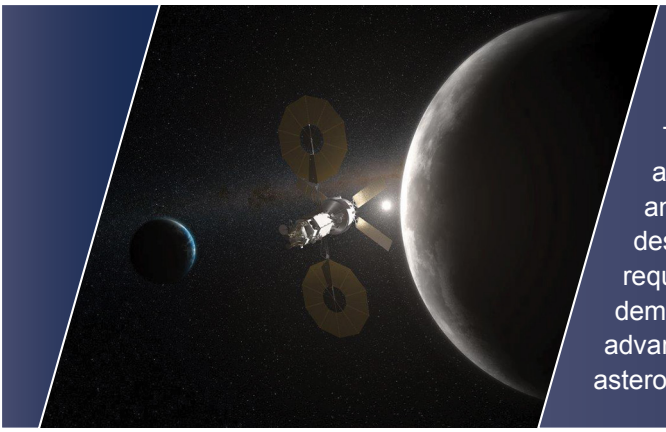


Asteroid Redirect Robotic Mission

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

Source: AMA Studios. | GAO-17-303SP

PROJECT INFORMATION

NASA Lead Center: **Jet Propulsion Laboratory**

International Partner: **TBD**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **6 years**

Requirement Derived from: **NASA Strategic Plan**

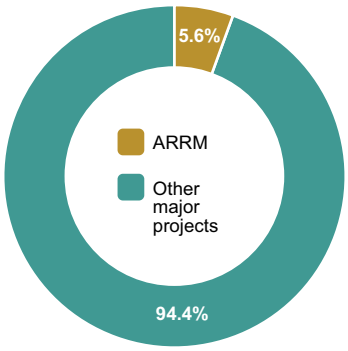
Budget Portfolio: **Exploration, Exploration Research and Development**

PROJECT SUMMARY

In August 2016, the ARRM project entered the preliminary design and technology completion phase with a higher cost and longer schedule than previously estimated. The project's estimated costs increased primarily because of a 1-year delay in its planned launch readiness date, which was driven by near-term funding constraints. Multiple NASA mission directorates are developing technologies for ARRM. Maturing technologies in separate technology development efforts is a best practice, but it could pose a challenge for the project if schedule, funding, or other issues arise with these related efforts. The ARRM project is tracking a variety of design and development risks related to its critical technologies, including the boulder capture system, which will require changes to the project's requirements. The ARRM project plans to select its spacecraft, payloads, and launch vehicle in 2017, but those plans could be affected if adequate funding is not available. The President's 2018 Budget Blueprint has proposed canceling the Asteroid Redirect Mission.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



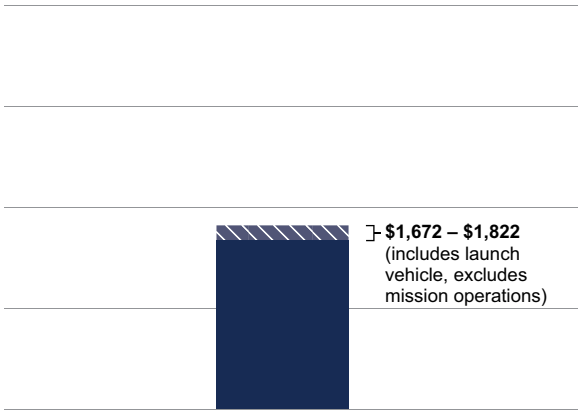
TOTAL FUNDED TO DATE

then-year dollars in millions

$111.8

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. 2017

Cost and Schedule Status

In August 2016, NASA approved the ARRM project to enter the preliminary design and technology completion phase, but with a higher cost and longer schedule than previously planned. NASA increased the development cost cap for the project from $1.25 billion to $1.4 billion, not including launch costs. The cost primarily increased because of a 1-year delay in ARRM's planned launch readiness date from December 2020 to December 2021, due to near-term funding constraints. In March 2017, the President's 2018 Budget Blueprint proposed canceling the Asteroid Redirect Mission, which includes the ARRM project.

Technology

The ARRM project is continuing to mature its critical technologies, but it is dependent on other projects for many of its key technology development efforts. Project officials said they expect to mature ARRM's four critical technologies to a technology readiness level 6 before its planned December 2017 preliminary design review. Maturing critical technologies to this level is a best practice, which helps minimize risks for space systems entering product development. Multiple NASA mission directorates are developing technologies for ARRM. From the Space Technology Mission Directorate, the project plans to leverage advanced controls, sensors, and robotics technologies in development for the Restore-L project, as well as high-powered solar electric propulsion (SEP) technologies. If significant schedule, funding, or other issues arise with the dependent technologies, ARRM could experience cost and schedule growth. The Restore-L and SEP schedules currently align with the ARRM project's need dates, but the President's 2018 Budget Blueprint proposed restructuring the Restore-L project. According to the ARRM project executive, the project has developed a memorandum of understanding related to these dependencies that includes actions it can take if there are schedule delays.

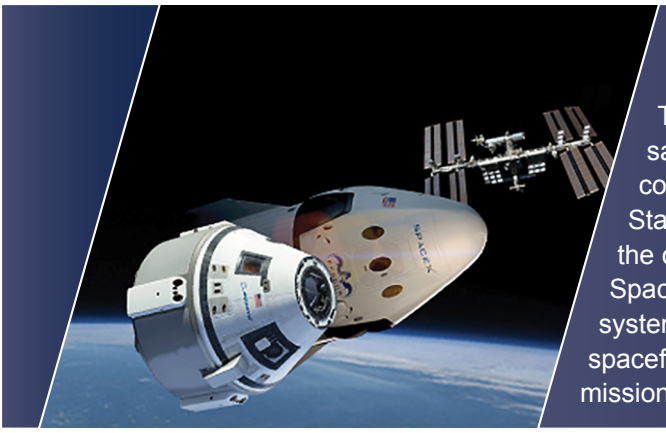
Design

The ARRM project is tracking a variety of design and development risks related to its propulsion and boulder capture systems. According to a project official, the project is primarily focused on the risks associated with the capture system's ability to successfully grip and retrieve a boulder from the asteroid. The project's independent review board raised concerns about the system's ability to meet current planned ARRM requirements. The project has completed a study of the capture system and has made changes to the design, but it will also have to make requirements changes.

The ARRM project plans to select its spacecraft, payloads, and launch vehicle in 2017, but those plans could be affected if adequate funding is not available. The project has decided to use a commercially available spacecraft to reduce project costs. The project received proposals in October 2016 and plans to award the spacecraft development contract in May 2017. NASA is also considering adding hosted payloads on ARRM that could decrease mission risk. The project issued a call for hosted payloads in September 2016 and expects to make selections in June 2017. Finally, project officials stated that they expect to select a launch vehicle by preliminary design review. The project plans to maintain compatibility with the Delta IV Heavy, Falcon 9 Heavy, and Space Launch System vehicles until selection.

PROJECT OFFICE COMMENTS

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



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-17-303SP

FORMULATION

- **09/14** Transportation Capabilities phase contract awards
- **01/17** **GAO review**
- **11/17** SpaceX uncrewed test flight
- **05/18** SpaceX crewed test flight
- **06/18** Boeing uncrewed test flight
- **08/18** Boeing crewed test flight
- **2018** Final certification review
- **2018 – 2024** Post-certification missions

PROJECT INFORMATION

NASA Lead Center: **Goddard Space Flight 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: **Pegasus**
Launch Vehicle: **Boeing-Atlas V; SpaceX-Falcon 9**
Mission Duration: **2 years**

Requirement Derived from: **2013 – 2022 Decadal Survey in Solar Space Physics**
Requirement Derived from: **NASA Strategic Plan**

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

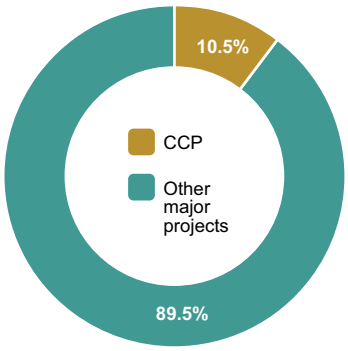
[a]Blue Origin and Sierra Nevada Corporation do not have contracts for the current phase and therefore were not included in this assessment.

PROJECT SUMMARY

Both of the Commercial Crew Program's contractors have made progress developing their crew transportation systems, but have aggressive development schedules that are increasingly under pressure. Boeing and SpaceX have determined that they will not be able to meet their original 2017 certification dates and expect certification to be delayed until 2018. In addition, the Commercial Crew Program is tracking risks that both contractors could experience additional schedule delays. In February 2017, NASA reached an agreement with Boeing giving NASA the option of acquiring crew transportation from Boeing on Russian Soyuz flights to the ISS in 2019, to protect against Commercial Crew program delays or contractor problems in certification. The program has also identified the ability of NASA and its contractors to meet crew safety requirements as one of its top risks. Program officials told us their main focus is to work with the contractors to ensure that the spacecraft designs are robust from a safety perspective.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



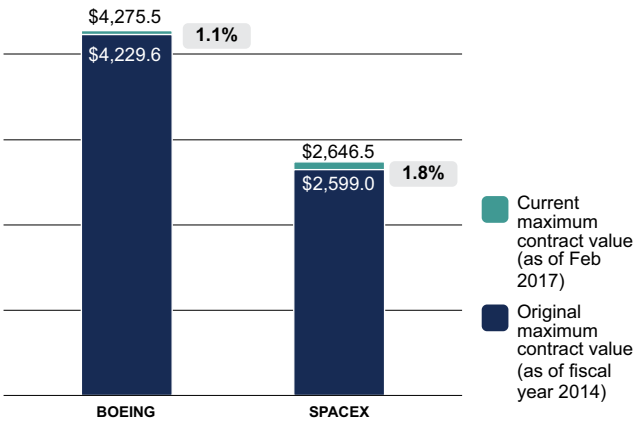
TOTAL NEEDED TO BE FUNDED[b]

then-year dollars in millions

[b]Includes costs to fund the contracts.

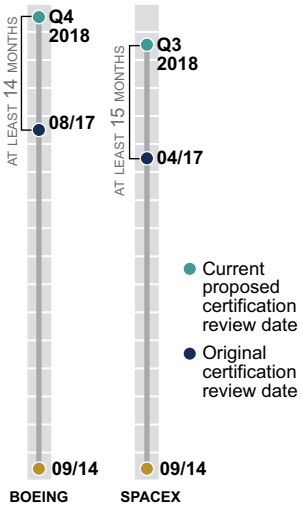
COST PERFORMANCE[c]

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 have aggressive development schedules that are increasingly under pressure. The contractors were originally required to provide NASA all the evidence it needed to certify that their systems met its requirements by 2017. In February 2017, we reported neither Boeing nor SpaceX can meet their original certification dates and both now expect certification to be delayed until 2018.[a] Boeing has proposed moving its certification review out to the fourth quarter of 2018—at least 14 months later than initially planned. SpaceX has moved its certification review to the third quarter of 2018—at least 15 months later than initially planned. The Commercial Crew Program is tracking risks that both contractors could experience additional schedule delays and its own analysis indicates that certification is likely to slip into 2019. NASA currently relies on the Russian space agency to transport astronauts to the ISS. In February 2017, NASA reached an agreement with Boeing giving NASA the option of acquiring crew transportation from Boeing on Russian Soyuz flights in 2019, to protect against Commercial Crew program delays or problems in certification.

