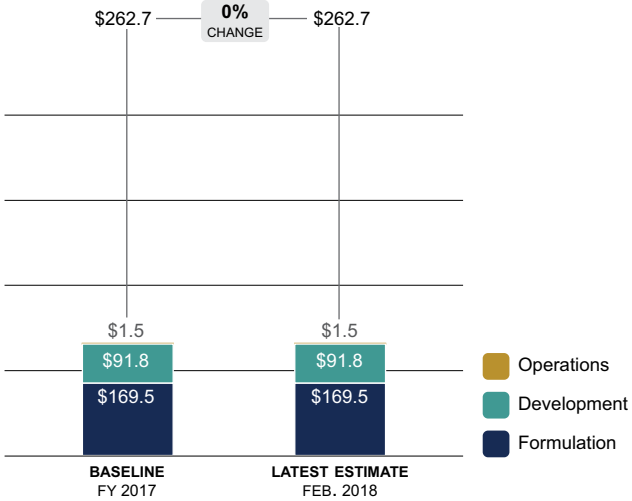


ESTIMATED FUNDING NEEDED

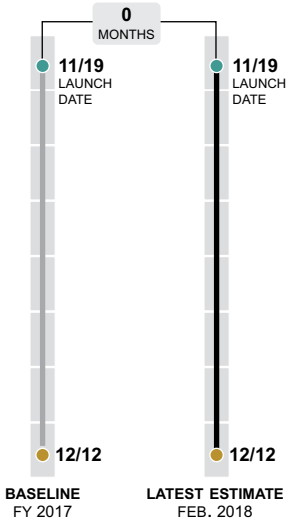
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The LCRD project's cost and schedule baselines increased compared to its preliminary estimates due to funding, programmatic, and design changes made after preliminary design review in October 2013. LCRD entered the implementation phase in April 2017 and formally established its cost and schedule baselines of $262.7 million to launch by November 2019, which is $23.4 million higher and 23 months later than the preliminary cost estimate. The cost and schedule increases over the preliminary estimate are due in part to externally driven design changes that the project has had to address. The new launch date also reflects the project delaying its confirmation review from late 2013 until April 2017 due to funding and programmatic challenges. For example, funding for fiscal years 2015 and 2016 was less than planned, which led the project to halt development of the ground segment for 2 years. The project has also changed management and undertaken numerous replans and descopes since 2013. As of October 2017, the project was holding cost reserves below levels required by NASA center policy.

Technology

LCRD's technologies were not mature by preliminary design review. As a technology demonstration, Goddard Space Flight Center does not require technologies to be at technology readiness level 6 at that review. However, the same risks of subsequent technical problems apply to technology demonstrations, which can result in cost growth and schedule delays. Further, because technologies are being demonstrated to support future missions, the project added a high-bandwidth radio transceiver as a backup to the optical modules to increase reliability, redundancy, and longevity. A drawback of the laser communication system is that it requires an unobstructed line of sight in order to transmit and receive data. The radio transceiver allows LCRD to transmit data with less interruption as the radio transceiver increases redundancy should the line-of-sight be obstructed, and longevity should an optical unit fail during the mission. In 2017, the proposal for the high-bandwidth radio transceiver came in at a higher than expected cost but LCRD received funding from sources outside the project office. In addition, LCRD is working with its host spacecraft to solve potential on-orbit vibration that could impact data transmission, but the project will have to fund additional damping.

Design

The project held its critical design review in December 2016 with a stable design and then held project confirmation in April 2017, which allowed the project to enter final design and fabrication. The project held its confirmation after its critical design review in part due to adding encryption to the project following its preliminary design review. Adding encryption to the project required a change in host spacecraft to one with proper facility clearances, changes to the interface designs between LCRD and the new host, and changes to the onboard LCRD hardware to accommodate encryption.

Integration and Test

Late component deliveries have delayed integration and testing and further delays could begin to affect LCRD integration as well as spacecraft integration prior to launch. For example, payload integration and testing has been delayed by about 6 weeks due to a number of late component deliveries. In one instance, delivery of the flight support assembly—which interfaces the LCRD payload to the host spacecraft and maintains the thermal environment—was behind schedule due to late procurement of heaters and temperature sensors. In another, delivery of one of the two flight modems was late due to rework and component replacement.

PROJECT OFFICE COMMENTS

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

Low Boom Flight Demonstrator

LBFD is a flight demonstration project planned to demonstrate that noise from supersonic flight—sonic boom—can be reduced to acceptable levels, allowing for eventual commercial use of overland supersonic flight paths. Plans include multiple flights beyond fiscal year 2022 to gather community responses to the flights and to create a database to support development of international noise rules for supersonic flight.

Source: NASA. | GAO-18-280SP

FORMULATION

- **03/13** Start of concept formulation studies
- **03/14** Mission definition review
- **09/16** LBFD formulation start
- **01/18** **GAO review**
- **07/18** Preliminary design review
- **09/18** Project confirmation

IMPLEMENTATION

- **07/19** Critical design review
- **06/21** Projected first flight date
- **03/22** System acceptance review

PROJECT INFORMATION

NASA Lead Center: **None**

International Partner: **None**

Requirement Derived from: **Aeronautics Research Mission Directorate Strategic Implementation Plan**

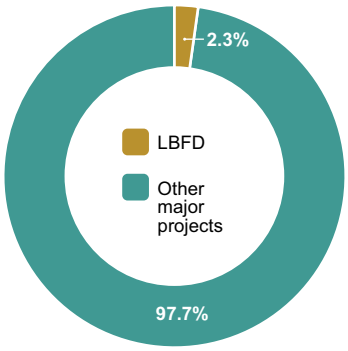
Budget Portfolio: **Aeronautics, Integrated Aviation Systems Program**

PROJECT SUMMARY

The LBFD project entered the preliminary design and technology development phase and established preliminary cost and schedule targets in September 2016. The project expects that its preliminary cost estimate of at least $390 million will increase when it establishes its cost and schedule baseline at project confirmation planned for September 2018, due in part to the estimate not including cost and schedule reserves. The project began under a concept study effort known as the Quiet Supersonic Technology (QueSST) project and was conducted under an existing research contract. NASA selected a post-preliminary design and build contractor in March 2018. Under the QueSST effort, the project matured three of LBFD's six technologies and will need to mature its remaining three technologies before the project's preliminary design review. These include one critical technology: the design tools needed to create the aircraft's outer shape, which is necessary to meet the project's mission.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



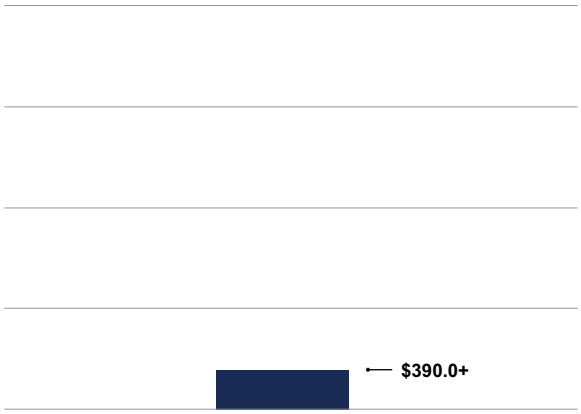
TOTAL FUNDED TO DATE

then-year dollars in millions

$75.7

PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE

LATEST ESTIMATE
MARCH 2018

Cost and Schedule Status

The LBFD project entered the preliminary design and technology development phase and established preliminary cost and schedule targets in September 2016. The project's preliminary cost estimate is $390 million but the project expects the estimate to increase when it establishes a cost and schedule baseline at its confirmation review planned for September 2018. For example, the preliminary cost estimate does not include cost reserves.

Further, according to project officials, the cost estimate will also include an additional $39 million associated with requirements and concept study efforts—that included developing a preliminary design—conducted from 2014 to 2016. Known as the Quiet Supersonic Technology (QueSST) project, the effort was conducted under an existing research contract with Lockheed Martin. Project officials explained that QueSST used funding available each year for concept studies, but that the LBFD project is slated for dedicated funding following its preliminary design review. However, project officials do not plan to include some of the costs associated with the flights to gather community responses because a separate NASA project—the Commercial Supersonic Technology project—will lead this effort.

Additionally, the project's preliminary schedule is in flux. Since the release of the fiscal year 2019 Presidential Budget Request in February 2018, project officials indicated that dates for some key events have changed, and the system acceptance review is now scheduled 5 months later than previously planned.

Design and Technology

In March 2018, NASA selected Lockheed Martin for the post-preliminary design contract for LBFD development. Officials reported that the solicitation did not require that proposals use the preliminary design developed by Lockheed Martin under QueSST. But officials said that part of the evaluation criteria was whether the proposed concept was at a preliminary design review-level of maturity.

Based on the work completed under QueSST, the LBFD project is continuing to mature its one critical technology—the design tools used to create the aircraft's outer shape, which is necessary to achieve low-boom supersonic flight. Project officials said developing these tools and the shape, which directly impacts the sound produced by the aircraft during supersonic flight, will be the majority of the development work necessary to fly and test the LBFD aircraft. The project has assessed the design tools to be at a technology readiness level 5, which means the basic components have been integrated and tested in a simulated environment.

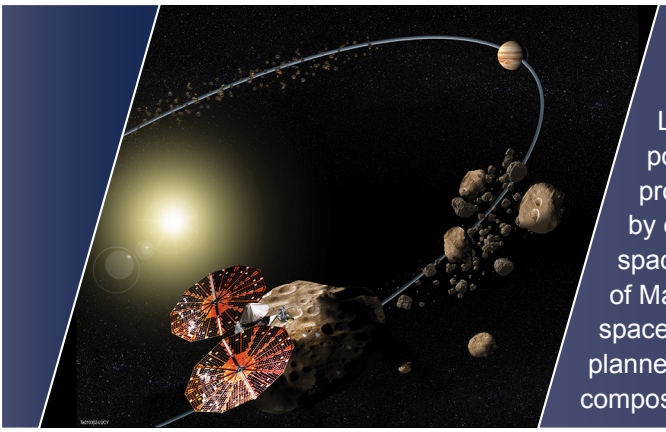
Three of LBFD's five heritage technologies were matured as part of the QueSST effort. The project will need to mature the remaining technologies as well as the design tools prior to its preliminary design review in July 2018. Maturing technologies during preliminary design helps reduce risks for systems entering product development. The fiber optic sensing system, which will measure bend and twist of the wings and stabilizer, and the external vision system, which includes cameras and monitors to provide forward visibility for the pilot—are not yet mature and will require additional development work. The project noted that these two technologies have flown before but not as part of a research aircraft.

Other Issues to Be Monitored

The LBFD project is using a virtual project office and is in the process of making decisions on how to execute the project using this model. The project team includes personnel from many NASA centers, allowing specialized staff in different centers to collaborate more than they would normally. The virtual project office model may highlight an organizational structure that could be beneficial for future projects, but it is too soon to tell. In addition, officials stated that the project has not decided which NASA center's policies it will follow, which include the cost and schedule reserve requirements the project will need to meet, among other guidelines.

PROJECT OFFICE COMMENTS

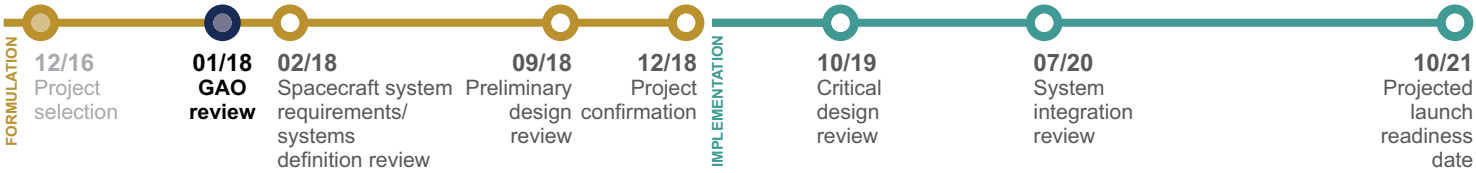
In commenting on a draft of this assessment, LBFD project officials stated that the project is continuing with its formulation activities in fiscal year 2018. These activities will lead to authorization to proceed, with implementation following the confirmation review planned for September 2018, at which time the project will be baselined. Project officials also stated that the information contained in this project assessment reflects the most currently available projections. Project officials also provided technical comments, which were incorporated as appropriate.



Lucy

Lucy will be the first mission to investigate the Trojans, which are a population of never-explored asteroids orbiting in tandem with Jupiter. The project aims to understand the formation and evolution of planetary systems by conducting flybys of these remnants of giant planet formation. The Lucy spacecraft will first encounter a main belt asteroid—located between the orbits of Mars and Jupiter—and then will travel to the outer solar system where the spacecraft will encounter six Trojans over an 11-year mission. The mission's planned measurements include asteroid surface color and composition, interior composition, and surface geology.