NASA has also made changes to the contracts that have increased their value. While the contracts are firm-fixed-price, their values can increase if NASA adds to the scope of the work or otherwise changes requirements. As of January 2017, the value of the design, development, and test portion of the contracts had increased by $47 million and $91 million, respectively for Boeing and SpaceX. According to a program official, these contract increases were covered by program cost reserves.

Other Issues to Be Monitored

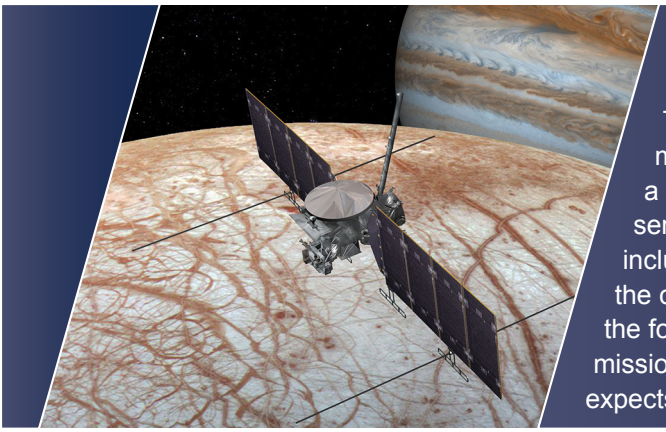
In addition to Boeing and SpaceX's schedule challenges, both contractors face other risks that will need to be addressed to support their certification. The Commercial Crew Program's top programmatic and safety risks for Boeing are, in part, related to having adequate information on certain systems, including its launch vehicle's main engine, to support certification. The Commercial Crew Program's top programmatic and safety risks for SpaceX are, in part, related to ongoing launch vehicle design and development efforts, including changes that could result from a September 2016 pre-launch mishap.

The Commercial Crew Program has identified the ability of it and its contractors to meet crew safety requirements as one of its top risks. NASA established the "loss of crew" metric as a way to measure the safety of a crew transportation system. The metric captures 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 their main focus is to work with the contractors to ensure that the spacecraft designs are robust from a safety perspective. For example, the program has identified the spacecrafts' ability to tolerate the micrometeoroid and orbital debris environment as the most significant driver of the loss of crew metric. Both contractors have lowered this risk through testing, which provides insight into how well their systems perform in these environments, and by making design changes. If the contractors have to make future design changes to improve their spacecraft's performance in this environment, certification could be further delayed.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, Commercial Crew Program officials stated that the assessment adequately represents the program's current status. The officials emphasized that competition is essential to achieving a safe and productive program and that having at least two companies developing disparate crew transportation systems provides benefits in redundancy, innovation, and cost effectiveness. Further, the officials noted that the Commercial Crew Program was not funded at the levels in the President's Budget request during fiscal years 2011-2015, which were critical years for design and development; adequate, timely funding remains essential to ensuring successful program performance. Finally, the Commercial Crew Program continues to support the crew transportation development activities of Blue Origin and Sierra Nevada Corporation through Space Act Agreements. Program officials also provided technical comments, which were incorporated as appropriate.

[a]GAO, *NASA Commercial Crew Program: Schedule Pressure Increases as Contractors Delay Key Events,* GAO-17-137 (Washington, D.C.: Feb. 16, 2017).



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 expects to manage as a separate project.

Source: Europa Project Personnel, California Institute of Technology, Jet Propulsion Laboratory. | GAO-17-303SP

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: **2010 Decadal Survey**

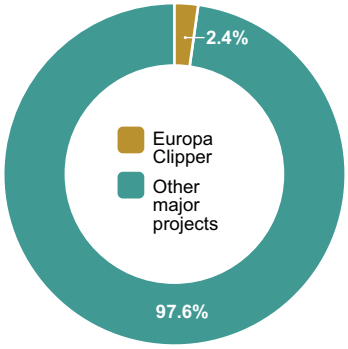
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The Europa Clipper project entered the preliminary design and technology completion phase in February 2017 and updated its preliminary cost and schedule estimates. Payload and spacecraft costs have increased, but the high end of the project's cost range did not change. The project's scope has also grown. At the project's most recent decision review, its independent review board stated that it was at risk of exceeding its preliminary cost and schedule ranges unless its scope or complexity was reduced. Growth in the mass of and power needed to operate the Europa Clipper and its instruments, as well as Jupiter's harsh radiation environment, also pose challenges for the project. The Consolidated Appropriations Act, 2016 requires the project to use NASA's Space Launch System (SLS) and to plan for a 2022 launch, which could pose risks. SLS is still in development and may not have its initial launch until November 2018 or later. Project officials said the project needs to select a launch vehicle by the end of 2018 to maintain a 2022 launch date.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

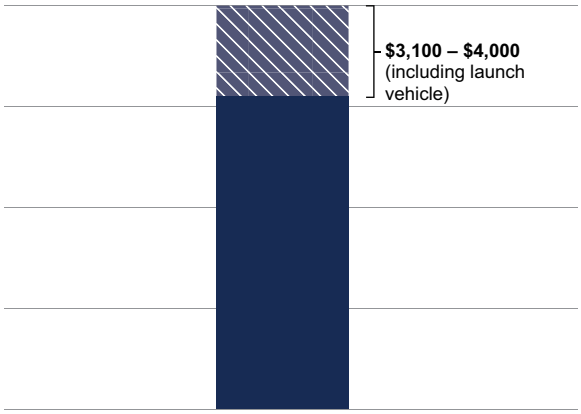


TOTAL FUNDED TO DATE

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. 2017

Cost and Schedule Status

The Europa Clipper project entered the preliminary design and technology completion phase in February 2017 and updated its preliminary cost and schedule estimates. Payload and spacecraft costs have increased, but the high end of the project's cost range did not change. The project's scope has also grown. NASA added two new project requirements—the capability to serve as communication relay for a lander and investigate plumes emitted from Europa's surface. At the project's most recent decision review, its independent review board stated that the project was at risk of exceeding its preliminary cost and schedule ranges unless its scope or complexity was reduced. The board recommended that the project identify potential instruments and science requirements that could be removed or reduced for the payload, which the project plans to do prior to entering implementation in 2018.

Technology and Design

Growth in the mass and power needed to operate the Europa Clipper and its instruments poses a continuing challenge for the project. NASA selected 10 instruments for the mission—2 more than initially planned. Several of these instruments, including a mapping spectrometer and ice-penetrating radar, experienced mass and power growth and cost increases after being selected. Spacecraft costs also increased to accommodate the growth. For example, the project added two panels to its solar arrays to increase power, although it is working to reduce its power needs. The project plans to establish mass and power caps for each instrument and the spacecraft to mitigate these issues going forward.

The radiation environment around Jupiter poses one of the biggest technical challenges for the project. The project is working to reduce or better understand the negative effects of radiation—such as diminished performance and loss of science data—by hardening its technologies and testing materials and parts, among other actions. The project is considering adding more shielding to the vault that will protect its electronics, but doing so would increase mass.

Launch

According to the Europa Clipper project, its top risk involves availability of a qualified and well-understood launch vehicle. The Consolidated Appropriations Act, 2016 requires the project to use NASA's SLS. However, SLS is in development and will not have its initial launch until November 2018 or later. The Europa Clipper project plans to hold its preliminary design review in August 2018, at which point projects prefer to select a launch vehicle. The project plans to maintain compatibility with the Delta IV Heavy, Falcon Heavy, and SLS launch vehicles, until at least this review. Project officials have also stated that the project needs to select a launch vehicle by the end of 2018 to maintain a 2022 launch date.

Funding

The Europa Clipper project has been working to a target launch date in 2022 that has not been supported by NASA's budget plans to date. For fiscal year 2017, the project needs approximately $215 million to maintain the 2022 launch date, but NASA only requested $49.6 million. The Consolidated Appropriations Act, 2016 required that NASA plan for a launch no later than 2022, and include the 5-year funding profile in its fiscal year 2017 budget necessary to achieve this and other goals. In February 2017, NASA officials signed a decision memorandum for the project that included a funding profile supporting a 2022 launch, but the agency has not yet released its fiscal year 2018 budget plan requesting these amounts.

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, Crawler Transporter, Vehicle Assembly Building, and launch pad, all of which need to be complete before the first uncrewed exploration mission (EM-1) using the SLS and Orion vehicles.

Source: NASA. | GAO-17-303SP (Note: Vehicle Assembly Building pictured above.)

FORMULATION

- **02/12** Formulation start
- **08/12** System requirements/ mission definition review
- **03/14** Preliminary design review
- **05/14** Project confirmation

IMPLEMENTATION

- **12/15** Critical design review
- **01/17** **GAO review**
- **05/17** System integration review
- **11/18** Committed launch readiness date

PROJECT INFORMATION

NASA Lead Center: **Kennedy Space Flight Center**

International Partner: **None**

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

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

Mission Duration: **2 years**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

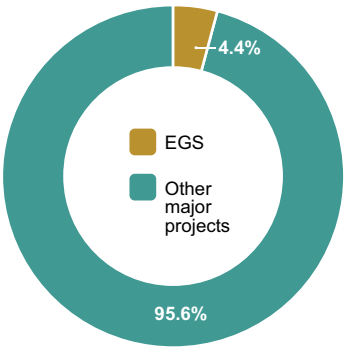
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The EGS program's schedule is deteriorating and it is at increased risk of exceeding its cost baseline and missing its November 2018 launch readiness date. The program has completed several of its projects, but it continues to experience technical challenges and delays and has limited cost and schedule reserves remaining to address them. The EGS program has used 5 months of reserve in the past year, and as of February 2017, it had 1 month of schedule reserve remaining. According to program officials, this reserve is being held for the program's integrated test period with SLS and Orion. As a result, the EGS program has no reserves left to address any issues or challenges associated with its own development or integration and test phase. Program officials said NASA management continues to work to mitigate the risk. The program is tracking schedule risks for the Mobile Launcher and one of its two major software development efforts.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

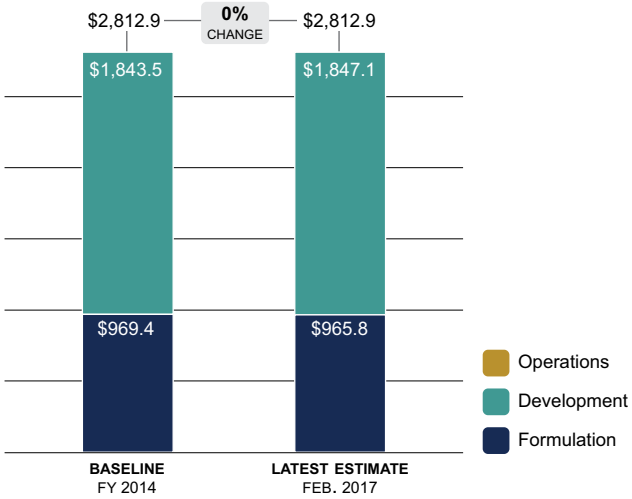


TOTAL NEEDED TO BE FUNDED

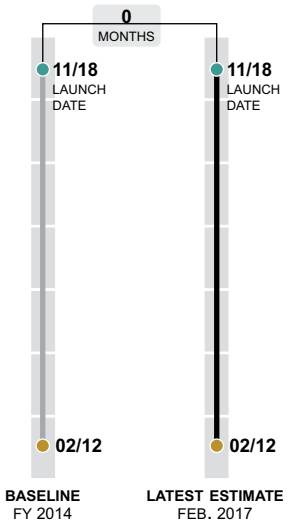
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The EGS program's schedule is deteriorating and it is at increased risk of exceeding its cost baseline and missing its November 2018 launch readiness date. The program has experienced multiple technical challenges and delays and has limited cost and schedule reserves remaining to address issues as they arise. It has used 5 months of schedule reserve over the past year and, as of February 2017, it had 1 month of schedule reserve remaining. According to program officials, this reserve is being held for the program's integrated test period with SLS and Orion. As a result, the EGS program has no reserves left to address any issues or challenges associated with its own development or integration and test phase. Program officials said NASA management continues to work to mitigate the risk. The program's schedule is also being revisited. Program officials stated they are working with NASA to conduct a schedule analysis for the Orion, SLS, and EGS programs that takes into account the 7-month continuing budget resolution for fiscal year 2017, a delay in the delivery of a key piece of the Orion spacecraft to Kennedy Space Center for integration and testing, and continued EGS technical challenges, among other issues. According to senior NASA officials, this analysis is likely to lead to a delay in the planned EM-1 launch date.

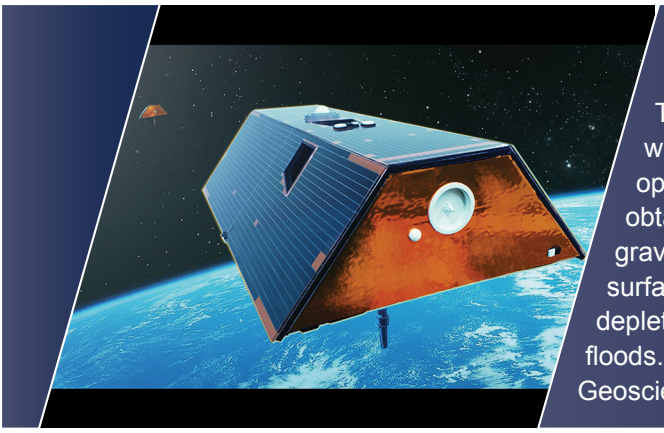
Design and Technical

The EGS program has completed several projects, including the Crawler Transporter and Launch Vehicle Offline Processing facility, but technical challenges and delays with the remaining work could put the overall schedule at risk. The Mobile Launcher—which supports the assembly, testing, and servicing of the SLS rocket and provides the platform on which SLS and Orion will launch—has experienced multiple technical challenges and delays. For example, in last year's assessment, we reported that there were design issues with a connection between the Mobile Launcher and SLS. According to EGS program officials, these issues are still being resolved. The program is also tracking several schedule risks related to launch equipment testing, ground support equipment installation, and analysis and testing of the Mobile Launcher. The EGS program does not have any reserves to accommodate further Mobile Launcher delays, and program officials stated that they have nearly exhausted other options to stay on schedule, such as adding extra shifts.

The EGS program has also experienced delays with the development and testing of one of its two main software efforts. The Ground Flight Application Software (GFAS)—software that will interface with flight systems and ground crews—continues to face challenges due to delays in the other main EGS software effort and late deliveries from the SLS and Orion programs. Over half of the GFAS software releases have been delivered; however according to EGS program officials, some content has been deferred due in part to Orion and SLS software delays. Due to the ongoing delays, the program may complete GFAS development as late as August 2018—6 months later than previously planned. EGS officials said this delay will not interfere with integrated testing and operations with SLS and Orion because key parts of the software, such as the launch countdown capability, will not be needed until later in the integration process. The EGS program is still tracking a risk that GFAS may not be ready when needed and it has hired additional staff as part of its efforts to address this risk.

PROJECT OFFICE COMMENTS

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



Source: NASA/JPL Caltech. | GAO-17-303SP

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 remains in operation. 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).

FORMULATION

- **01/12** Formulation start
- **07/12** System requirements/ mission definition review
- **01/14** Preliminary design review
- **02/14** Project confirmation

IMPLEMENTATION

- **02/15** Critical design review
- **07/15** System integration review
- **01/17** GAO review
- **12/17 - 02/18** Manifested launch readiness date
- **02/18** Committed launch readiness date

PROJECT INFORMATION

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

Lead Center: **Jet Propulsion Laboratory**

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

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

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

Launch Vehicle: **Pegasus**

Launch Vehicle: **Falcon 9**

Mission Duration: **2 years**

Mission Duration: **5 years**

Requirement Derived from: **2013 - 2022 Decadal Survey for Solar Physics**

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

Budget Portfolio: **Science, Heliophysics**

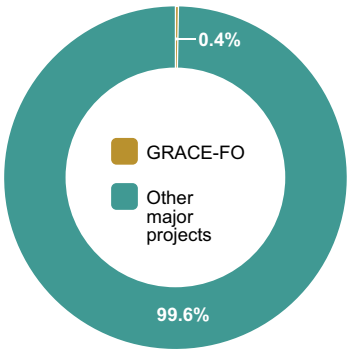
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The GRACE-FO project has successfully integrated both of its spacecraft and plans to launch by its February 2018 committed launch date despite a late change to its launch vehicle and launch site. In February 2016, the Russian Federal Space Agency notified GFZ that the Dnepr launch vehicle, which is manufactured by a Russian firm in conjunction with a Ukrainian firm, was no longer available for GRACE-FO due to Russian restrictions on Ukrainian personnel accessing the launch site. The project now plans to launch on a SpaceX Falcon 9 with commercial satellites in a shared ride arrangement. The launch vehicle change resulted in at least a 4-month delay in the project's planned launch, but the project has adequate cost reserves to cover the cost of the delay. The project told us that they plan to use the extra time in the schedule to conduct additional risk reduction activities.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

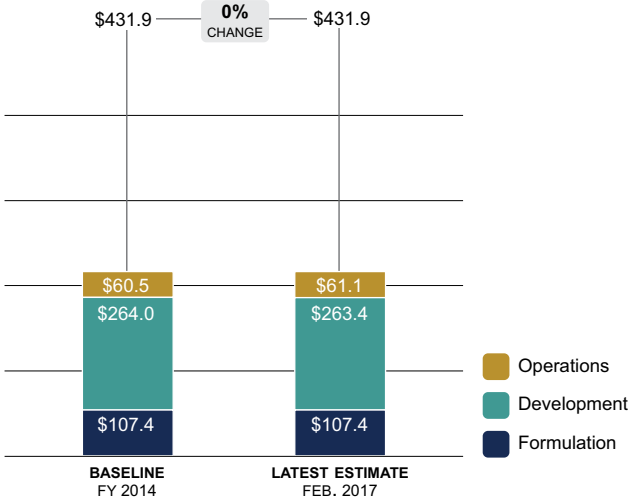


TOTAL NEEDED TO BE FUNDED

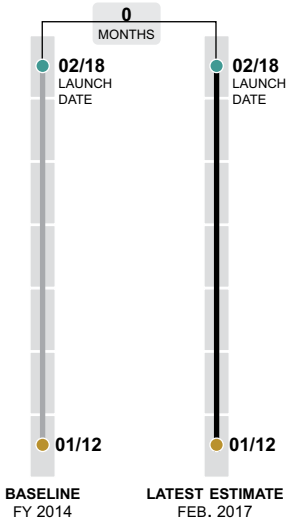
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The GRACE-FO project plans to launch by its committed February 2018 launch date despite a late change to its launch vehicle and launch site. The launch vehicle change resulted in at least a 4-month delay in the project's planned launch. The project has adequate reserves to cover the cost of the delay.

Launch and Developmental Partner

The GRACE-FO project has delayed its launch readiness date by at least 4 months, from August 2017 to December 2017, due to issues with its planned launch vehicle and launch site. The launch vehicle is the responsibility of NASA's partner on the project—GFZ. In February 2016, the Russian Federal Space Agency notified GFZ that the Dnepr launch vehicle was no longer available for GRACE-FO due to Russian restrictions on launch site access by Ukrainian personnel who provided support for the launch vehicle. As a result, GFZ entered into a shared ride agreement with Iridium Communications Inc. to launch the two GRACE-FO spacecraft, along with five Iridium satellites, on a Falcon 9 from Vandenberg Air Force Base in California. GFZ also signed a contract with Airbus Defence and Space to provide launch service management and develop a new multi-satellite dispenser. The multi-satellite dispenser, which project officials told us is different from the one planned for use with the Dnepr, releases the satellites at the right time into the correct orbit.

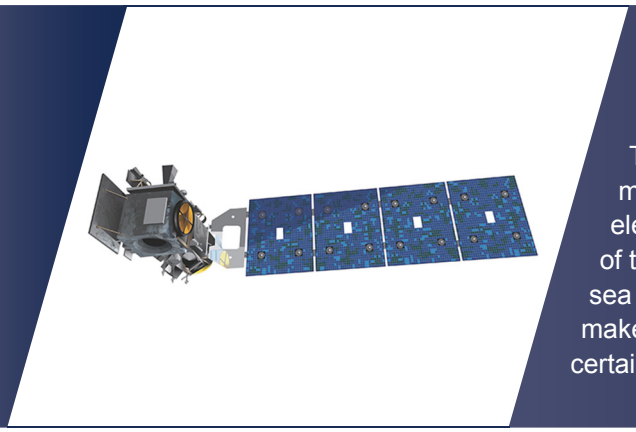
GRACE-FO officials told us that they are aiming to prevent any significant design changes to its spacecraft because of the late launch vehicle change. Project officials only anticipate minor design changes, such as how the spacecraft attaches to the multi-satellite dispenser. The project is coordinating with GFZ to determine if the project needs to conduct any additional risk mitigation activities or environmental testing because of the launch vehicle and satellite dispenser changes.