Source: Southwest Research Institute (SwRI). | GAO-18-280SP



PROJECT INFORMATION

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

International Partner: **None**

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

Launch Vehicle: **TBD**

Mission Duration: **11.6 years**

Requirement Derived from: **Discovery Program Announcement of Opportunity 2014**

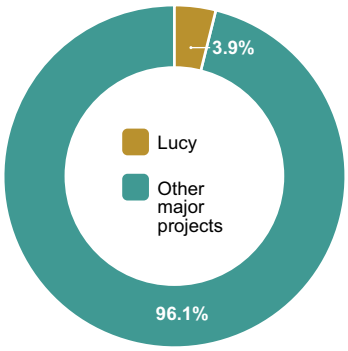
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

In December 2016, Lucy was one of two projects selected by the Discovery program—a series of competed missions that have focused investigations and short development periods—to proceed to preliminary design and technology completion phase. Lucy is expected to have its rehearsal flyby of a main belt asteroid in 2025, and then fly by Trojan asteroids over the course of the next 8 years. Project officials stated that the design is based heavily on heritage hardware and does not require development of any critical technologies. The project is evaluating the extent to which risks are posed by existing hardware. For example, the project is tracking a risk related to the size of the solar array, which is larger than what the contractor typically builds. The project also implemented a trade on its spacecraft to address the risk of on-orbit failure from a heritage engine. Additionally, the project and NASA Launch Services have identified two launch vehicle options, but the project does not expect NASA to select a vehicle before its preliminary design review in September 2018.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



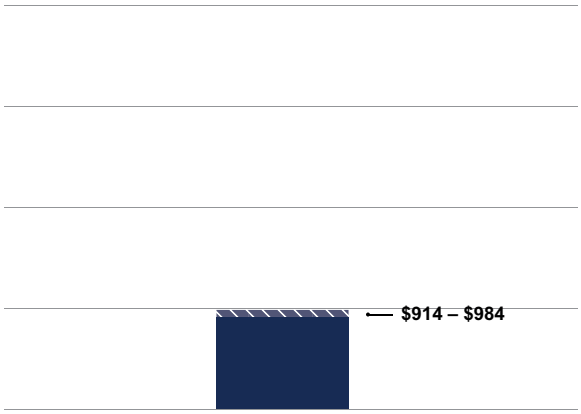
TOTAL FUNDED TO DATE

then-year dollars in millions

$57.4

PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE

LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

In December 2016, Lucy was one of two projects selected by the Discovery program—a series of competed missions that have focused scientific investigations and short development periods—to proceed to the preliminary design and technology completion phase. At that same time, the project established preliminary cost and schedule estimates. The project's planned launch window is October-November 2021. Under that planned launch date, Lucy is expected to have its rehearsal flyby–a main belt asteroid encounter that will allow the project to test instruments—in 2025 and then fly by Trojan asteroids over the course of the next 8 years. If the project misses that launch date, another launch window opens in 2022. The project's preliminary cost range is $914 million to $984 million, and the project is currently holding cost and schedule reserves consistent with the level required by NASA center policy. The project plans to hold its preliminary design review in September 2018 and its confirmation review in December 2018, at which point it will establish its cost and schedule baseline.

Technology and Design

Project officials characterize the Lucy design as low risk because it does not require development of any critical technologies and has a high heritage design. For example, these officials stated that Lucy's design has the same architecture as prior NASA projects such as Juno and the Mars Atmosphere and Volatile Evolution Mission (MAVEN). The project plans to fly three instruments—a thermal spectrometer, a reconnaissance imager, and an imaging spectrometer—that are not exact replicas of previously flown versions but leverage heritage hardware. The Lucy project reports that its one heritage technology—an ultraflex solar array—is mature, but the project plans to use the technology in a different environment than previously demonstrated as well as make modifications that affect form, fit, and function. We have previously asserted that mature, heritage technologies must be demonstrated in a relevant environment and should be very close to form, fit, and function. The project is tracking a risk related to the size of the solar array since, at approximately 6 meters, it is larger than what the contractor typically builds. Because the contractor has not flown an array of this size, officials said they anticipate being more involved in this procurement, but there are no technical issues at this point.

According to officials, the Lucy spacecraft's proposed main engine was the same model used on a series of environmental satellites that have had engine performance problems. The engine has failed in flight more than once and was a single point failure for the Lucy project. As a result, the project completed an engine trade study in July 2017 and decided to select a different engine.

Launch

In coordination with NASA Launch Services at Kennedy Space Center, project officials identified the Atlas V and Falcon Heavy as vehicles that meet mission requirements. However, as of January 2018, the Falcon Heavy had not flown, so launch environment data was not yet available to the project. Project officials are tracking a risk that it could be necessary to rework hardware due to the Falcon Heavy launch environment. However, the project has assessed the cost impact of this scenario should the Falcon Heavy be selected. Officials said they do not expect NASA to select a launch vehicle prior to the project's planned September 2018 preliminary design review, the point at which projects prefer to select a launch vehicle. Until then, the project is designing to a mix of the two potential launch vehicles' requirements.

PROJECT OFFICE COMMENTS

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

Mars 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 explore Mars and conduct geological assessments, search for signs of ancient life, determine potential environmental habitability, and prepare soil and rock samples for potential future return to Earth. The rover will include a technology demonstration instrument designed to convert carbon dioxide into oxygen. Mars 2020 is based heavily on the Mars Science Laboratory, or Curiosity, which landed on Mars in 2012 and remains in operation.

Source: NASA/JPL-Caltech. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

International Partners: **Centre National d'Etudes Spatiales (France), Centro de Astrobiología and Center for the Development of Industrial Technology (Spain), Norwegian Defence Research Establishment (Norway)**

Launch Location: **Eastern Range, FL**

Launch Vehicle: **Atlas V**

Mission Duration: **2 years**

Requirement Derived from: **2011 Planetary Science Decadal Survey**

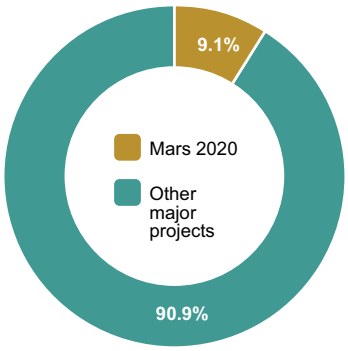
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The Mars 2020 project has encountered cost growth and schedule delays due to technical and design challenges for some components and subsystems—including a new and highly complex development—but these delays have not affected the project's overall schedule. The project did not mature all of its technologies until after the project's critical design review, which is later than recommended by best practices. Further, the project's new and complex developments continue to face technical challenges that could affect cost and schedule. Additionally, the project had an unstable design at its critical design review, with 72 percent of its drawings released. This is lower than recommended by best practices and new and highly complex developments were not stable at the time of the design review. The project is working toward system integration review in February 2018, but the project is tracking several risks that may affect schedule. For example, the new Sampling and Caching System (SCS) that will collect and cache Martian soil and rock samples is facing technical and schedule challenges.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

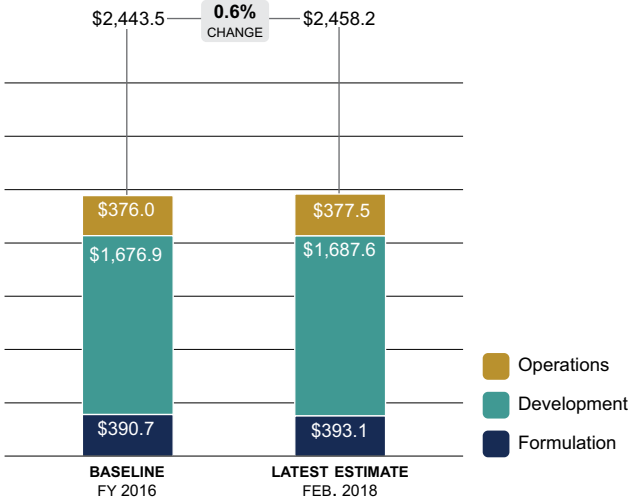


ESTIMATED FUNDING NEEDED

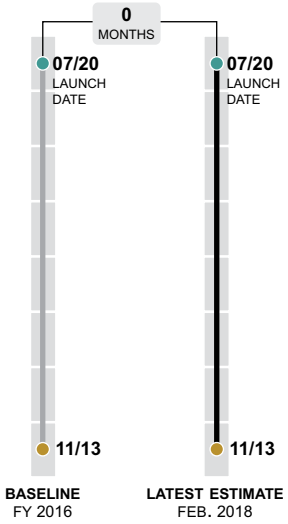
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The Mars 2020 project continues to meet its schedule baseline, but is not meeting the cost baseline established at its confirmation review in June 2016. The project experienced $14.7 million in cost growth due to technical challenges with a technology demonstration instrument and higher than expected integration costs for an entry, descent, and landing instrument. In addition, the project has also experienced schedule delays for some of its new developments, but these delays have not affected the project's overall schedule. For example, the project delayed its system integration review by about 3 months to February 2018 to allow for more time to build new development hardware, which were behind schedule due to technical and design challenges. Even with this delay, project officials said they are confident in the schedule established at the confirmation review because the project is holding schedule reserves at about two times the level required by Jet Propulsion Laboratory policy. In addition, the project allocated a significant portion of cost reserves to the new development items. The project is not holding cost reserves at the level required by Jet Propulsion Laboratory policy, but expects to be meeting the policy once the project receives additional funds in February 2018.

Technology

The Mars 2020 project matured its technologies later than recommended by best practices and several new and highly complex developments continue to face significant technical challenges that could affect cost and schedule. Best practices recommend maturing technologies to a technology readiness level 6 by the project's preliminary design review to help minimize risks for space systems entering product development. However, all of the technologies for the Mars 2020 project were not mature until after the program's critical design review. Further, the project is concerned late hardware deliveries and unfavorable sample contamination test results might cause the Sampling and Caching System (SCS)—the project's most challenging development that will collect and cache Martian soil and rock samples—to be delivered late to integration and test. Additionally, the project experienced technical issues with multiple components within an instrument that will search for organics and minerals that have been altered by water, which have negatively affected the instrument's cost and schedule. To mitigate these challenges, the project allocated additional reserves and brought on additional expertise. Further, the project is utilizing existing SCS development models rather than build new ones to reduce cost and schedule risk.

Design

The Mars 2020 project held its critical design review before it had a stable design, which increases the project's risk of cost growth and schedule delays during the integration and test phase. At this review, the project released about 72 percent of design drawings, which is less than the best practice of releasing 90 percent of design drawings at this review. Project officials stated that they held the design review earlier than normal to avoid delaying progress on the development of heritage technologies, which make up a large percentage of the rover. As a result of holding the review early, new and highly complex developments, such as the SCS, were not stable at the time of the design review. The unstable design contributed to delays in fabricating parts for the SCS engineering unit. As a result, the project reduced the number of engineering models it will build to help meet schedule.

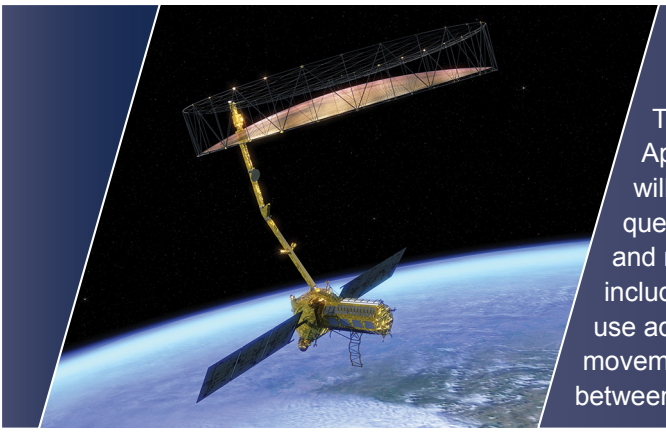
The project has a series of parachute tests underway to determine whether it can fly with its heritage parachute or needs to use a strengthened parachute. These tests are to help mitigate risks related, in part, to supersonic test failures observed on an unrelated project. Officials said the project successfully tested its heritage design at supersonic speeds in October 2017, which reduces the risk that a new parachute design will be necessary. However, if future tests do not successfully demonstrate that either the heritage or redesigned parachute inflate as intended, the project may have to conduct additional development and tests, which could consume all of Mars 2020's available schedule reserve.

Other Issues to Be Monitored

The Mars 2020 project has experienced workforce shortages in several key areas, but, according to officials, the Jet Propulsion Laboratory has largely been able to meet the project's needs because it prioritized staffing for the Mars 2020 project. Other Jet Propulsion Laboratory projects have experienced workforce issues as well, which NASA attributes to the amount of work the laboratory is managing.

PROJECT OFFICE COMMENTS

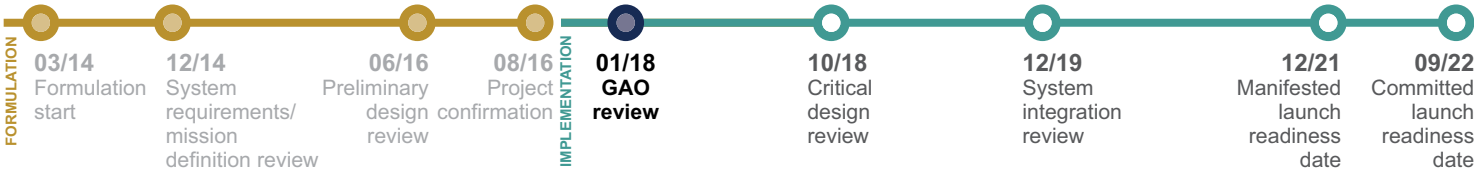
In commenting on a draft of this assessment, Mars 2020 project officials stated the project matured all its new technologies to the appropriate level by critical design review. Further, officials stated the project had backup technologies but none were required. Officials also stated the project has accommodated schedule delays within available schedule reserves and continues to maintain robust schedule reserve along the critical path. Project officials also provided technical comments, which were incorporated as appropriate.