Integration and Test

The GRACE-FO project has finished building both spacecraft and has remained on schedule with its integration and testing activities. The project expects to begin integrated system testing on both spacecraft in January 2017. The project said they plan to use the extra time in the schedule due to the launch delays to conduct additional risk reduction activities during system-level integration and test.

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. The 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: Orbital Sciences Corporation. | GAO-17-303SP

FORMULATION

- 12/09 Formulation start
- 05/11 System requirements/ mission definition review
- 10/12 Preliminary design review
- 12/12 Project confirmation

IMPLEMENTATION

- 02/14 Critical design review
- 05/14 Project rebaseline
- 01/17 GAO review
- TBD System integration review
- 06/18 Committed launch readiness date
- 09/18 Manifested launch readiness date

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: **2003 Decadal Survey, 2013 Decadal Survey in Solar Space Physics**

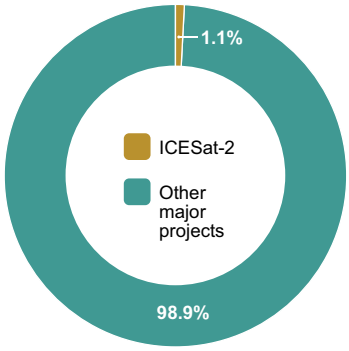
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The ICESat-2 project has encountered problems with the flight lasers in its sole instrument—the Advanced Topographic Laser Altimeter System (ATLAS)—that will likely cause it to miss its committed launch date and could cause it to exceed its current cost baseline. The project was previously rebaselined in 2014 because of ATLAS-related development and design issues. During ATLAS environmental testing in July 2016, the project observed a cracked crystal within the laser optical module, and it is now working to repair the lasers. A spare laser encountered the same problem during earlier testing, which indicates a systemic problem. The instrument carries two flight lasers and one must be working for the mission to succeed. Due primarily to the laser problems, the project now plans to launch no earlier than September 2018, which is 11 months later than its previously planned October 2017 launch date, and 3 months later than its committed launch date. The project plans to complete the laser repair in parallel with system-level integration and testing in an effort to mitigate the effect of the delays.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

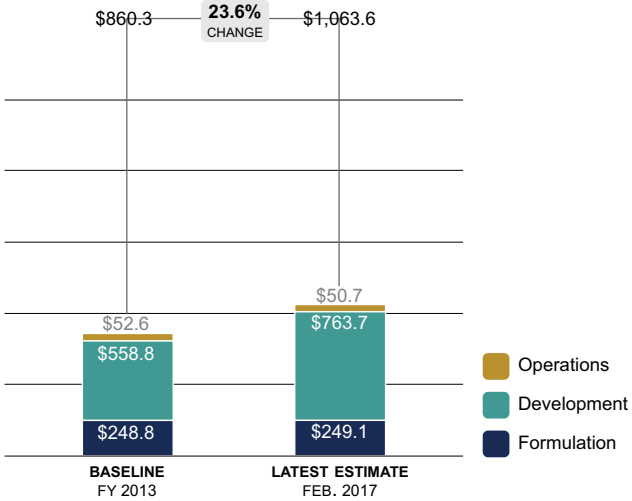


TOTAL NEEDED TO BE FUNDED

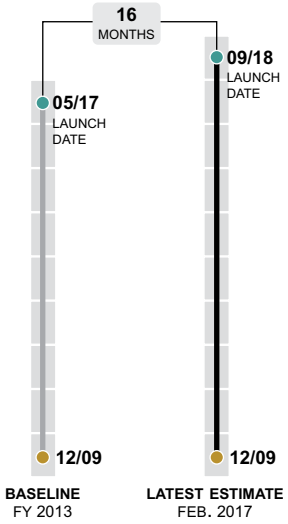
then-year dollars in millions

COST PERFORMANCE[a]

then-year dollars in millions



SCHEDULE PERFORMANCE[a]



[a]The ICESat-2 project expects to experience additional cost growth and schedule delays, and was re-evaluating their cost and schedule at the time of our review.

Cost and Schedule Status

The ICESat-2 project is likely to miss its committed launch date and could exceed its current cost baseline. During environmental testing for the project's only instrument—the Advanced Topographic Laser Altimeter System (ATLAS)—in July 2016, it experienced a problem with a flight laser that required repairs and led to significant schedule delays. Due primarily to the laser problems, the project now plans to launch no earlier than September 2018, which is 11 months later than its previously planned October 2017 launch date, and 3 months later than the committed launch date in its 2014 baseline. The project was rebaselined in 2014, at which time its estimated costs increased by $203 million and its launch date was delayed by 13 months. According to project officials, the project will spend about $8 million per month for each month past its previously planned October 2017 launch; this includes penalties NASA must pay to the launch provider. For example, if the project launches in September 2018, its estimated cost would increase by about $88 million, which would exhaust all the cost reserves for the project. The project is currently re-evaluating its cost and schedule and expects to complete that process in spring 2017.

Technical and Design

The ICESat-2 project has continued to experience technical and design issues with the ATLAS instrument, which has posed challenges since the beginning of the project. The project is investigating an anomaly in one of its two flight lasers that occurred during environmental testing in July 2016. The project observed a cracked crystal within the laser optical module, removed the laser from ATLAS, and shipped it to the manufacturer's facility for investigation and repair. The manufacturer determined the primary cause of the anomaly was a flaw in the design of the mount that ensures a component of the optical module remains in a specific, precise position. The spare flight laser encountered the same problem during earlier testing, which indicates a systemic problem. The project has encountered other problems with the lasers in the past. For example, the project conducted additional testing in 2016 to mitigate a risk that a crystal in the each of ATLAS's two lasers may become de-bonded from its mount, which would result in loss of laser function. ICESat-2 only needs one laser for mission success, but will carry two for redundancy. According to officials, it could take at least 8 to 10 months to repair, reintegrate, and realign the two ATLAS flight lasers to address the most recent issues, which will likely cause the project to miss its committed launch date.

Integration and Test

The ICESat-2 project has taken steps in integration and testing to try to mitigate the flight laser delays. The project shipped ATLAS to Orbital ATK in October 2016 for system-level integration and testing with one flight laser and a model that replicates the weight of a second laser, so that testing could continue while the other lasers are repaired. The project will conduct additional testing after the repaired lasers are delivered, which is currently planned for August 2017.

Launch

The ICESat-2 launch delays could also pose challenges related to its launch vehicle. According to NASA and project officials, ICESat-2 will be the last flight of United Launch Alliance's (ULA) Delta II vehicle. NASA officials said staff retention could be a concern because ULA may need to reassign staff to other areas while the project resolves the ongoing laser issues. The ICESat-2 Delta II is already built and ULA will place it in storage. In addition, project officials said the project will incur a $2 million penalty each month the launch is delayed past the previously planned October 2017 launch.

PROJECT OFFICE COMMENTS

ICESat-2 project officials provided technical comments on a draft of this assessment, which were incorporated as appropriate.

Source: © California Institute of Technology. | GAO-17-303SP

Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport Project

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.

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**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

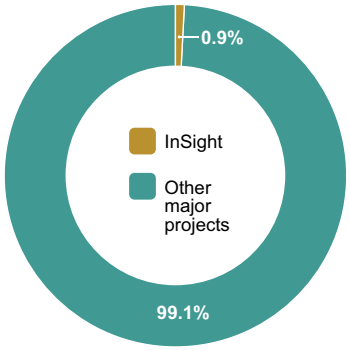
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The InSight project missed its committed launch date of March 2016 and exceeded its cost baseline due to technical issues with its primary science payload—the Seismic Experiment for Interior Structure (SEIS) instrument—which is contributed by the French space agency (CNES). NASA delayed the InSight launch by 26 months to May 2018, which is the next available planetary launch window, and increased the project's estimated cost by almost $154 million. Due to the earlier problems, NASA has taken over design and fabrication of the SEIS container from CNES. The SEIS container had to be redesigned to hold a vacuum, which is required for the instrument to perform properly. The project plans to deliver the rebuilt SEIS to system-level integration and test in June 2017. The project has used the additional time from the delays to mitigate other project risks, such as addressing anomalies identified late in testing on its other instrument—the German-contributed Heat Flow and Physical Properties Probe, which drills into the Martian surface to collect temperature data.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

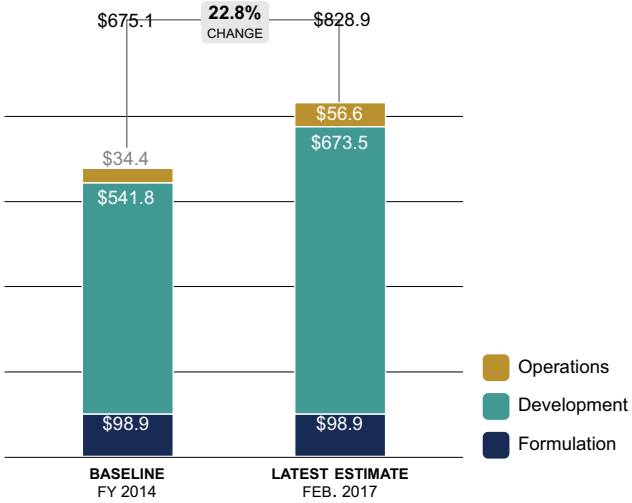


TOTAL NEEDED TO BE FUNDED

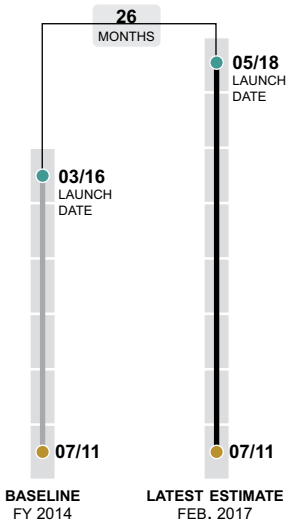
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The InSight project missed its committed launch date of March 2016 and exceeded its development cost baseline due to technical issues with the Seismic Experiment for Interior Structure (SEIS) instrument, the project's primary science instrument. In August 2016, NASA approved the project's replan—a process initiated if development costs increase by 15 percent or more and requires a report to congressional committees. NASA delayed the InSight launch by 26 months to May 2018, which is the next available planetary launch window, and increased the project's total estimated cost by almost $154 million, or almost 23 percent. The development cost increases are primarily due to having to recomplete system-level assembly, test, and launch operations activities. The project has also increased its operations cost estimate by $22 million as it has gained a better understanding of what it will take to safely deploy InSight's instruments on the ground with less risk.

Design and Developmental Partner

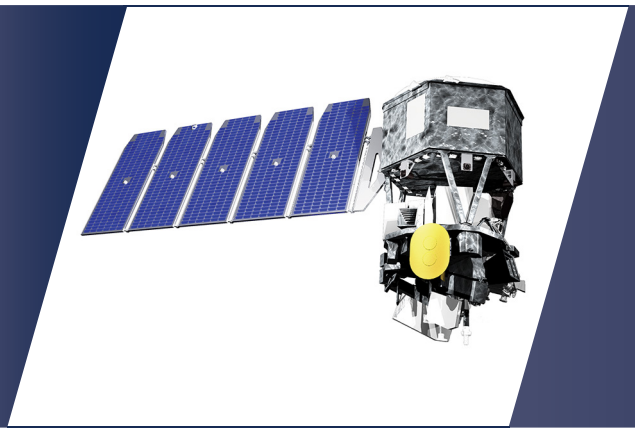
NASA has redesigned the SEIS container to address the technical issues that caused the launch delays. Prior to its planned March 2016 launch, the InSight project experienced vacuum seal leaks in the SEIS container, which prevented it from properly sealing and holding a vacuum. A seal is required for the instrument to perform properly. The SEIS, a seismometer contributed by the Centre National d'Etudes Spatiales (CNES), is critical for meeting three of the project's six top-level science requirements. Project analysis indicated the failure was related to a feedthrough leak. Feedthroughs provide a leak-free path for the wiring that connects the SEIS to the spacecraft computer. The project selected a new feedthrough vendor in September 2016 and received and tested the flight parts in December 2016, which resulted in a container delivery two months later than planned. The project adjusted its schedule to accommodate the delay, and plans to deliver the integrated SEIS to system-level integration and test in June 2017. The SEIS schedule remains one of the project's top risks.

After the launch delay, NASA and CNES redefined their roles and responsibilities with regard to the SEIS. CNES is responsible for integration and test of the flight SEIS instrument, but NASA has taken over the design, testing, and development of the SEIS container. In addition, CNES reduced the role of the contractor that had been responsible for the container. According to project officials, CNES and NASA will provide on-site support to the contractor for its remaining SEIS work because, in addition to the container failure, it had previously experienced development delays and quality assurance issues that could have caused contamination of flight hardware.

The InSight project has used the additional development time it gained from the launch delay to mitigate other project risks. For example, the Heat Flow and Physical Properties Probe (HP3)—a contributed instrument from the German Aerospace Center (DLR) that drills into the Martian surface to take temperature measurements—experienced anomalies late in testing when the hammering mechanism damaged internal wiring. The project redesigned the internal wiring and started to fabricate and integrate the new HP3 in January 2017. If the redesigned HP3 demonstrates improved robustness during life tests, the project will use it for the mission. The project has also identified operational workarounds to minimize the effects of the anomaly if it occurs again.

PROJECT OFFICE COMMENTS

InSight project officials were provided a draft of this assessment and did not have any comments.



Source: University of California, Berkeley. | GAO-17-303SP

PROJECT INFORMATION

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

International Partner: **None**

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

Launch Vehicle: **Pegasus**

Mission Duration: **2 years**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

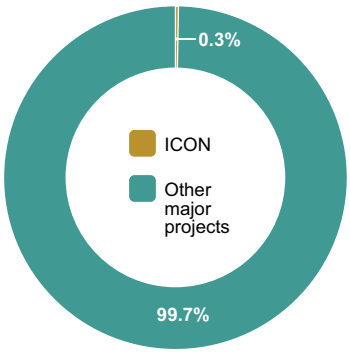
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The ICON project has experienced technical issues and delays in system integration and testing, but it still on track to launch in July 2017—3 months earlier than its committed launch date. The most significant delay occurred when a primary component of the spacecraft's electronics control system failed during system-level testing. The project delayed system-level testing activities by about 3 months, while it made design changes to the failed part and retested it. The project delays led to scheduling conflicts at the contractor's test facility. The contractor was able to move testing to an alternate location, which helped prevent additional delays. The project plans to complete system-level integration and testing in April 2017 and ship the spacecraft for launch by May 2017.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

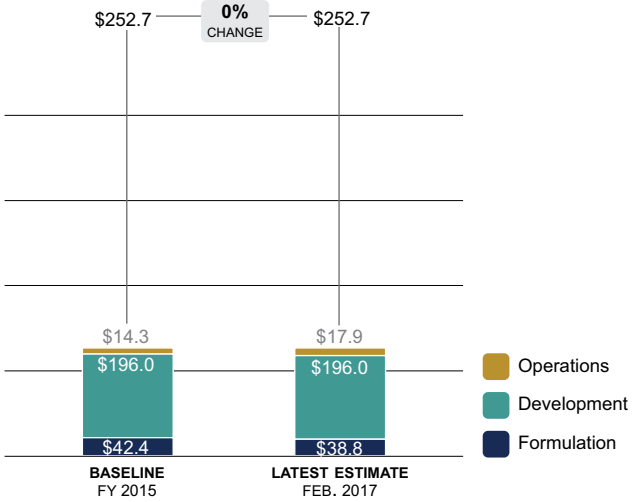


TOTAL NEEDED TO BE FUNDED

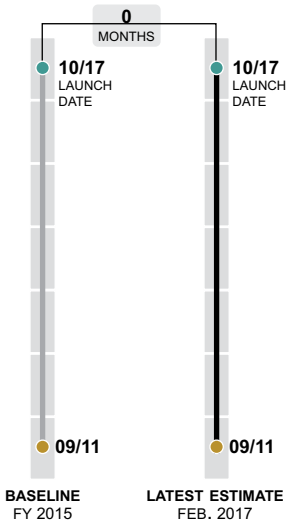
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The ICON project plans to launch in July 2017—3 months earlier than its committed launch date. The project held its system integration review and entered the assembly, integration, and test phase in August 2016. The project plans to complete system-level integration and testing in April 2017 and ship the spacecraft for launch no earlier than May 2017. The project is holding cost and schedule reserves consistent with the level required by NASA center policy.

Integration and Test

The ICON project discovered a design issue in system-level integration and testing that has caused delays, but has not affected the project's planned launch date. Part of the spacecraft's electronics control system experienced a failure during its first system-level performance test. Specifically, the electronics control system's actuator board failed, due to a design error, and was damaged. To resolve the issue, the project modified the design and produced a replacement board. To minimize the effect on the schedule, the project used an engineering model to continue testing during the 4 months it took to address the issue. In January 2017, the electronics control system was shipped back to the contractor test facility to be reintegrated with the spacecraft and tested. The project planned to have all system-level testing complete in January 2017, but the electronics failure delayed the completion of testing by 3 months to April 2017. This delay, in part, led to contractor test facility conflicts with other programs and forced the project to move testing to an alternate location, which helped prevent further delays.

The ICON project experienced other technical issues with its spacecraft and payload in 2016, but had sufficient cost and schedule reserves to address them. For example, the project encountered prior technical problems with the electronics control system during spacecraft integration and test. The issue was isolated to a specific module and only occurred when the unit reached certain temperatures. The project used 30 days of schedule reserve to test other components to reproduce the event and determined the configuration of its ground support equipment was the cause.

In addition to maintaining adequate levels of reserves to address issues when they arose, the ICON project took steps to reduce integration-related risks by identifying potential challenges early. To do so, the project built full-scale, high-fidelity models of every payload component including the payload interface plate. The project used the model to route harnesses, determine accessibility to instruments, design flight blankets, and determine the integration sequence prior to receiving the flight hardware. According to project officials, the models were worth the investment because they saved time and money by retiring integration risks.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, ICON project officials reported the project continues to progress toward the end of system-level testing, and the ground segment has completed its first operational readiness test. Project officials also said there are no known technical risks at this time on the spacecraft, payload, or ground segment and that sufficient reserves exist to achieve its planned launch date. The project recently moved its planned launch date from June to July 2017 due to a delay in the delivery of two of the three segments of the Pegasus launch vehicle. 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-17-303SP

PROJECT INFORMATION

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

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

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

Location: **Kourou, French Guiana**

Launch Vehicle: **Pegasus**

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

Requirement Derived from: **2001 - 2022 Decadal Survey in Astrophysics**

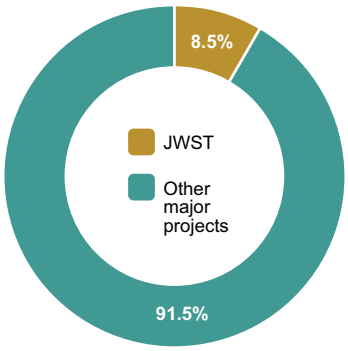
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

The JWST project is on track for its planned October 2018 launch, but it still must complete a series of challenging integration and test activities. The project is holding schedule reserves above NASA center requirements, but it must complete three of five major integration and test efforts, one of which has not yet begun. Integration and test is when problems are often identified and schedules tend to slip. The project is also facing cost pressures, due to cost increases on the observatory development and integration contract with Northrop Grumman. The contractor has maintained a larger workforce than planned in order to address technical issues while minimizing impacts to the project's schedule. In July 2016, the contractor submitted a proposal to NASA for the cost overruns. The project is currently evaluating the proposal, including its effect, if any, on project costs; it does not expect to conclude negotiations before early 2017.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

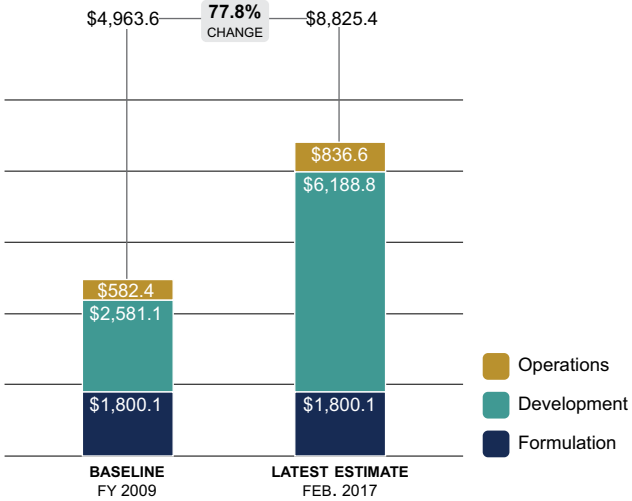


TOTAL NEEDED TO BE FUNDED

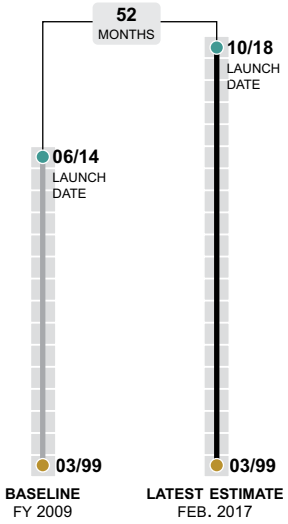
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The JWST project continues to operate within its 2011 cost and schedule baseline. The project has used about 9 months of the 14 months of schedule reserve established in its 2011 replan, including about 1 month in early 2017 to address technical challenges. The project's remaining schedule reserves are at the level required by NASA's Goddard Space Flight Center. The project will likely have to use some of its cost reserves to cover cost overruns on its observatory development and integration contract, but it is still negotiating the magnitude of the increase.