NASA ISRO – Synthetic Aperture Radar

The NASA Indian Space Research Organisation (ISRO) – Synthetic Aperture Radar (NISAR) is a joint project between NASA and ISRO that will study the solid Earth, ice masses, and ecosystems. It aims to address questions related to global environmental change, Earth's carbon cycle, and natural hazards, such as earthquakes and volcanoes. The project will include the 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: © California Institute of Technology/Jet Propulsion Laboratory. | GAO-18-280SP



PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

International 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: **2007 Earth Science Decadal Survey**

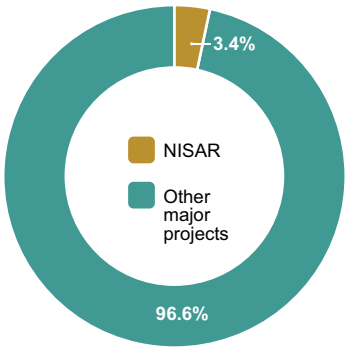
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The NISAR project continues to operate within its schedule baseline, but is not meeting its cost baseline established at its confirmation review in August 2016. The project experienced $30 million in cost growth as the result of an increase in the scope of data collection. Also, about 2 months after confirmation, the project learned that its radar reflector contractor entered into two commercial contracts, which could put a strain on the contractor's workforce and increased cost and schedule risk to the project. NASA increased near-term funding of the project in May 2017, which allowed the project to accelerate radar reflector development. In addition, the project made design changes to the radar reflector boom assembly—used to deploy the reflector when the spacecraft reaches orbit—to address risks that could prevent the boom from latching in place. The NISAR project continues to track cost and schedule risks related to its partnership with ISRO. NISAR is progressing toward its critical design review in October 2018.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

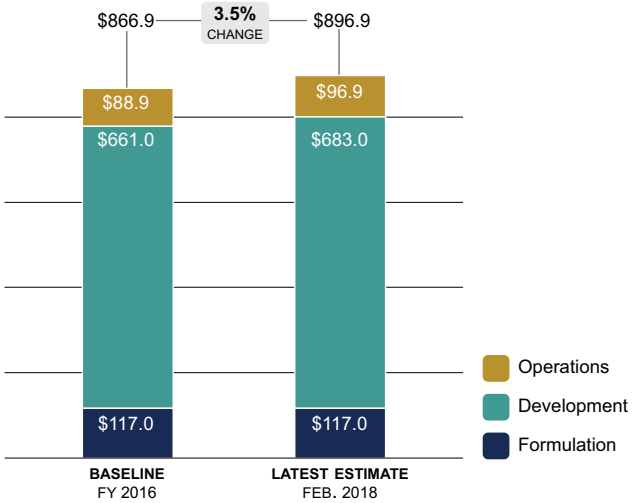


ESTIMATED FUNDING NEEDED

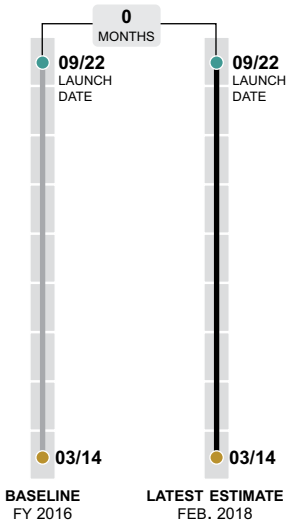
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The NISAR project continues to operate within its schedule baseline, but is not meeting the cost baseline established at its confirmation review in August 2016. The project experienced $30 million in cost growth as the result of an increase in the scope of data collection in response to additional data needs being identified by an interagency working group. The additional data include soil moisture and natural hazard data that would be of value for other federal agencies and the science community. Also, about 2 months after confirmation, the project learned that its radar reflector contractor entered into two commercial contracts, which could put a strain on the contractor's workforce and increased cost and schedule risk to the project. To avoid schedule conflicts with the contractor's new contracts, NASA increased the project's near-term funding in May 2017 so that the project could accelerate development of the radar reflector. NISAR is progressing toward its critical design review in October 2018 and is currently holding cost and schedule reserves consistent with the level required by Jet Propulsion Laboratory policy.

Design

The NISAR project made design changes to the radar reflector boom assembly—used to deploy the radar reflector when the spacecraft reaches orbit—to address risks that could prevent the boom from latching in place. Specifically, the project modified how the boom is deployed, including using spring dampers to deploy the boom instead of a cable-driven system and non-explosive launch restraints to reduce shock levels. Project officials said the boom redesign has single point failures, but the probability of failure is lower compared to the previous design.

The NISAR project continues to track the system's mass as a significant risk. Maintaining adequate mass margins is a key indicator of design stability. Project officials stated that they continue to improve their knowledge of mass through the use of engineering models and more matured design, and sometimes this has led to an increase in mass. For example, the project used computer aided design to determine the length of cabling needed and found this increased its mass estimate over prior estimates. In July 2017, the project instituted a mass control plan, which project officials said would require all increases in mass to be reported and determinations be made regarding the necessity of the change.

Developmental Partner

The NISAR project continues to track a risk that process differences between NASA and its development partner, the Indian Space Research Organisation (ISRO), could negatively affect cost and schedule, but a recent project assessment concluded that collaboration between the two organizations has been effective. For example, in July 2017, the project signed an updated cooperative project plan that outlines how the two organizations should interface on topics such as requirements and technical information.

The project is also tracking a risk related to the ISRO-provided launch vehicle—the Geosynchronous Satellite Launch Vehicle (GSLV) Mark II—which must meet all NASA-ISRO agreed-upon criteria before it can be used. For example, the GSLV Mark II must have three successful launches and one successful 4-meter fairing launch prior to NISAR's planned launch date in 2021. As of January 2018, ISRO had four consecutive successful GSLV Mark II launches, but had not yet planned a 4-meter fairing launch.

PROJECT OFFICE COMMENTS

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

Orion Multi-Purpose Crew Vehicle

The Orion Multi-Purpose Crew Vehicle (Orion) is being developed to transport and support astronauts 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 canceled 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: © 2017 Lockheed Martin Corporation. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Johnson Space Center**

International 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 four crew**

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

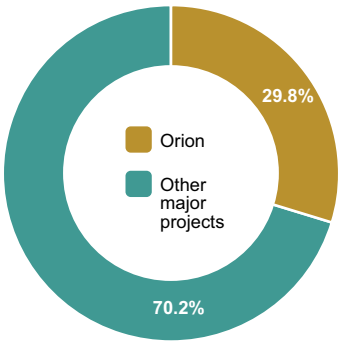
Budget Portfolio: **Exploration, Exploration Systems Development**

PROJECT SUMMARY

The Orion program continues to operate within its schedule baseline but NASA expects the program to exceed its cost baseline through Exploration Mission-2 (EM-2) due to new hardware and the program addressing development challenges. The extent of cost growth is unknown, but NASA plans to complete a new cost estimate by June 2018. For example, according to NASA, the cost increases have been driven in part by moving from a single-piece, or monolithic, heatshield design to one that employs blocks in order to improve its structural strength. The program's service module—contributed by the European Space Agency—is currently driving the program schedule as well as the launch schedule for the first mission. The module has proven more difficult to produce than expected and has been delayed numerous times. The service module is at risk of further delays that may affect NASA's planned launch date for EM-1, which would begin to consume schedule reserve for EM-2. In addition, the program is addressing some parts material failures. Specifically, the spacecraft's avionics cards did not withstand vibration testing and required a materials change.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

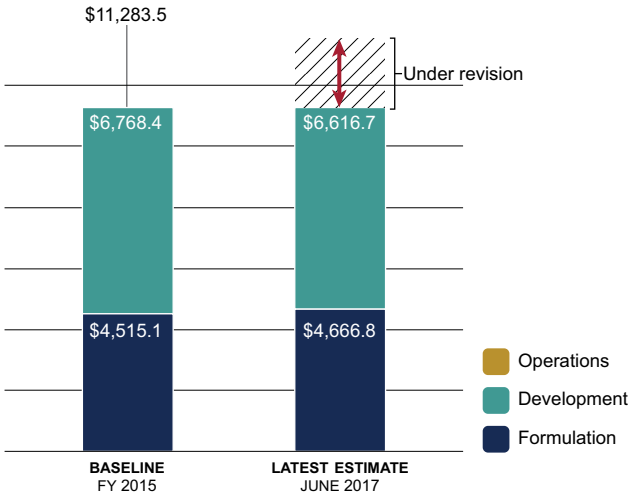


ESTIMATED FUNDING NEEDED[a]

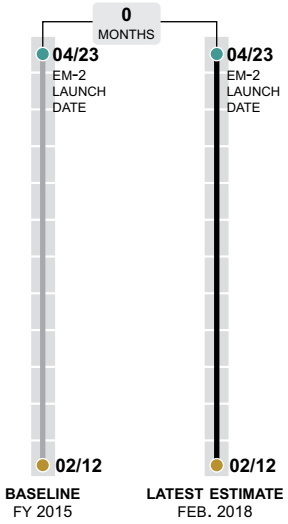
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



[a]Includes funding through Exploration Mission-2.

Cost and Schedule Status

The Orion program continues to operate within its schedule baseline but NASA expects the program to exceed its cost baseline through EM-2, and is at risk for future schedule delays. The project's life-cycle cost estimate is expected to increase beyond its $11.28 billion baseline—due in part to the EM-1 schedule delay—when a planned, new cost estimate for the program is complete in June 2018. According to preliminary analysis, major drivers of the potential cost increase also include new hardware and addressing development challenges. For example, there was a cost impact when the program moved from a single-piece, or monolithic, heatshield design to one that employs blocks in order to improve its structural strength.

In December 2017, NASA announced December 2019 as the new internal launch readiness date for EM-1 and that the agency also allocated 6 months of schedule reserve to June 2020 for possible manufacturing and production schedule risks. While the Orion program did not have a committed launch date for EM-1, the recent delay has reduced the amount of time available to the program between EM-1 and its committed EM-2 launch date of April 2023. In addition, the delay means that the program will continue to consume resources for EM-1 that would have otherwise been available for development on EM-2, thus increasing pressure on the EM-2 cost and schedule. If NASA delays EM-1 beyond December 2019—which is likely given both Orion and the Space Launch System have no schedule margin to meet their deliveries for this date—the schedule reserve for Orion's committed EM-2 launch date of April 2023 would continue to erode and put the program at risk for future schedule delays.

Developmental Partner

The late completion and delivery of the European Service Module (ESM)—a European Space Agency contribution via agreement with NASA—is driving the program's schedule and may further delay EM-1. The European Space Agency has delayed delivery of the service module 14 months since the element's critical design review in June 2016. The ESM currently has no schedule reserve to support the December 2019 launch schedule, meaning that any additional delays will compress or delay integration activities prior to launch. Further, NASA is tracking a risk that the ESM could be delayed beyond the current estimated delivery date of June 2018. Such a delay would likely delay the EM-1 launch date beyond December 2019.

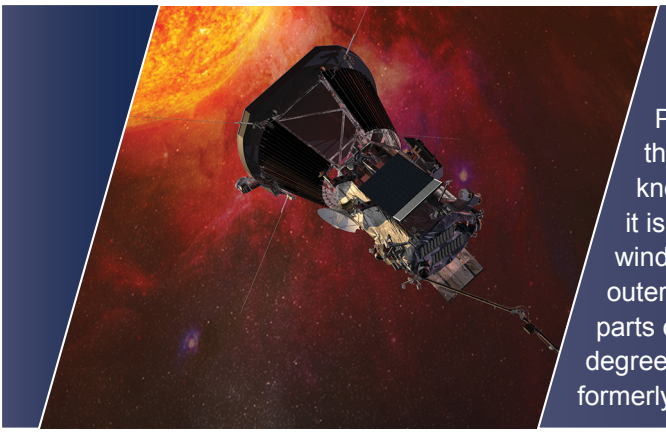
Program officials stated that recent ESM delays are due in part to late component deliveries from subcontractors, especially valves. However, they also noted at least one of those valves is currently not meeting specifications, indicating that the design was not sufficiently mature prior to production. The valve, a heritage design from the Space Shuttle program that maintains pressure in the propulsion system, is not sealing properly due to the increased pressures necessary on the ESM. The program has previously stated that all sides believed that the development of the ESM would be easier than it has proven to be, being based on a prior European Space Agency spacecraft. However, the changes have been more substantial than expected and the production of the first flight unit has faced setbacks. The program stated that they expect the production of the flight unit for the second flight to be quicker, though it will require some additional elements to support crew.

Technology and Design

Avionics design has recently become an issue for the Orion program and is currently 2 months behind the ESM in terms of driving the program's schedule. The avionics cards, along with many other onboard systems, have to withstand the vibration and radiation environment on Orion. The program found that the circuits on the avionics cards were cracking under operating conditions due to a poor design. As a result, officials stated that the program determined the root cause of the failure and redesigned the cards' base material to better withstand the environment. The program worked to reorganize the integration and test schedule to allow for the replacement of the cards.

PROGRAM OFFICE COMMENTS

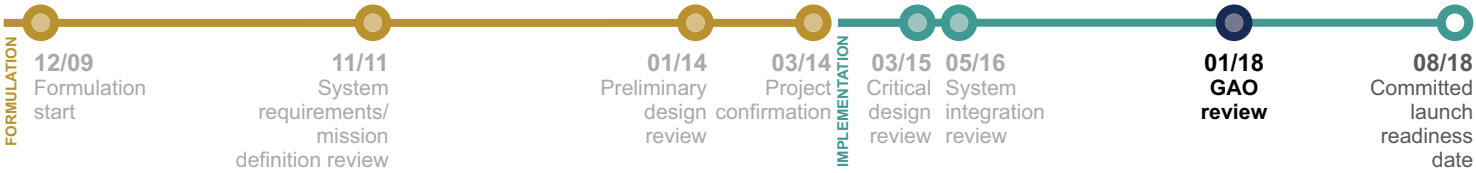
In commenting on a draft of this assessment, Orion program officials stated that they believe the risk-informed approach that they use to address and resolve issues has proven to be successful. Also, program officials stated the program remains on track to meet its April 2023 baseline for EM-2. Program officials also provided technical comments, which were incorporated as appropriate.