Integration and Test

The JWST project is currently in its riskiest phase of development—integration and test. Some integration and test activities have taken longer than planned and the project has had to use schedule reserves to keep the overall schedule on track. In 2016, the project completed two of five major integration and test efforts for the instrument module and telescope. Two other efforts—integrating the telescope and instrument module together and integrating the spacecraft—are underway. In early 2017, the project used over 1 month of schedule reserves to address test anomalies on the telescope and instrument module element and to replace spacecraft propulsion system components that were damaged during testing. The final integration and test effort, which involves the entire observatory, is scheduled to begin in fall 2017.

In December 2016, we found that as integration and testing moves forward, the project will need to be able to reduce a significant amount of risk in a timely manner to stay on schedule.[a] Many of these risks relate to the project's numerous deployments, such as the unfolding of the sunshield, or the over 100 single point failures, which, if they occur, could threaten the mission.

Contractor

In December 2016, we found that the primary threat to the JWST project continues to be the ability of the observatory development and integration contractor, Northrop Grumman, to control its costs.[b] The contractor has continued to maintain a larger workforce than planned in order to address technical issues while minimizing impacts to the project's schedule. Based on its projections at the beginning of the fiscal year, Northrop Grumman exceeded its monthly workforce projections for fiscal year 2016 by about 37 percent. In July 2016, the contractor submitted a proposal to NASA for the agency to cover the cost overruns, which was the first such proposal since the project's replan in 2011. The project is currently evaluating the proposal, including the effect on its cost reserves, and does not expect to conclude negotiations before early 2017.

Launch

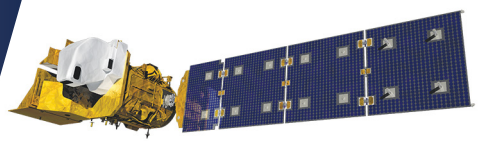
The JWST project has been working with its launch vehicle provider to expand its potential launch window in the event the project experiences delays. According to program officials, prior mass reduction efforts have made the observatory lighter and resulted in more flexibility in launch dates. At its former expected mass, JWST could not launch for a period before and after the solstices, due to its planned trajectory and its relationship to the moon. If the project missed its planned October 2018 launch date, it would have had to wait until February 2019 for another opportunity.

PROJECT OFFICE COMMENTS

JWST project officials were provided a draft of this assessment and did not have any comments.

[a]GAO, *James Webb Space Telescope: Project Meeting Cost and Schedule Commitments but Continues to Use Reserves to Address Challenges*, GAO-17-71 (Washington, D.C.: Dec. 7, 2016).

[b]GAO-17-71.



Landsat 9

Landsat 9 is the next satellite in the Landsat 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 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-17-303SP

PROJECT INFORMATION

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

International Partner: **None**

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

Launch Vehicle: **TBD**

Mission Duration: **5 years**

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

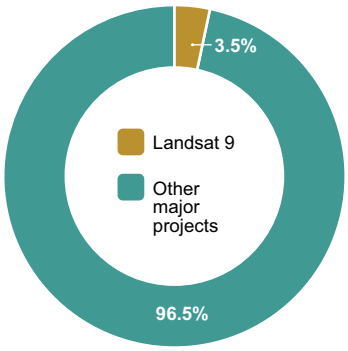
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The Landsat 9 project is on track to begin implementation in October 2017 with a low level of technology risk, but an ambitious schedule. Due to direction in the Explanatory Statement accompanying the Consolidated Appropriations Act, 2016, the project is working to an accelerated launch readiness date of December 2020, which is about 3 years earlier than originally planned. According to officials, the earlier launch date will help ensure that the Landsat program is able to maintain two satellites on orbit simultaneously, which is a goal of the scientific community. The project stated that this schedule is aggressive, but plausible because of the high use of heritage technologies, mature instrument designs, and the extensive use of hardware from the prior land data continuity mission, Landsat 8. Landsat 9 will use the same two primary instruments as Landsat 8; however, the project plans to make several design changes to its Thermal Infrared Sensor 2 (TIRS-2) instrument to improve its reliability and performance. The project plans to hold its confirmation review in October 2017, at which point it will establish its cost and schedule baseline.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



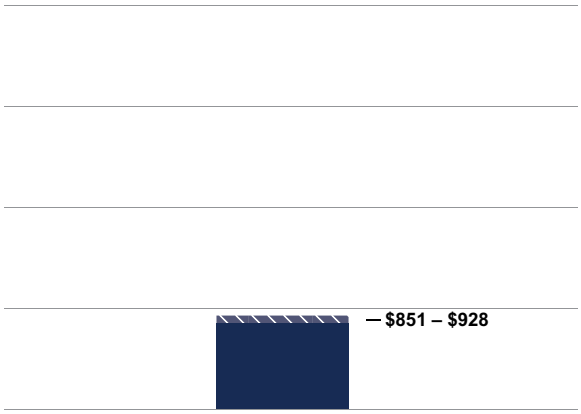
TOTAL FUNDED TO DATE

then-year dollars in millions

$116.4

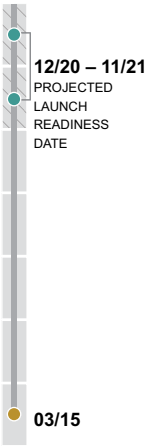
PRELIMINARY COST[a]

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. 2017

Cost and Schedule Status

The Landsat 9 project entered the preliminary design and technology completion phase in August 2016 with an ambitious schedule. Due to direction in the Explanatory Statement accompanying the Consolidated Appropriations Act, 2016, the Landsat 9 project is working to an accelerated launch readiness date of December 2020, which is about 3 years earlier than originally planned. According to officials, the earlier launch date will help ensure that the Landsat program is able to maintain two satellites on-orbit simultaneously, which is a goal of the scientific community, but not a requirement for the program. The project plans to hold its confirmation review in October 2017, at which point it will formally establish its cost and schedule baseline. If the project is baselined with a December 2020 launch readiness date, the project may move into implementation with less schedule reserves than required by NASA center policy. As a result, the program may have less time than recommended to address known and unknown risks.

Project officials consider the accelerated schedule aggressive, but plausible because of the high use of heritage technologies, mature instrument designs, and the extensive use of hardware from the prior land data continuity mission, Landsat 8. For example, the spacecraft development schedule is expected to be 8 months shorter than it was for Landsat 8, but according to the project, having more mature and stable requirements and interfaces helps mitigate this risk.

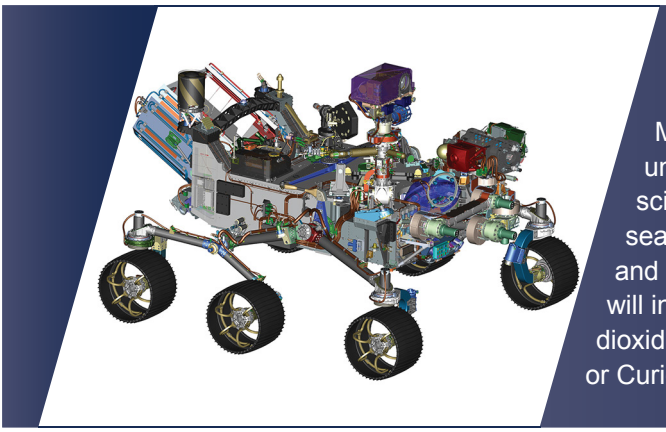
Technology and Design

The Landsat 9 project will enter implementation with mature technologies and stable instrument designs, which helps to minimize development risk. The design of Landsat 9 is largely based on Landsat 8 and uses existing or heritage technology. Utilizing heritage technologies and designs on projects can help to reduce risk and control costs when they are used for similar purposes in similar environments. The project has two primary instruments—the Operational Land Imager 2 (OLI-2) and the Thermal Infrared Sensor 2 (TIRS-2). The OLI-2 instrument is being built to the same design and by the same contractor used for Landsat 8, but at a lower cost. According to project officials, the cost for Ball Aerospace to build the OLI-2 instrument is approximately $76 million lower for Landsat 9. NASA plans to make several changes to the TIRS-2 instrument design, which will be built in-house at the Goddard Space Flight Center, to improve its reliability and performance. For example, the project added redundant electronics systems and survival heaters, improved telescopes, and better protection from orbital debris. The project expects to hold critical design reviews for both instruments by February 2017.

The project also plans to use spare flight hardware from Landsat 8, which provides cost, schedule, and technical benefits and poses risks. For example, the project identified and then mitigated a risk that the performance of the spare Landsat 8 focal plane modules for OLI-2 could have degraded in the interim, which would have affected mission performance. The project tested the spares and found that they met or exceeded Landsat 9 performance requirements.

PROJECT OFFICE COMMENTS

Landsat 9 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-17-303SP

FORMULATION

- **11/13** Formulation start
- **10/14** System requirements/ mission definition review
- **02/16** Preliminary design review
- **06/16** Project confirmation

IMPLEMENTATION

- **01/17** **GAO review**
- **02/17** Critical design review
- **11/17** System integration review
- **07/20** Committed launch readiness date

PROJECT INFORMATION

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

International Partners: **Centre National d'Etudes Spatiales (France), Centro de Astrobiologia (Spain), Norwegian Defence Research Establishment (Norway)**

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

Launch Vehicle: **Pegasus**

Launch Location: **Eastern Range, FL**

Mission Duration: **2 years**

Launch Vehicle: **Atlas V**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

Mission Duration: **2 years**

Requirement Derived from: **2011 National Research Council Decadal Survey**

Budget Portfolio: **Science, Heliophysics**

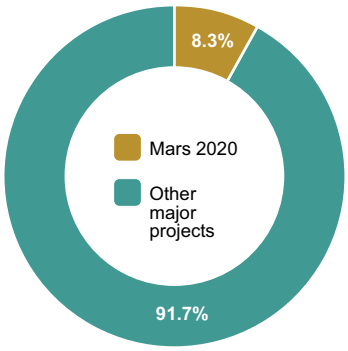
Budget Portfolio: **Science, Planetary Science**