Parker Solar Probe

PSP 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. PSP 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, where solar particles are energized. To achieve its mission, parts of the spacecraft must be able to withstand temperatures exceeding 2,500 degrees Fahrenheit and endure blasts of extreme radiation. The project was formerly named Solar Probe Plus, or SPP, and was renamed in May 2017.

Source: Johns Hopkins University/Applied Physics Lab. | GAO-18-280SP



PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Cape Canaveral Air Force Station, FL**

Launch Vehicle: **Delta IV-heavy class with NASA-provided upper stage**

Mission Duration: **7 years**

Requirement Derived from: **2012 Heliophysics Decadal Survey**

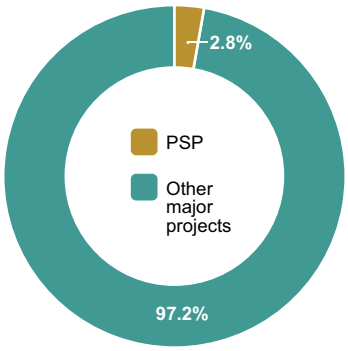
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The PSP project continues to target an August 2018 planetary launch, but the project is encountering a number of technical issues that may lead to a schedule delay or result in the project launching with fewer capabilities than originally planned. The project will need to resolve the following three issues by spring 2018 to maintain the launch window. First, the Solar Probe Cup, which is one component of an instrument package necessary to meet top-level mission requirements, has encountered several technical issues during development. Some of these issues may require the project to descope this instrument. Second, the project is completing qualification testing of the separation system after several separation bolts in the launch vehicle interface failed during a test. Lastly, the project has identified contamination stemming from an alloy used in three locations on two instruments. In one of the locations, the project must determine if it can limit the contamination. If it cannot, the project will need to delay its launch in order to replace the affected part.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

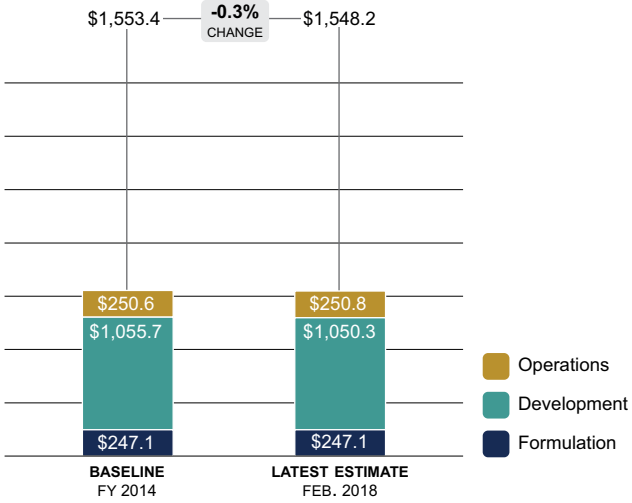


ESTIMATED FUNDING NEEDED

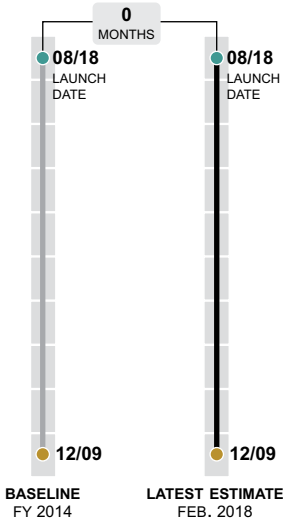
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The PSP project continues to target an August 2018 planetary launch, but the project is encountering a number of technical issues that may lead to a schedule delay. Maintaining the project's 2018 launch window is important because a potential window only opens every 10 months. The 2019 launch window would result in a longer mission duration and require more fuel, and after that, the next window that meets requirements is 2023. The project continues to hold schedule reserves at Applied Physics Laboratory-recommended levels, but the project is tracking a risk that there may not be adequate reserves to address any future issues that may arise. The project is also tracking a risk that it may exhaust its cost reserves in fiscal year 2018 addressing instrument issues and retaining project staff, which could lead to the need for additional headquarters-held cost reserves.

Launch

In September 2017, while testing the interface between the launch vehicle and the spacecraft, three of the six separation nuts failed to release their bolts. If this occurred during launch, it would result in a total mission failure. NASA's Launch Services Program, which obtained launch services for PSP, initiated an anomaly investigation. This investigation determined that the bolts were improperly installed. The investigation board identified corrective actions, which have passed initial tests. The separation system plan includes completing qualification testing by April 2018 and includes schedule margin. However, if additional issues are identified, the project could potentially miss the 2018 launch window.

Integration and Test

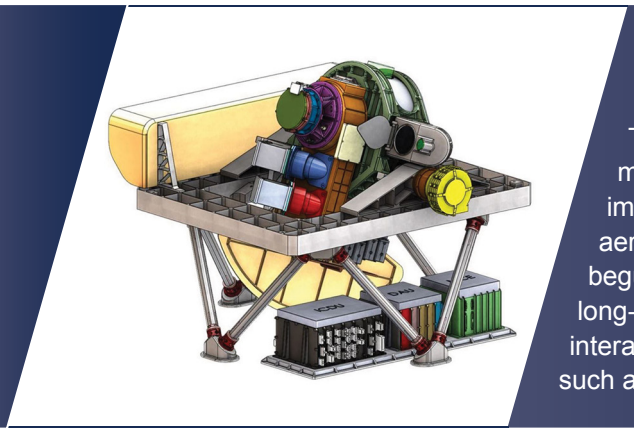
The Solar Probe Cup (SPC), which is part of an instrument package necessary to meet top-level mission requirements to gather information about particles in the solar wind, has encountered several technical issues during integration and testing. For example, recent testing has identified scenarios where the spacecraft's different operating temperature environments could result in twisting between the SPC and spacecraft, which could lead to cracks over time. To mitigate this risk, the project is conducting testing to determine the scope of this issue. If twisting could occur repeatedly throughout the mission, the project will consider de-scoping the SPC, which would require approval from NASA. The project plans to make a decision in March 2018 about whether to fly the SPC.

Other Issues to Be Monitored

The project is tracking a risk that an alloy used in several locations on the spacecraft will release gases when exposed to the high temperatures found where the spacecraft is intended to operate. The released gases can later re-solidify and contaminate the spacecraft. The alloy is found in three locations, supporting two instrument suites, on the spacecraft—the four FIELDS whip antennas, their respective thermal shields, and the SPC thermal shield—which are required to meet top-level mission requirements. Testing to understand the alloy's performance revealed that the alloy released gases even at temperatures much cooler than where the spacecraft will operate. The project is pursuing two mitigations. First, it is conducting tests to develop a contamination model, which should indicate the effects, if any, the re-solidified gases have on the spacecraft and help project officials determine if it is safe to fly the spacecraft with the existing alloy. Second, officials told us that they have ordered new material which could be used to replace the four FIELDS whip antennas and the SPC thermal shield. The project plans to make a decision if they will replace existing parts with the new material by February 2018. The project cannot replace the FIELDS thermal shields, so they have designed and implemented an additional shield, which will undergo testing in March 2018.

PROJECT OFFICE COMMENTS

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



Plankton, Aerosol, Cloud, ocean Ecosystem

The Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) is a polar-orbiting mission that will use advanced global remote sensing instruments to improve scientists' understanding of ocean biology, biogeochemistry, ecology, aerosols, and cloud properties. PACE will extend climate-related observations begun under earlier NASA missions, which will enable researchers to study long-term trends on Earth's oceans and atmosphere, and ocean-atmosphere interactions. PACE will also enable assessments of air and coastal water quality, such as the locations of harmful algae blooms.

Source: NASA. | GAO-18-280SP (Note: Ocean Color Instrument pictured above.)

FORMULATION

- **06/16** Formulation start
- **01/17** System requirements/ mission definition review
- **01/18** **GAO review**
- **03/19** Preliminary design review
- **06/19** Project confirmation

IMPLEMENTATION

- **01/20** Critical design review
- **05/21** System integration review
- **08/22** Projected launch readiness date

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **3 years**

Requirement Derived from: **2007 Earth Science Decadal Survey**

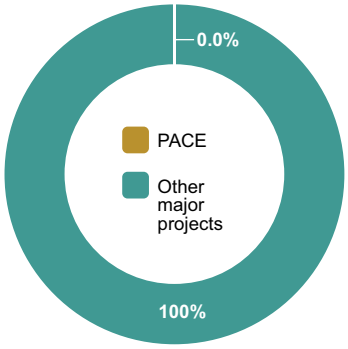
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The PACE project entered the preliminary design and technology completion phase in July 2017, but is facing funding uncertainty. The fiscal year 2018 President's Budget Request did not include funding for PACE. In order to meet scientific requirements and stay within NASA's established $805 million cost cap, the PACE project modified capabilities and made system trades. The project used a design-to-cost process, which requires the project to determine what baseline capabilities are achievable within cost limitations. The PACE mission cost cap continues to create risk around the project's launch vehicle selection, but officials are mitigating this risk by exploring alternative launch options, such as a ride share agreement with the Air Force. Project officials said they expect NASA to select a launch vehicle before project confirmation, currently planned for June 2019.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



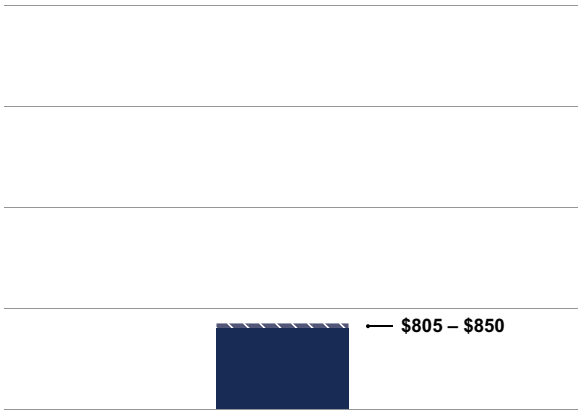
TOTAL FUNDED TO DATE

then-year dollars in millions

$98.1

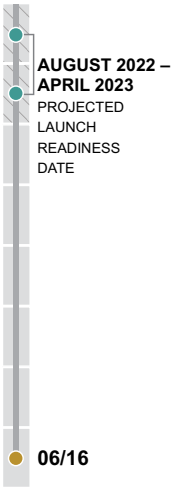
PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE



LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

In July 2017, NASA approved the PACE project to enter the preliminary design and technology completion phase, but with funding uncertainty. NASA did not request funding for PACE in its fiscal year 2018 budget request—an action attributed to budget constraints and higher science mission priorities. NASA also did not request funding for PACE in its fiscal year 2019 budget request. Despite proposed cancellation, the project is working toward preliminary design review scheduled for March 2019 and is continuing to use the design-to-cost process that requires the project to determine a baseline set of capabilities that are achievable within the project's $805 million mission cost cap at the 65 percent confidence level. This includes the $705 million allocated to the project and $100 million allocated to NASA headquarters for science-related activities, such as the calibration and validation of instrument data and processing of science data. The project is holding cost and schedule reserves consistent with NASA center policy.

Technology and Design

The PACE project modified capabilities and made system trades to meet scientific requirements within NASA's established $805 million cost cap. As part of the design-to-cost process, the project added capability to its primary instrument—the Ocean Color Instrument (OCI)—including extending performance to a new ultraviolet range and adding components for daily calibration. Additionally, the project originally sought an agreement with the Indian Space Research Organisation (ISRO) for a contributed polarimeter because the cost of procuring the instrument was higher than the amount allocated under the project's cost cap. However, according to officials, ISRO's inability to meet schedule needs and the uncertainty surrounding the future of the project led ISRO to withdraw its concept of a contributed polarimeter. The project is now pursuing two smaller contributed instruments that have mature designs from the University of Maryland-Baltimore County and the Netherlands Space Office—the Dutch space agency. According to officials, the project would use these smaller instruments in place of the larger ISRO polarimeter. While the ISRO polarimeter was a more capable instrument, the two polarimeters are expected to provide substantive scientific information for the cloud and atmospheric science community. The project will continue to make capability trades as part of the design-to-cost approach until project confirmation.

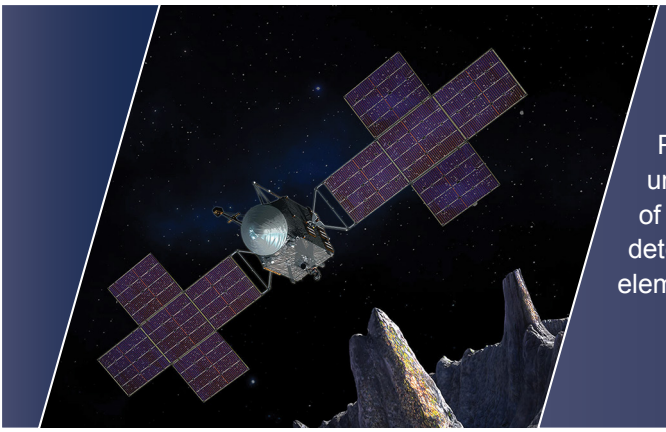
The PACE project made a design decision to tilt the OCI on a platform as opposed to tilting the entire spacecraft in order to meet a requirement that the OCI must tilt during some points of operation to avoid sun glint, or reflection of the sun off the ocean that causes a loss in data. The project came to this decision through a trade study, which, according to officials, demonstrated that tilting the entire spacecraft would take longer than tilting just the platform, lessening the amount of time the project has to collect data. However, the project is now tracking a risk that the inertia created by the OCI platform could interfere with data collection, which the project plans to mitigate by optimizing the placement and alignment of the OCI on its platform.

Launch

The PACE project is pursuing a shared ride agreement with the Air Force, which could help to mitigate a launch vehicle risk that the project is tracking. The launch vehicle cost remains the project's top risk, which could cause the project to exceed the $705 million allocated to the project or have to reduce its science capabilities. According to officials, a shared ride option would allow PACE to be the primary mission with a secondary Air Force payload at launch, which would reduce the project's launch vehicle costs and free up funding for other areas. The project has a launch vehicle budget of $105 million, and under a potential shared ride agreement, the project would be required to cover only a portion of the total vehicle costs. Project officials said they expect NASA to select a launch vehicle before project confirmation, currently planned for June 2019.

PROJECT OFFICE COMMENTS

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



Source: NASA/JPL-Caltech/Arizona State Univ./Space Systems Loral/Peter Rubin. | GAO-18-280SP

Psyche

Psyche will be the first mission to visit a metal asteroid and aims to understand a previously unexplored component of the early building blocks of planets: iron cores. The project plans to orbit the Psyche asteroid to determine if it is a planetary core, characterize its topography, assess the elemental composition and determine the relative ages of its surface regions.

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

International Partner: **None**

Launch Location: **Cape Canaveral Air Force Station, FL**

Launch Vehicle: **TBD**

Mission Duration: **21 months science operation**

Requirement Derived from: **Discovery Program Announcement of Opportunity 2014**

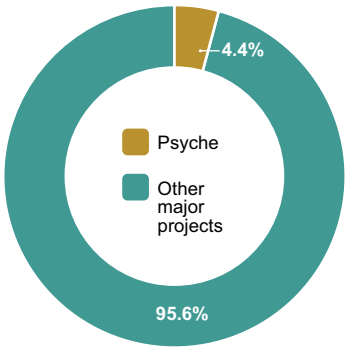
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

In December 2016, Psyche was one of two projects selected by the Discovery program—a series of competed missions that have focused scientific investigations and short development periods—to proceed to the preliminary design and technology completion phase. NASA selected the project's 2023 launch proposal, but later directed the project to work to an accelerated launch readiness date of August 2022. The accelerated launch date will allow Psyche to arrive at the asteroid over 4 years earlier than the original timeline due to a quicker flight. According to project officials, the Psyche project's current design utilizes mature, heritage technologies with some modifications. The project plans to fly three instruments that have flown on prior planetary missions and buy a commercially available spacecraft design. The project also plans to fly the Deep Space Optical Communications technology demonstration (DSOC), which is a laser-based communication device that could be beneficial to future deep space missions requiring high data rates, but it is not needed to meet Psyche's science requirements. As a result, Psyche could launch without DSOC if it experiences delays.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



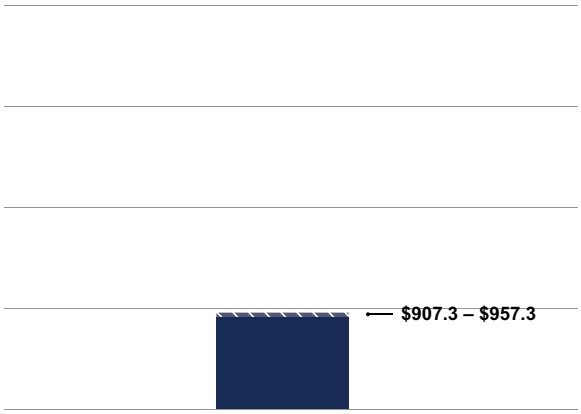
TOTAL FUNDED TO DATE

then-year dollars in millions

$50.3

PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE

LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

In December 2016, Psyche was one of two projects selected by the Discovery program—a series of competed missions that have focused scientific investigations and short development periods—to proceed to the preliminary design and technology completion phase. NASA selected the project's 2023 launch proposal, but later directed the project to work to an accelerated launch readiness date of August 2022. The accelerated launch will allow Psyche to arrive at the asteroid over 4 years earlier than the original timeline due to a quicker flight path. At the most recent decision point, the project set a preliminary cost range of $907.3 million to $957.3 million. The project plans to hold its preliminary design review in March 2019 and its confirmation review in May 2019, at which point it will formally establish its cost and schedule baseline. The project is currently holding cost and schedule reserves consistent with the level required by Jet Propulsion Laboratory policy.

Technology and Design

The Psyche project reported that its current design does not use any critical technologies and is based heavily on heritage technologies with modifications, which project officials assess as all being matured to at least technology readiness level 6. We have previously asserted that mature technologies must be demonstrated in a relevant environment and should be very close to form, fit, and function. The Psyche project reports that its heritage technologies are mature, but the project plans to modify some technologies. For example, the project plans to modify the Gamma Ray Neutron Spectrometer instrument—previously used on a mission to Mercury and will be used to determine Psyche's elemental composition—by adding a new cooling system, which the project is tracking as a risk because of possible problems accommodating the new cooling system. Project officials stated the spacecraft bus design—reported mature by the project—is based on a commercially available design that is used for Earth-orbiting communication satellites. The project plans to make minor modifications to some of the spacecraft bus to enable it to operate more robustly in deep space.

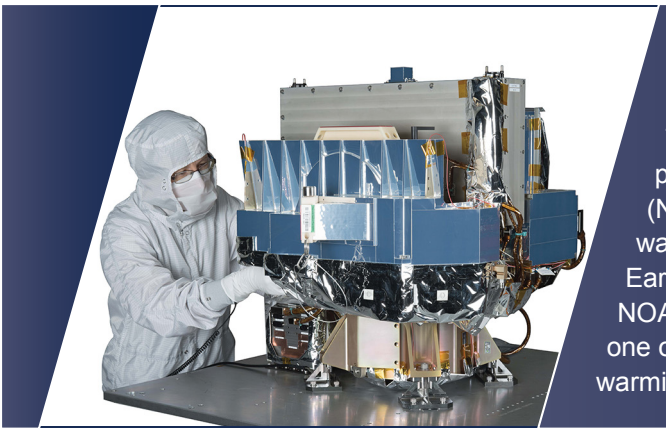
The project also plans to fly the Deep Space Optical Communications technology demonstration (DSOC), which is a laser-based communication device that could be beneficial to future deep space missions requiring high data rates. NASA is developing and funding DSOC as a separate project in the Space Technology Mission Directorate. As a result, the Psyche project does not control the cost or schedule for DSOC. The Psyche and DSOC projects have been working closely together to align their schedules, such as by establishing regular team meetings and developing a memorandum of understanding to ensure consistent expectations between both projects. If DSOC experiences delays, project officials stated that there is an option that Psyche could launch without it because DSOC is not needed to meet Psyche's science requirements.

Other Issues to be Monitored

In September 2017, the project reported a risk that it may have to conduct integration and testing off-site because it is planning to share a clean room with the Europa Clipper project, which has stricter planetary protection and contamination control requirements. These stricter requirements have a cost impact and the project is researching options to partition the clean room without jeopardizing the Europa Clipper project's requirements. The project is also researching options to conduct integration and testing off-site, such as using the contractor's facilities.

PROJECT OFFICE COMMENTS

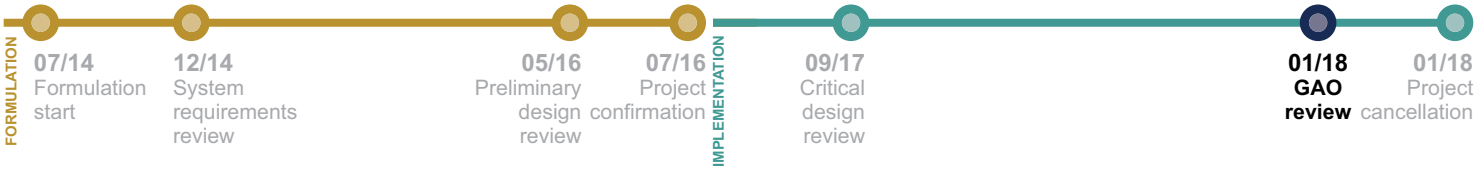
Psyche project officals provided technical comments on a draft of this assessment, which were incorporated as appropriate.



Source: Harris Corporation. | GAO-18-280SP

Radiation Budget Instrument

The Radiation Budget Instrument (RBI) is a scanning radiometer that NASA planned to launch on the National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System 2 (JPSS-2). RBI's planned mission was to support global climate monitoring by continuing measurements of the Earth's reflected sunlight and emitted thermal radiation made by NASA and NOAA satellites over the past 30 years. This data was intended to represent one of two key sets of measurements needed to determine whether the Earth is warming or cooling.



PROJECT INFORMATION

NASA Lead Center: **Langley Research Center**

International Partner: **None**

Launch Location: **Not applicable**

Launch Vehicle: **Not applicable; instrument hosted on JPSS-2 spacecraft**

Mission Duration: **7 years**

Requirement Derived from: **NASA Strategic Plan**

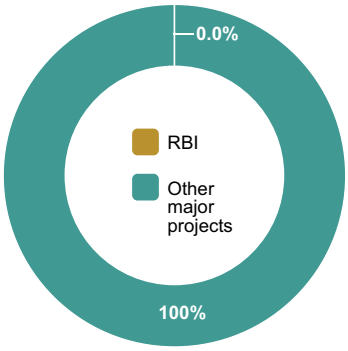
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

According to NASA's cancellation memorandum, NASA canceled the RBI project because of continued cost growth, technical issues, and poor contractor performance. The RBI project continued to experience contract cost growth, and as of November 2017, contract costs for design, fabrication, and delivery of RBI had grown by about 110 percent from the original value for this work, or an increase of $115 million. This increase depleted all remaining project-held cost reserves as the project entered the riskiest point of the development cycle. Ultimately, NASA determined that continuing to fund RBI from within the Earth Science Division budget would slow other important activities.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

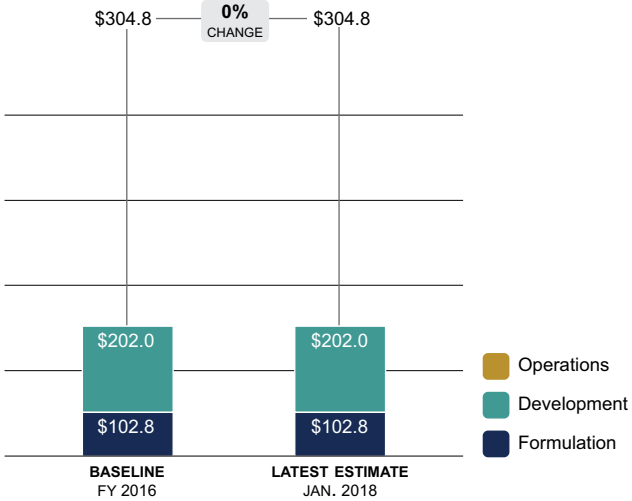


ESTIMATED FUNDING NEEDED

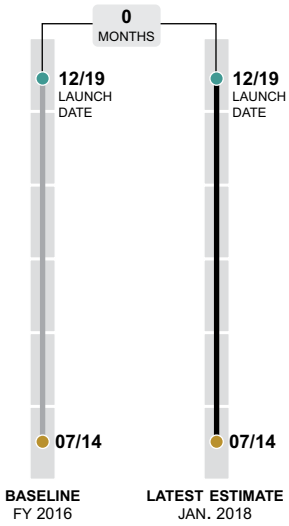
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Project Status

According to NASA's cancellation memorandum, the RBI project was canceled because of continued cost growth, technical issues, and poor contractor performance. The project identified the following specific issues that contributed to poor project cost and schedule performance: schedule planning that did not realistically account for contractor past performance, insufficient oversight of the contractor and its subcontractors, and poor integration of government and contractor teams with limited transparency concerning risks and issues. In 2017, both the government and the contractor took steps to respond to poor project performance, including changes to both the government and contractor program management teams, but ultimately NASA determined that continuing to fund RBI from within the Earth Science Division budget would slow other important activities. Based on the historical performance of other instruments and assessments of the likely remaining lifetime of on-orbit satellites, NASA believes the risk of a data gap is low if the next radiation budget-measuring instrument launches in 2027.

Cost and Schedule Status

The RBI project continued to experience contract cost growth, and was likely to exceed its cost baseline. As of November 2017, contract costs for design, fabrication, and delivery of RBI had grown by about 110 percent from the original value for this work, or an increase of $115 million. This cost increase depleted all remaining project-held cost reserves as the project entered the riskiest point of the development cycle—the integration and test phase. In 2016 and 2017, we found that projects appear most likely to rebaseline during this period.[a] In November 2017, the project requested additional reserves to cover increased contractor costs. If NASA would have approved the increase, it would have brought the project's costs to within approximately $2 million of its established cost baseline, which officials said was likely to be exceeded.

To support the decision of whether or not to continue the project, the project updated its joint cost and schedule confidence level, which is the likelihood that a project will meet its cost and schedule baseline. The update indicated that the project had a 30 percent chance of meeting the original delivery date of April 2019. As a result, the project updated the delivery date with NOAA to July 2019. The confidence level update showed that RBI had a 70 percent chance of meeting the later delivery date, but it would likely require additional funding in excess of the project's cost baseline if other technical issues arose.

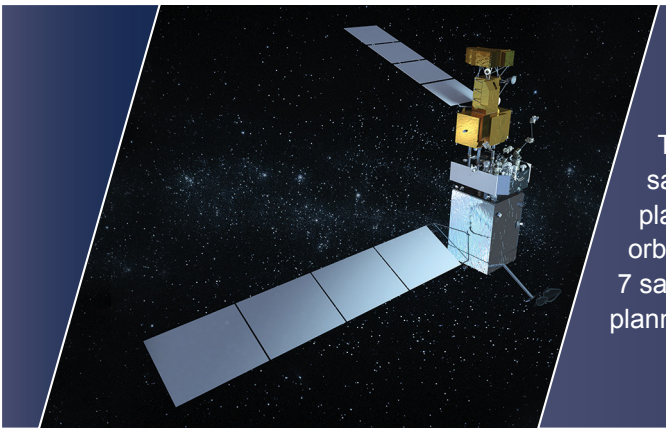
[a]GAO-16-309SP and GAO-17-303SP.