PROJECT SUMMARY

The Mars 2020 project has not met key best practices for reducing product development risk, but it has set aside significant cost and schedule reserves to address its most challenging developments. The project held its preliminary and critical design reviews, in February 2016 and February 2017 respectively, with a lower level of technology and design knowledge than recommended by best practices. The project has since matured all but one of its technologies, but other technical challenges and design-related issues still pose cost and schedule risks. For example, according to the project, substantial technical challenges remain with one of the instruments that will be used to detect organic compounds and it may not be ready for integration as planned. Mass will also continue to be a risk. Finally, the project plans to conduct additional testing on its parachute design, which was previously used for the Mars Science Laboratory, and develop a strengthened parachute, after parachute test failures on an unrelated NASA project.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

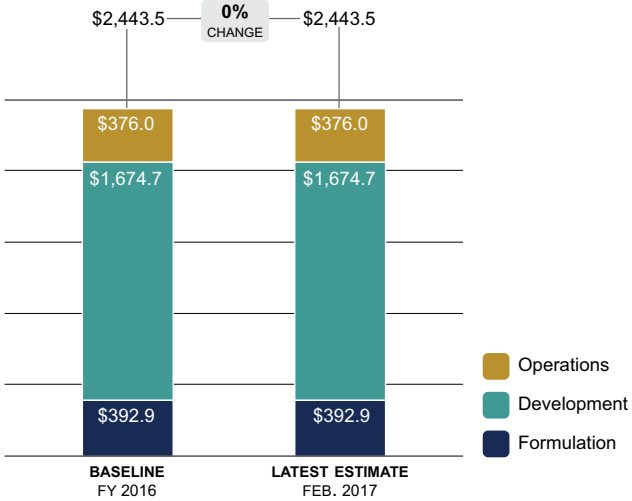


TOTAL NEEDED TO BE FUNDED

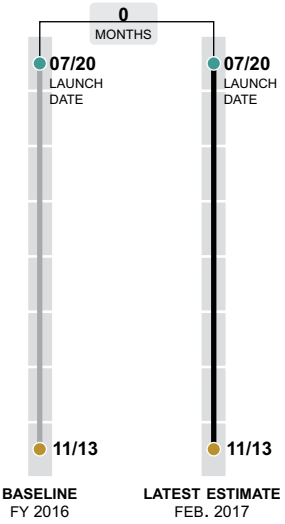
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The Mars 2020 project entered the implementation phase in June 2016 and formally established its cost and schedule baselines. The cost baseline is higher than the project's preliminary estimate range because contributions from outside the Science Mission Directorate, such as a technology demonstration designed to convert carbon dioxide into oxygen, were not included in earlier estimates. The project is holding cost and schedule reserves consistent with the level required by NASA center policy.

Technology

The Mars 2020 project entered implementation with a lower level of technology maturity than recommended by best practices, but most technologies have since matured. The project held its preliminary design review in February 2016 with two of its seven critical technologies and one of its two heritage technologies matured to technology readiness level 6. Maturing technologies to this level is a best practice, which helps minimize risks for space systems entering product development. A Mars 2020 project official said the project conducted the review with immature technologies to avoid delaying progress on other parts of the project. Schedule is a key driver for Mars 2020. If the project misses the 2020 launch window, it must wait 26 months before another launch opportunity is available. The project set aside a significant portion of its reserves to cover potential cost growth for its new and modified instruments, which would help mitigate remaining technology risk. As of January 2017, the project had not yet matured one technology—an improved sensor on the entry, descent, and landing instrument—but it could be replaced with a heritage sensor, if necessary.

The project has made progress addressing technical risks on its instruments, but several of its new developments still present cost and schedule risks. For example, the project has addressed prior concerns about the performance of the laser that will be used to detect organic compounds, but according to the project, substantial technical challenges remain with that instrument and it may not be ready for integration as planned in fall 2018.

Design

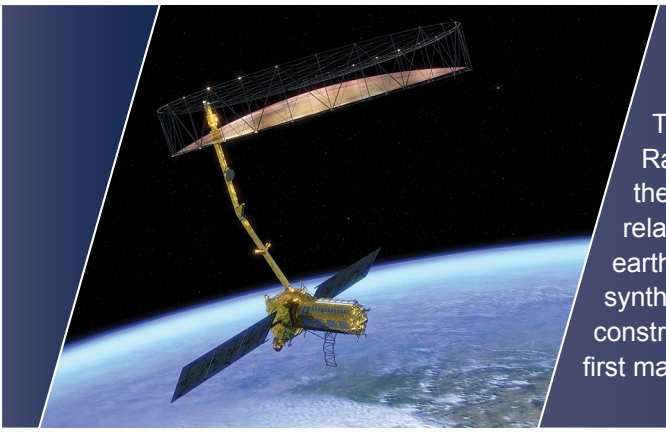
The Mars 2020 design is almost stable, but the project will have to continue to manage mass closely. The project planned to release 80 percent of its design drawings by its late February 2017 critical design review. Best practices show that releasing less than 90 percent of design drawings by this review can increase the project's risk of cost growth and schedule delays. The project also continues to track a risk that the combined mass of the rover, payload, and sampling and caching system could exceed its mass requirements. It previously increased the maximum allowable mass from 980kg to 1050kg and formed an assessment team to evaluate the effect of any future increases. Additional capabilities could still be added to the project. NASA has proposed including a helicopter technology demonstration. The helicopter could assist with route planning for the rover. NASA planned to make a decision on the helicopter by the Mars 2020 critical design review, but the project was still studying how to accommodate it within the design.

The Mars 2020 project is also exploring whether it needs to make changes to its parachute design. NASA's Low-Density Supersonic Decelerator parachute, which is different than the one that will be used for Mars 2020, unexpectedly failed two tests. The project is concerned that there may be unknown parachute performance characteristics that could affect Mars 2020. To mitigate this risk, the project plans to conduct additional testing on its existing design and begin development on a strengthened parachute.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, Mars 2020 project officials stated that by the project's critical design review the project matured all of its critical technologies and the project released 80 percent of their design drawings, which is above average for large projects. Project officials also stated that rover mass is no longer considered a key risk and the project has approximately 80 kilograms of unallocated mass margin to address unforeseen issues. 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 climate 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: © 2016 California Institute of Technology/Jet Propulsion Laboratory. | GAO-17-303SP

FORMULATION

- 03/14 Formulation start
- 12/14 System requirements/ mission definition review
- 06/16 Preliminary design review
- 08/16 Project confirmation

IMPLEMENTATION

- 01/17 **GAO review**
- 10/18 Critical design review
- 12/19 System integration review
- 12/21 Manifested launch readiness date
- 09/22 Committed launch readiness date

PROJECT INFORMATION

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

NASA Project Manager: **Jet Propulsion Laboratory**

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

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

Launch Location: **Satish Dhawan Space Centre, India**

Launch Vehicle: **Pegasus**

Launch Vehicle: **Geosynchronous Satellite Launch Vehicle Mark II**

Mission Duration: **2 years**

Mission Duration: **3 years**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

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

Budget Portfolio: **Science, Heliophysics**

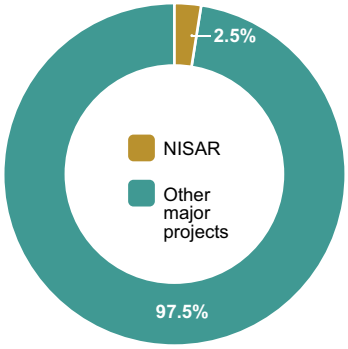
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The NISAR project took steps to reduce its development risk prior to entering implementation in August 2016, but it was baselined at a higher than expected cost and with a later than expected launch date. The primary drivers of the higher cost estimate were near-term funding shortfalls that stretched out the schedule by 1 year and additional risk reduction activities for the radar reflector boom assembly. The radar reflector boom was one of three critical technologies the project matured to the level recommended by best practices by its preliminary design review. This reduced the project's overall development risk, but several boom assembly risks remain. The project is also tracking risks related to differences in the ways NASA and ISRO manage projects, and the reliability of its ISRO-contributed launch vehicle, but has made progress mitigating these risks.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

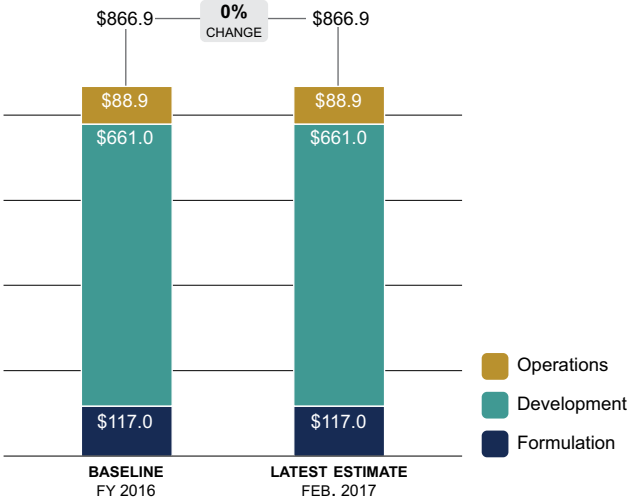


TOTAL NEEDED TO BE FUNDED

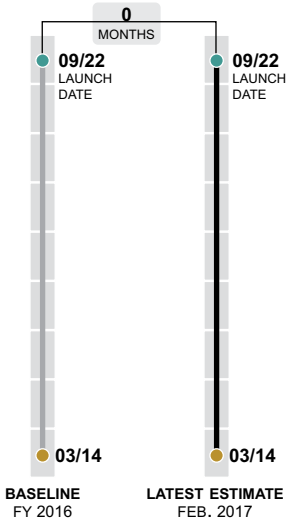
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

In August 2016, the NISAR project held its project confirmation review and established its cost and schedule baselines. The cost baseline is $59 million higher than the top end of the project's preliminary cost estimates, primarily due to near-term funding shortfalls that stretched out the schedule by 1 year and additional risk reduction activities for the radar reflector boom—a complex and critical path development—and radar reflector. The boom will be used to deploy the radar reflector as part of the radar reflector boom assembly that will be used to transmit and receive radar signals. The launch date was also delayed by 1 year. The project would have needed more funding than planned in fiscal years 2017 and 2018 to meet its original launch date. The project is currently holding cost and schedule reserves at the amount required by Jet Propulsion Laboratory policy.

Technology

The NISAR project met a key best practice by maturing its three critical technologies to a technology readiness level 6 by its preliminary design review. Maturing critical technologies—including the radar reflector boom—to this level helps minimize risks for space systems entering product development. The project spent several years and approximately $63 million prior to beginning the concept and technology development phase to mature the technology associated with the synthetic aperture radar and reduce associated risks.

Design

The NISAR project is working to address risks related to its radar reflector boom assembly and mass as it finalizes the system design. The project is redesigning the boom assembly to increase its reliability. The project identified several single point failures on the boom that could prevent it from latching in place, which could compromise the mission. The project changed its electronics and hinge designs to mitigate this risk. The project also added environmental and deployment tests for the radar reflector boom assembly to reduce risk prior to system integration and testing.