Technology and Design

The RBI project held its critical design review in September 2017 with 100 percent of its design drawings released. Best practices show that releasing 90 percent of design drawings by critical design review lowers the risk of subsequent cost and schedule growth. The review, previously scheduled for June 2017, was delayed to provide more time to resolve technical issues and to have additional test results available to inform the review board on the project's readiness to proceed. More specifically, the project conducted testing on an engineering development unit as a risk reduction measure and identified technical issues with the telescope and various electronic components that needed to be addressed prior to the review.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, RBI project officials stated that RBI was not included in the President's fiscal year 2018 budget request and continuing to fund RBI from within the Earth Science Division budget would slow other important activities. Project officials stated that multiple efforts by the RBI government and contractor team to improve performance were yielding positive results, including the resolution of technical issues leading to a successful critical design review. Officials also said improved cost and schedule controls were also proving to be effective. Project officials also provided technical comments, which were incorporated as appropriate.



Restore-L

The Restore-L project will demonstrate the capability to refuel on-orbit satellites for eventual use by commercial entities. Specifically, Restore-L plans to autonomously rendezvous with, inspect, capture, refuel, adjust the orbit of, safely release, and depart from the U.S. Geological Survey's Landsat 7 satellite. Landsat 7 can extend operations if successfully refueled, but it is planned for retirement if the technology demonstration is unsuccessful.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **TBD**

Mission Duration: **12 months**

Requirement Derived from: **Consolidated Appropriations Act, 2016**

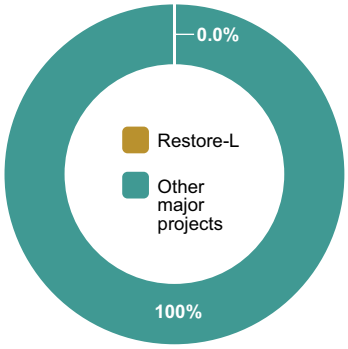
Budget Portfolio: **Space Technology, Research and Development**

PROJECT SUMMARY

The Restore-L project is no longer working to the preliminary cost and schedule estimates that NASA approved when it entered the preliminary design phase because the Space Technology Mission Directorate's proposed budget does not allow the project to execute to that plan. The mission directorate asked the project to evaluate two scenarios based on future funding possibilities. The project is to present a plan based on these scenarios to the mission directorate prior to the project establishing its cost and schedule baselines at its confirmation review in April 2018. The project reported that it does not use any new, critical technologies and that all six heritage technologies are modified from prior projects to fit the Restore-L design. The project matured five of these six technologies to the level recommended by best practices at its November 2017 preliminary design review. The technology that was not mature was a replacement for the prior vision navigation system, which did not meet requirements and the vendor was unable to resolve the issue. Project officials stated that they have a plan in place to mature the new system by December 2018.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

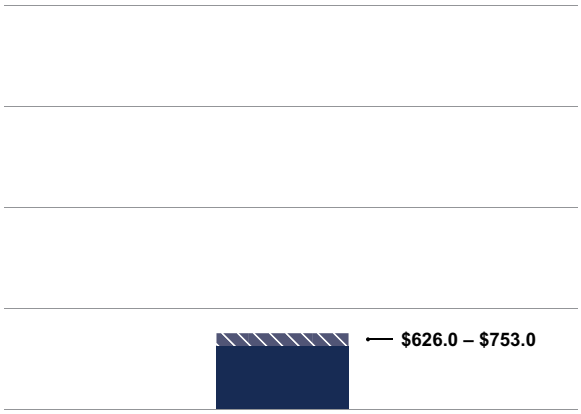


TOTAL FUNDED TO DATE

then-year dollars in millions

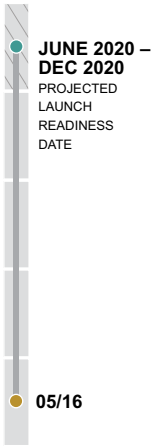
PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE



LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

The Restore-L project is no longer working to the preliminary cost and schedule estimates that NASA approved when it entered the preliminary design phase because the Space Technology Mission Directorate's proposed budget does not allow the project to execute to that plan. In April 2017, NASA set a preliminary cost estimate range of $626 million to $753 million with a projected launch readiness date between June and December 2020. However, the funding profile the Space Technology Mission Directorate proposed for future years will not allow the project to maintain a launch in 2020. As a result, the mission directorate asked the project to evaluate two scenarios based on future funding possibilities. According to NASA officials, one scenario assumes $130 million in project funding per fiscal year through the updated preliminary launch date for on-orbit demonstration. The other assumes $130 million for fiscal year 2018 followed by about $45 million for each of the fiscal years 2019 through 2024—focusing on technology development for industry use. The project is to present a plan based on these scenarios to the mission directorate prior to project confirmation review—the point at which the project will formally establish its cost and schedule baselines. The project has delayed its confirmation review from September 2017 to April 2018, in part to allow for more time to evaluate the scenarios. As of December 2017, the project's notional schedule is for a launch readiness date in December 2021, 1 year later than planned when the project entered the preliminary design phase. This notional schedule is based on various funding scenarios the project could face, and provides additional schedule reserve.

Technology and Design

The Restore-L project matured five of its six technologies to the level recommended by best practices at its preliminary design review in November 2017. Best practices recommend maturing technologies to a technology readiness level 6 by the project's preliminary design review to help minimize risks for space systems entering product development. The technology that was not mature at the review was a replacement vision navigation system that is new to the project. The prior vision navigation system did not meet requirements and the vendor was unable to resolve the issue. The project's independent review board stated that Restore-L needed a comprehensive plan to mature the technology at the review and project officials said they have a plan in place to mature the new system to a technology readiness level 6 by December 2018. The project reported that it does not use any new, critical technologies and that all 6 heritage technologies are modified from prior projects to fit the Restore-L design. Project officials said that although Restore-L uses all heritage technologies, the technologies will be used together in a new way to complete the mission's requirements.

The robot system is driving the project's schedule and the project has had to redesign system components, which consumed schedule reserve and put pressure on the project's preliminary launch schedule of December 2020. The robot system, which includes the spacecraft's robotic arm and associated components, will be used to capture the Landsat 7 spacecraft and will then employ tools to access the Landsat 7's propellant system, transfer propellant, and seal the system prior to releasing the spacecraft. The resolver pre-amp assembly—a component used to amplify signals to the robotic arm—is undergoing redesign to address signal distortion concerns. Another element, the robotic electronics units used to control the arm, is being redesigned to simplify and reduce the number of components in order to reduce schedule risk during integration and test. This redesign consumed schedule reserve before the project began working to a December 2021 notional schedule.

Other Issues to be Monitored

The project's current notional schedule would delay Restore-L's launch outside the servicing window for Landsat 7. Specifically, the agreed upon servicing window is January through September 2021, which the notional project launch schedule in December 2021 does not meet. However, that window may be extended if NASA reimburses the U.S. Geological Survey for additional costs to continue Landsat 7 operations.

PROJECT OFFICE COMMENTS

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

Space Launch System

The Space Launch System (SLS) is intended to be NASA'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 spacecraft and other systems on missions between the Earth and Moon and to enable deep-space missions, including Mars. NASA is designing SLS 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 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 use a new upper stage and evolved boosters.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Marshall Space Flight Center**

International Partner: **None**

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

Launch Vehicle: **N/A**

Mission Duration: **Varied based on destination**

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

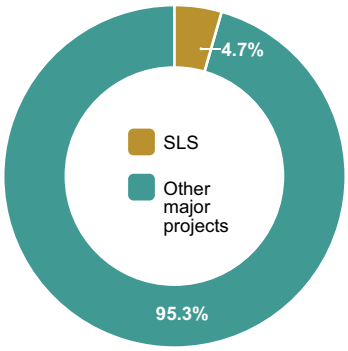
Budget Portfolio: **Exploration, Exploration Systems Development**

PROJECT SUMMARY

In December 2017, NASA announced a new schedule and cost estimate for the SLS program, after determining that the November 2018 launch readiness date for Exploration Mission-1 (EM-1) was no longer feasible. NASA is now planning to an internal launch readiness date of December 2019, with 6 months of schedule reserve to a June 2020 date. The life-cycle cost estimate for SLS is approximately $9.7 billion to the December 2019 date and $9.8 billion to the June 2020 date. The delivery schedule for the program's core stage—which functions as the SLS's fuel tank and structural backbone—has continued to slip as the program addresses a series of technical challenges, including the completion of welding its large, first stage. The program currently has no schedule reserve to ship the core stage for testing, as well as from the test site to the launch site, in order to meet the December 2019 launch readiness date. Should problems or issues arise during testing, they will likely affect the enterprise integration and test schedule.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

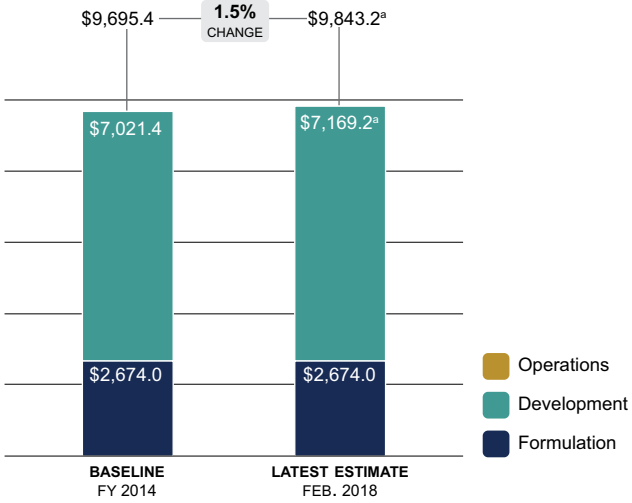


ESTIMATED FUNDING NEEDED

then-year dollars in millions

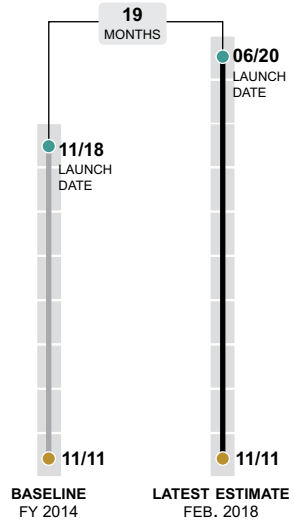
COST PERFORMANCE

then-year dollars in millions



[a]Assumes June 2020 launch date.

SCHEDULE PERFORMANCE



Cost and Schedule Status

In December 2017, NASA announced a new schedule and cost estimate for the SLS program, after determining that the November 2018 launch readiness date for Exploration Mission-1 (EM-1) was no longer feasible. In April 2017, we found that the date was likely unachievable for all three human spaceflight programs—Exploration Ground Systems, SLS, and Orion Multi-Purpose Crew Vehicle—due to technical challenges continuing to cause schedule delays and the programs having little to no schedule reserve to the EM-1 date, meaning they would have to complete all remaining work with little margin for error for unexpected challenges that could arise.[b] The new internal launch readiness date for EM-1 is now December 2019, but NASA has also allocated 6 months of schedule reserve to June 2020 for possible manufacturing and production schedule risks. This represents a delay of 13-19 months for EM-1. The life-cycle cost estimate for SLS is about $9.7 billion to the December 2019 date and $9.8 billion to the June 2020 date, or 0.4 to 1.5 percent above the project's committed baseline.

Technology, Design, and Manufacturing

The delivery schedule for the program's core stage—which functions as the SLS's fuel tank and structural backbone—has slipped 14 months in the last year to May 2019, due in large part to production issues that have delayed completion of the core stage element. According to program officials, the liquid hydrogen tank has proven difficult to weld to specifications because it is thicker than metals that have been used by industry in the past. Without a history of similar efforts to compare to, officials explained that they have to check and test every potential anomaly with increased scrutiny than if they were producing something already used throughout the aerospace industry. In addition, according to officials, because this is the first flight article, the contractors are performing extensive testing to ensure that their production processes and methods are resulting in end items that meet or exceed specifications so that the next unit can be produced more quickly.

In addition to these issues, the program has faced work slowdowns and stoppages due to severe weather. In February 2017, a tornado hit parts of the Michoud Assembly Facility in Louisiana, where the core stage is being produced. While work resumed shortly after the storm, according to program officials, it did so at less than full capacity and delayed the program by a total of about 2 months. According to officials, repair work is complete in SLS manufacturing areas and should not further impact production work at the facility.

Integration and Test

The program has no schedule reserve through delivery of the core stage to Kennedy Space Center for the December 2019 launch date. In addition to completing production of flight and test articles, the program has to integrate the engines to the core stage and ship them to Stennis Space Center for a green run test. During this test, the core stage is fueled and the four main engines fired for about 500 seconds for the first time. This test will stress the flight components as well as the ground equipment used for the test. For example, according to program officials, 7 of the 12 cryogenic fluid pumps at Stennis Space Center must work together in order to fuel the vehicle. Should issues arise, the program will likely need additional time to assess and mitigate difficulties or glitches, which would likely affect delivery to Kennedy Space Center and could delay the enterprise integration and test schedule.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, SLS program officials stated that a vast majority of SLS development and production work is on track for EM-1 and that work is also proceeding for the first crewed flight—EM-2. In addition, officials state that the program is successfully working through first-time production issues that are not unprecedented for a program of this scope and ambition. Program officials also provided technical comments, which were incorporated as appropriate.

[b] GAO-17-414.

Space Network Ground Segment Sustainment

The Space Network Ground Segment Sustainment (SGSS) project plans to develop and deliver a new ground system for one Space Network site. The Space Network provides essential communications and tracking services to NASA and non-NASA missions. Existing systems, based on 1980s technology, are increasingly obsolete and unsustainable. The new ground system will include updated systems, software, and equipment that will allow the Space Network to continue to provide critical communications services for the next several decades. The Space Network is managed by the Space Communication and Navigation (SCaN) program.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **N/A**

Launch Vehicle: **N/A**

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

Requirement Derived from: **March 2008 Space Network modernization concept study**

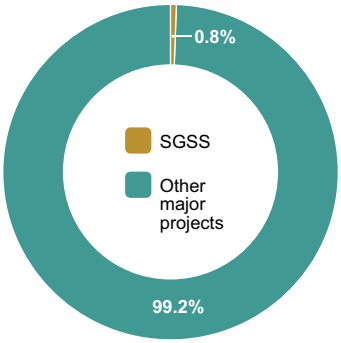
Budget Portfolio: **Space Operations, Space and Flight Support**

PROJECT SUMMARY

In 2017, the SGSS project experienced additional cost growth and schedule delays beyond the rebaselined cost and schedule estimate NASA set in 2015. Since the 2015 rebaseline, the project's total costs increased by at least $112.9 million, from $1,207.9 million to $1,320.8 million even as the scope decreased from nine terminals at three Space Network sites to six terminals at one site. According to the fiscal year 2019 budget request, NASA plans to conduct an independent review in 2018 to inform a decision on whether to continue the project. If the project continues, additional cost growth is expected as the latest cost estimate covers only through the initial operational readiness review, currently planned for September 2019. Project officials attributed the cost growth and delays to an incomplete understanding of requirements by the contractor, which led to poor contractor plans and late design changes. Contractor performance has been a concern for the project, but project officials stated that contractor performance improved in fiscal year 2017. The project delivered the final software increment in May 2017 and the software is now in integration and testing.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

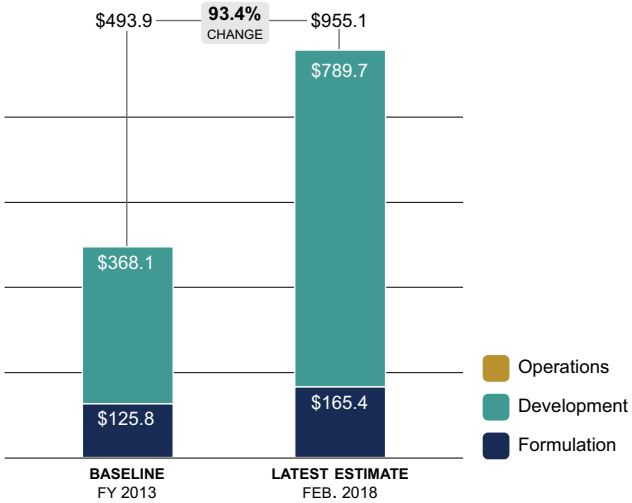


ESTIMATED FUNDING NEEDED

then-year dollars in millions

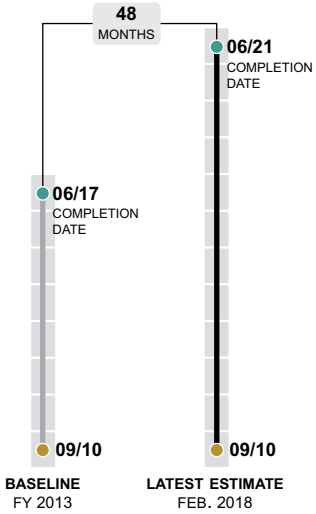
COST PERFORMANCE

then-year dollars in millions



Note: The SGSS project has received an additional $365.7 million from Space Network users outside of NASA.

SCHEDULE PERFORMANCE



Cost and Schedule Status

In 2017, the SGSS project experienced additional cost growth and schedule delays beyond the cost and schedule rebaseline NASA set for it in 2015. In 2016, SGSS was reclassified as a hybrid sustainment project instead of a major project, which means that NASA is no longer measuring the project against its cost and schedule baseline, among other oversight implications. However, according to officials, the project is still required to provide quarterly and annual status reports to NASA on their cost and schedule. Since the 2015 rebaseline, however, the project's total costs increased by at least $112.9 million, from $1,207.9 million to $1,320.8 million, even as the scope decreased from upgrading nine terminals at three Space Network sites to six terminals at one site. The SGSS project presented its new cost and schedule estimate to NASA headquarters in August 2017, which NASA approved up through the initial operational readiness review, currently planned for September 2019.

Additional cost growth is expected for SGSS when NASA revisits project costs through future budget cycles. According to the fiscal year 2019 budget request, an independent review of the project is underway to determine whether the project will continue and was initiated due to budget challenges. In the event the project continues, officials stated the project plans to evaluate various funding scenarios, including continuing but receiving less funding than requested. Project officials attributed the cost growth and delays to an incomplete understanding of requirements by the contractor, which led to poor contractor plans and late design changes, but project management has been a challenge as well. For example, the project has historically struggled to manage contractor performance and has faced staffing shortfalls in key areas, such as systems engineering and business management. However, as of January 2018, NASA officials stated that these workforce issues had largely been resolved because some positions were filled by reassigning staff to these areas and others are no longer needed. The project delivered the final software increment in May 2017 and the software is now in integration and testing. The project is working toward the systems integration review in May 2018.

Contractor

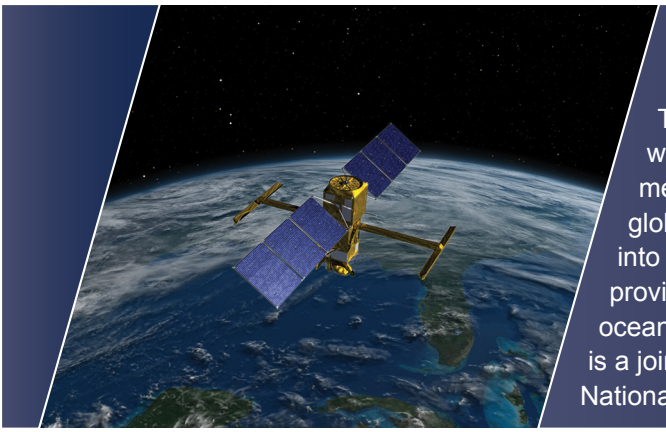
Contractor performance has been an ongoing concern for the project, but project officials stated that performance improved in fiscal year 2017. The SGSS project attributes most of its cost and schedule growth to the contractor underestimating the scope of the development effort. The contractor moved a large portion of the software's required functionality into the last software development increment after experiencing problems with earlier increments. Project officials stated the contractor did not fully understand the requirements, technical planning was inadequate, and the contractor's planning did not account for resolving software defects. In response to the issues the project has faced, the SGSS project has taken action to try to address contractor performance problems. For example, the project worked with the contractor to develop new, more reliable cost and schedule estimates both for 2017 and beyond. The new schedule focuses on discrete tasks, which enables better tracking and measurability. In addition, the project managers for the project and the contractor were replaced. Project officials stated that contractor performance improved in fiscal year 2017 as the project successfully completed most of the plan it created for fiscal year 2017, which included delivery of the final software increment to integration and testing in May 2017.

Integration and Test

The project is tracking several risks to completing integration and testing—a period where problems are commonly found and schedules tend to slip—on schedule. For example, the project is tracking a risk that Space Network and mission partner users may be unavailable for testing, which could slow progress. The project is also tracking the number of software defects as a risk. While the project and the contractor's models generally agree on defect resolution timeframes, officials said there is a risk that defects could arise that would take longer than planned to fix. Additionally, the project is continuing work to demonstrate end-to-end performance and stability of the SGSS system. As part of the fiscal year 2017 plan, the project established five operational scenarios as measures of performance and stability. The project completed four of the operational scenarios, but was unable to complete the fifth due to a problem with third-party software. The project is working with the software vendor to resolve the issue.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, project officials noted the contractor performed on plan for fiscal year 2017 and completed all the milestones within the critical path. The project also provided technical comments, which were incorporated as appropriate.



Surface Water and Ocean Topography

The Surface Water and Ocean Topography (SWOT) mission 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: California Institute of Technology/Jet Propulsion Laboratory (artist depiction). | GAO-18-280SP

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

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

Launch Location: **Vandenberg Air Force Base, CA**

Launch Vehicle: **Falcon 9**

Mission Duration: **3 years**

Requirement Derived from: **2007 Earth Science Decadal survey**

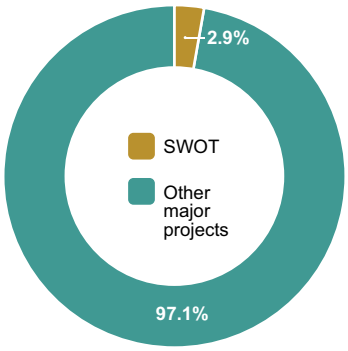
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The SWOT project continues to operate within its cost baseline and plans to launch in April 2021, a year earlier than its committed schedule baseline, despite encountering technical issues with its main instrument—the Ka-Band Radar Interferometer (KaRIn). An engineering model of the KaRIn high voltage power supply was damaged during testing due to three electrical arcing events that were caused by manufacturing and handling of parts, and weaknesses in the packaging design. In addition, the project augmented the main beams that connect the instrument antennas to the spacecraft, which resulted in delays to releasing design drawings. The project discovered signal interference off the main beams that could distort KaRIn's science measurements. Project officials said they planned to release about 90 percent of design drawings at the planned February 2018 critical design review, which is a best practice.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

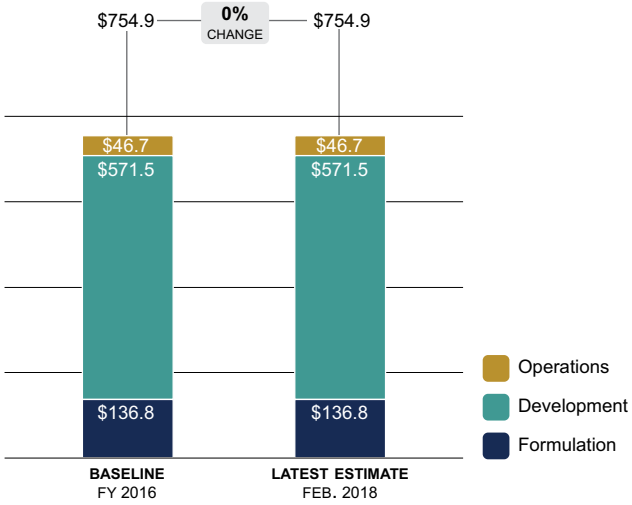


ESTIMATED FUNDING NEEDED

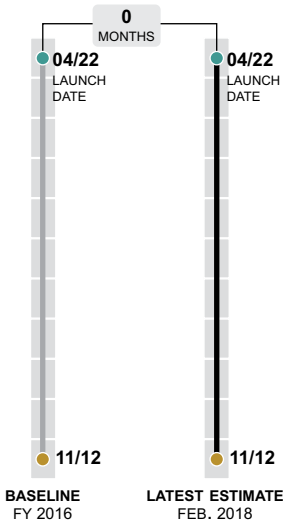
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The SWOT project continues to operate within its cost baseline and plans to launch in April 2021, a year earlier than its committed schedule baseline. The project is holding schedule reserves consistent with the level required by Jet Propulsion Laboratory policy, but did not meet cost reserve requirements in fiscal year 2017 due to costs associated with risk reduction activities and to stay on schedule. For example, project officials said they used cost reserves to build higher-fidelity engineering models and to secure a higher than planned workforce to execute fiscal year 2017 tasks. However, the project was able to reconstitute some of its cost reserves due to lower-than-expected launch vehicle costs and is meeting cost reserve requirements for fiscal year 2018 as of January 2018. The project is progressing toward its critical design review scheduled for February 2018.

Technology and Design

The project's primary instrument—the Ka-Band Radar Interferometer (KaRIn)—continues to be the most complicated development effort and has experienced technical issues that have had cost and schedule implications. During testing, an engineering model of the KaRIn high voltage power supply (HVPS) was damaged due to three electrical arcing events that were caused by manufacturing and handling of parts as well as weaknesses in the packaging design. To mitigate these events, the project repaired the electrical board within the engineering model with temporary fixes to support upcoming testing and built a second electrical board with enhanced handling procedures for a key thermal vacuum test in February 2018. As a result, HVPS development is driving the project's schedule. To maintain its current schedule, the project is building the HVPS flight model in parallel to its ongoing testing of the engineering model. The project determined this approach was less risky than delaying flight model development until engineering model testing is complete. The project is tracking a risk, however, that development of the flight model concurrently may cause late rework.

In addition, the project augmented the main beams that connect the instrument antennas to the spacecraft, which resulted in delays to releasing design drawings. The project discovered signal interference off the main beams that could distort KaRIn's science measurements. To mitigate this risk, the project added a reflective plate to the main beam to minimize signal distortion and successfully held a mechanical critical design review with the modified main beam design. As a result, however, the project is 3 months behind schedule in releasing drawings for the modified design and is working with the Jet Propulsion Laboratory to secure additional staff to accelerate drawing production.

As of January 2018, SWOT released 87 percent of its expected drawings and project officials said they plan to release about 90 percent of design drawings at critical design review. Best practices show that releasing at least 90 percent of design drawings by this review can decrease a project's risk of cost growth and schedule delays.

Other Issues to Be Monitored

After the project experienced challenges with one of the tools—AirSWOT—that it plans to use to help understand the data returned from the KaRIn instrument once SWOT is in orbit, the project selected two additional methods to augment ocean measurements. The project determined that the performance of AirSWOT, which is an airborne sensor, was likely to be insufficient and that heavy wave activity when collecting ocean data was the root cause of measurement abnormalities. The project selected an airborne laser-based remote sensor along with a network of underwater gliders to augment the measurements from in-orbit satellites that were planned with AirSWOT. This approach successfully passed a technical peer review in December 2017 and the project plans to complete additional experiments using the selected approach to inform its calibration and validation plan.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, project officials stated that SWOT is a challenging mission making a first of a kind measurement of global surface water. Officials also stated the project has been advancing the heritage systems development allowing the project to focus on the challenging KaRIn development. The project is completing thorough testing of engineering models along with a series of technical reviews in preparation for the flight model development. The project's focus remains on systematically rectifying technical issues while devising workarounds to maintain the overall milestones. SWOT officials also provided technical comments, which were incorporated as appropriate.

Transiting Exoplanet Survey Satellite

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 for transiting exoplanets—or planets in other solar systems. The mission's goal is to discover these exoplanets during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth. The project plans to discover rocky and potentially habitable Earth-sized and super-Earth planets orbiting nearby bright stars for further evaluation through ground- and space-based observations by other missions, such as the James Webb Space Telescope.

Source: NASA. | GAO-18-280SP

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Cape Canaveral Air Force Station, FL**

Launch Vehicle: **Falcon 9**

Mission Duration: **2 years**

Requirement Derived from: **2010 Astrophysics Decadal Survey**

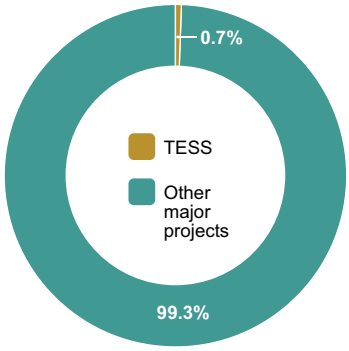
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

The TESS project launched on April 18, 2018, before its committed launch date and within its cost baseline. The project expected to launch in March 2018 but did not meet this date due to certification delays with the SpaceX Falcon 9 upgrade known as Block 4. To cover the 1-month delay, NASA shifted funding previously budgeted for the operations phase to the development phase. The project did not have headquarters-held reserves to cover a launch past March 2018 because NASA reallocated $15 million of TESS's headquarters-held reserves to another astrophysics project. The TESS project completed environmental testing and conducted additional testing on its spare camera at temperatures seen in space to better understand expected camera performance on orbit. During thermal testing, the project found that the substance attaching the lenses to the camera barrel places pressure on the lenses and causes the cameras' focus to shift slightly. However, in June 2017, NASA directed the project to integrate the cameras because they are still expected to meet TESS's top-level science requirements even with the anomaly.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019

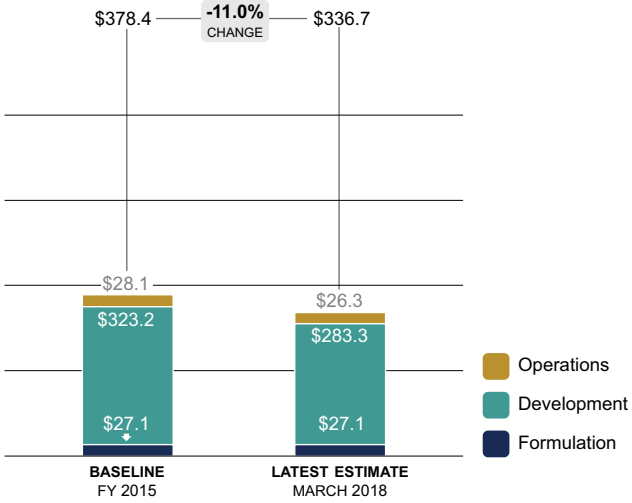


ESTIMATED FUNDING NEEDED

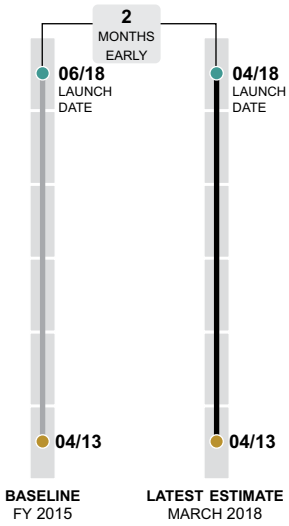
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The TESS project launched on April 18, 2018—2 months early and within its cost baseline. The project had planned to launch in March 2018, but the launch date was moved by a month due to delays related to its launch vehicle. At the key decision review prior to the project entering the operations and sustainment phase, NASA approved shifting $1.9 million prevously budgeted for the operations phase to the development phase to cover the 1-month delay. The project did not have any headquarters-held cost reserves available to cover a launch past March 2018 because NASA reallocated $15 million of TESS's headquarters-held reserves to another astrophysics project, the Wide-Field Infrared Survey Telescope project. The project is holding cost and schedule reserves at the level required by NASA center policy.

Integration and Test

The project completed observatory environmental testing after overcoming spacecraft and instrument challenges to its cost and schedule. The project entered system assembly, integration and test—the phase where problems are most commonly found and schedules tend to slip—in August 2017. The project mitigated two risks related to its spacecraft. First, the project integrated its flight Ka-band transmitter in October 2017 after a 2-year delivery delay. The transmitter, essential for TESS as it transmits the mission data back to Earth, experienced continued contractor performance and manufacturing issues such as incorrectly placed parts. The project used schedule reserves to accommodate delays, installed an on-site representative to oversee the contractor's work, and developed a contingency plan to fly TESS with the transmitter's engineering development unit, which performed well in testing. Second, the project closed a risk that its slip rings—components within the solar array drive assembly necessary for power transmission—could be unsafe for flight. In May 2017, the project found damage to a small number of its slip rings, but later determined the slip rings were acceptable for flight after testing showed that they performed as expected.

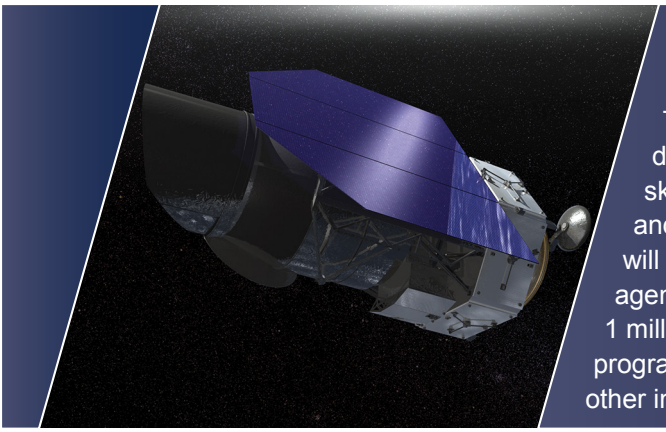
The project conducted additional testing on its spare camera at temperatures experienced in space to better understand expected camera performance on orbit after finding that the focus of each camera shifts slightly at the temperatures in which TESS will operate. In thermal testing, the project found that the substance attaching the lenses to the camera barrel places pressure on the lenses and causes the cameras' focus to shift slightly at on-orbit temperatures. Prior to system integration review, NASA deemed the four cameras acceptable as they are expected to meet top-level science requirements even with the anomaly and in June 2017 directed the project to integrate the cameras. In July 2017, the project integrated the cameras with an alternative data handling unit, which powers the cameras and serves as the instrument data storage and processing computer. The project decided to use the alternative data handling unit because the unit originally designed for the project was behind schedule due to technical issues and contractor performance.

Launch

The project did not meet its expected March 2018 launch date due to certification delays for its launch vehicle, the SpaceX Falcon 9 upgrade known as Block 4. Certification is necessary because it will be the first time that a NASA instrument will launch on the Block 4 version of the vehicle. The TESS project expected that NASA's Launch Services Program would certify the Block 4 in September 2017, 7 months before TESS is scheduled to launch. However, NASA needed additional time to investigate the Falcon 9 second stage pressure vessel, which was involved in an anomaly that caused an explosion in September 2016. SpaceX also required extra time to meet NASA's Launch Services Program requirements.

PROJECT OFFICE COMMENTS

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



Wide-Field Infrared Survey Telescope

The Wide-Field Infrared Survey Telescope (WFIRST) is an observatory designed to perform wide-field imaging and survey of the near-infrared sky to answer questions about the structure and evolution of the universe, and expand our knowledge of planets beyond our solar system. The project will use a telescope that was originally built and qualified by another federal agency. The project plans to launch WFIRST in the mid-2020s to an orbit about 1 million miles from the Earth. The project is also planning a guest observer program, in which the project may provide observation time to academic and other institutions.

Source: NASA. | GAO-18-280SP

FORMULATION

- **02/16** Formulation start
- **01/18** **GAO review**
- **03/18** System requirements/ mission definition review
- **12/19** Preliminary design review
- **01/20** Project confirmation

IMPLEMENTATION

- **06/21** Critical design review
- **06/23** System integration review
- **09/25** Projected launch readiness date

PROJECT INFORMATION

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

International Partner: **TBD**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **5¼ years (Including on-orbit commissioning)**

Requirement Derived from: **2010 Astrophysics Decadal Survey**

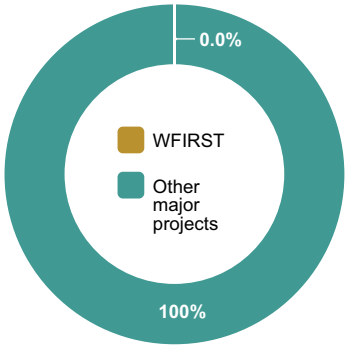
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

NASA's preliminary cost and schedule estimates for the WFIRST project are currently under review as the project responds to findings from an independent review. The review found that the mission is not aligned with the resources provided and concluded that the mission is not executable without adjustments and/or additional resources. NASA agreed with the study team's results and directed the project to reduce the cost and complexity of the design in order to maintain costs within the project's $3.2 billion preliminary cost target. As a result of the review, design trade-offs are being made. The project plans to make a final decision on the design features and international partners as it prepares for its system requirements and mission definition review in March 2018. The WFIRST project also matured its two critical technologies, but is tracking a risk concerning the production of Wide Field Instrument detectors. Project officials stated large array detectors always pose fabrication challenges. The President's 2019 Budget Request proposed canceling the WFIRST project.

PROJECT BUDGET INFORMATION

percent of current portfolio for fiscal year 2019



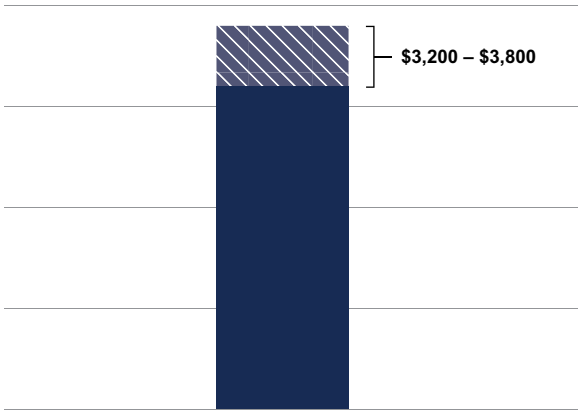
TOTAL FUNDED TO DATE

then-year dollars in millions

$195

PRELIMINARY COST[a]

then-year dollars in millions



[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.*

PRELIMINARY SCHEDULE

LATEST ESTIMATE
FEB. 2018

Cost and Schedule Status

The WFIRST project's preliminary cost and schedule estimates are currently under review as the project responds to findings from an October 2017 independent review conducted to ensure the mission's scope and required resources are well understood and executable. The review found that the project is not executable unless its mission scope is redesigned or its preliminary cost target is increased. NASA agreed with the study team's results and directed the project to reduce the cost and complexity of the design in order to maintain costs within the project's $3.2 billion preliminary cost target. In February 2018, the President's 2019 Budget Request proposed canceling the WFIRST project.

Design and Technology

In response to the independent review, the project developed a system design proposal that will be presented at its system requirements and mission definition review in March 2018 to reduce WFIRST cost and complexity. As of January 2018, the project was planning to reach the $3.2 billion cost target by treating the coronagraph—designed to perform high contrast imaging and spectroscopy of nearby exoplanets—as a technology demonstration as opposed to a science instrument. This, according to officials, allows the project to make a trade between performance and risk, and thereby avoid potential impacts to the project's cost and schedule. In addition, the project plans to review the capabilities of the Wide Field Instrument, which is intended to measure light from a billion galaxies and perform a survey of the inner Milky Way, as part of the review. NASA is also considering whether or not to maintain capability for WFIRST to be "starshade ready." A starshade is a device that is launched with or separately from an observatory and positioned between it and the star being observed to block out the starlight while allowing the light emitted by the planet through. NASA planned to review and formally approve the changes at the project's next key decision review, planned for April 2018, prior to entering the preliminary design and technology completion phase. Finally, in response to the independent review, NASA upgraded the risk classification of the project, which could increase project costs due to more system reliability and mission assurance requirements.

The WFIRST project has matured its two critical technologies to a technology readiness level 6, which helps to minimize risks for space systems when entering production, but is tracking a risk concerning the production of Wide Field Instrument detectors. Project officials stated large array detectors always pose fabrication challenges. To date, detector production has exceeded historical trends, but the project is completing ongoing tests to validate detector quality.

Developmental Partner

NASA is considering several potential contributions with various international partners, including the Canadian Space Agency, European Space Agency, France, Germany, and Japan, for elements of the Wide Field Instrument, coronagraph, and ground system. These contributions could potentially reduce the project's cost. NASA also expects to determine its international partners before the project enters the preliminary design and technology completion phase.

PROJECT OFFICE COMMENTS

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