The NISAR project is not meeting project mass margin requirements and is tracking the system's mass as a significant risk. Maintaining adequate mass margins is a key indicator of design stability. Since the project's preliminary design review, ISRO has reported a spacecraft mass increase and the project has made design changes, such as increasing the thickness of its electronics box, that have also increased mass. The project is working to better understand the spacecraft changes and reduce mass in other areas.

Developmental Partner

Because NISAR is the first major partnership between NASA and ISRO, the project continues to track a risk that differences in NASA and ISRO management processes could negatively affect cost and schedule. The project established a joint management plan that outlines roles and responsibilities for each agency and the cooperative project plan to help mitigate this risk.

One of the main ISRO contributions to the NISAR project is the launch vehicle, but the Geosynchronous Satellite Launch Vehicle (GSLV) Mark II must meet all NASA-ISRO agreed-upon criteria before it can be used. In September 2016, the GSLV Mark II had its third consecutive successful launch, which is one of the criteria.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, NISAR project officials stated that they agreed with the assessment, and did not have any technical comments.

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: NASA. | GAO-17-303SP

PROJECT INFORMATION

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

International Partner: **European Space Agency**

Other International Partner: **None**

Launch Location: **Kennedy Space Center, Florida (Marshall Islands)**

Launch Vehicle: **Space Launch System**

Mission Duration: **Orion 21 day active mission duration capability with four crew**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

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

Budget Portfolio: **Science - Heliophysics**

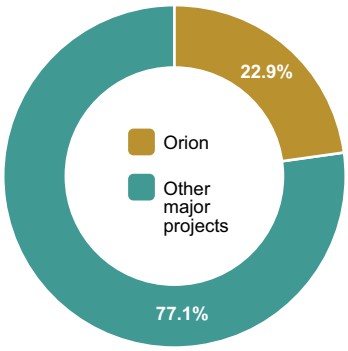
Budget Portfolio: **Exploration, Exploration Systems Development**

PROJECT SUMMARY

The Orion program is increasingly at risk of missing the November 2018 launch date for its first uncrewed exploration mission (EM-1). The program has limited cost reserves and no schedule reserves for EM-1, which compromises the program's ability to address issues as they arise. The late delivery of the European Space Agency-contributed service module (ESM) is one of the main reasons that the program is at risk of missing the planned launch date. Since the ESM's critical design review in June 2016, its delivery to the Orion program has been delayed by at least 8 months and may face further delays. These delays will affect other Orion program efforts—like software development—that need to be completed before the Orion crew and service modules can be provided to Kennedy Space Center for integration and launch preparations, as well as modeling and testing efforts for the Exploration Ground Systems (EGS) program. The Orion program has made progress in key areas, such as heatshield design and production as well as structural testing.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

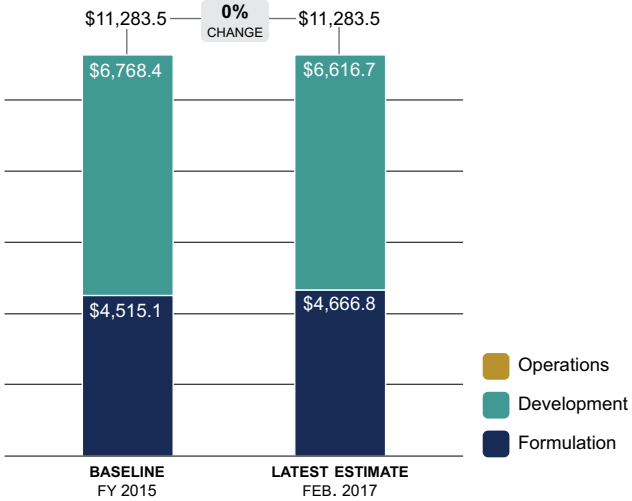


TOTAL NEEDED TO BE FUNDED[a]

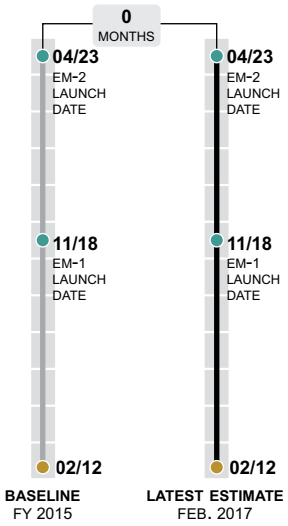
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



[a]Includes funding through Exploration Mission-2.

Cost and Schedule Status

The Orion program is increasingly at risk of missing the November 2018 launch date for its first uncrewed exploration mission (EM-1). The program has limited cost reserves and, according to officials, no schedule reserves for EM-1, which compromises the program's ability to address issues as they arise. Until now, the program has been able to rearrange its schedule when additional time was needed for a particular effort. However, prime contractor and program officials both stated that as the program gets closer to the EM-1 launch readiness date, the ability to shift work decreases. NASA is currently conducting a schedule analysis for the Orion, SLS, and EGS programs and, according to senior NASA officials, is likely to delay the planned EM-1 launch date.

Developmental Partner

The late delivery of the European Space Agency (ESA)-contributed service module (ESM) is one of the main reasons that the Orion program is at risk of missing the planned EM-1 launch date. ESA is responsible for designing, developing, and providing a service module—which provides air, water, power, and propulsion to Orion during in-space flight—for EM-1 and EM-2, the first crewed mission. Since the ESM's critical design review in June 2016, the ESM delivery date has been delayed by 8 months to September 2017 with a risk of an additional 2-month delay. According to program officials, the delays are largely due to late deliveries to the service module contractor and underestimating the effort needed to complete the service module itself. If NASA cannot mitigate these delays, it will likely miss the planned EM-1 launch date. According to program offices, the program needs 12 months to integrate and test the ESM with the crew module following delivery from ESA. NASA officials stated the complete Orion crew vehicle must be delivered to Kennedy Space Center by July 2018 to maintain the planned EM-1 launch readiness date. The ESM delivery delays have also affected Orion software development and may negatively affect EGS's schedule, which needs Orion software and modeling data to perform integrated testing.

Design

The Orion program has made progress in a key outstanding area of the crew vehicle design—the heatshield. The program redesigned the heatshield to improve its structural strength and has nearly completed production of the heatshield blocks for EM-1. The program previously switched from a single-piece, or monolithic, heatshield design to one that employs blocks similar in concept to those used on the Space Shuttle. The program plans to complete testing that will verify the blocks properly adhere and bond to representative crew module hardware by May 2017.

Integration and Test

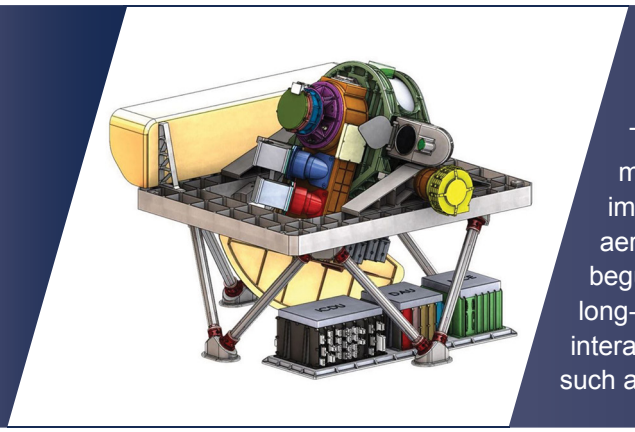
According to program officials, testing for EM-1 is proceeding according to plan, but looming schedule delays could have a cascading effect on EM-2 due to the program's test strategy. The program plans to perform testing for EM-2 using flight hardware from EM-1 in order to reduce costs, but this could pose a schedule risk. Program officials said that this plan places the program at risk of significant delays for EM-2 should the crew module suffer damage during the first mission. To mitigate this risk, program officials stated that they have set aside time between EM-1 and testing for EM-2 to refurbish the spacecraft's avionics and replace damaged parts with spares. If EM-1 is delayed, the schedule risks for EM-2 would increase.

Funding

The Orion program's internal EM-2 cost goal of $10.8 billion and launch readiness date of August 2021 is not supported by NASA's planned budget requests. To stay on this schedule, NASA is counting on receiving more appropriated funds than it plans to request.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, Orion program officials said the program continues to successfully manage the complex and challenging design, development, and testing of the EM-1 components in a budget and schedule constrained environment. In addition, officials said the EM-2 development has commenced with the initiation of machining of the primary crew module structure and ESA committing to produce a second service module. The program stated that it remains on track to meet its schedule baseline for EM-2 of no later than April 2023. Program officials also provide technical comments, 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-17-303SP (Note: Ocean Color Instrument pictured above.)

PROJECT INFORMATION

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

International Partner: **TBD**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **3 years**

Requirement Derived from: **2010 Decadal Survey**

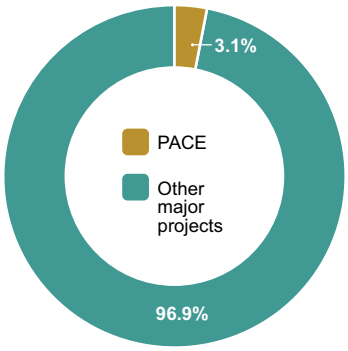
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The PACE project entered the concept and technology development phase in June 2016 and is using a unique design-to-cost process to determine what set of baseline science capabilities are achievable within the mission's $805 million cost cap. The project held its system requirements and mission definition review in January 2017, at which point a project typically sets its top-level requirements. However, under the design-to-cost process, the project will continue to analyze mission, spacecraft, and instrument concepts through project confirmation. NASA has made several key decisions about PACE's spacecraft and payload. The agency decided to build the spacecraft in-house, rather than buy it commercially, and procure a secondary instrument, a polarimeter. The project is also exploring options to reduce its launch costs, such as arranging for a foreign partner to contribute a launch vehicle. The President's 2018 Budget Blueprint has proposed canceling PACE.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



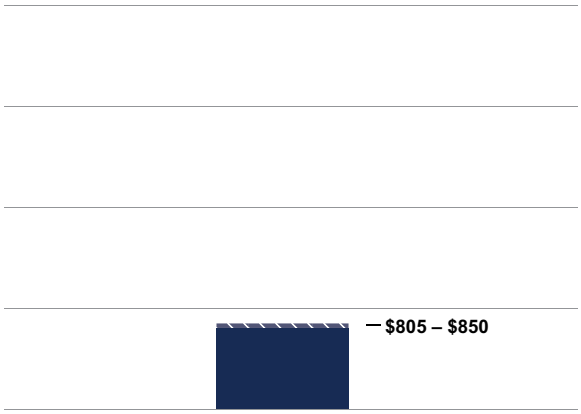
TOTAL FUNDED TO DATE

then-year dollars in millions

$70.3

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. 2017

Cost and Schedule Status

The PACE project entered the concept and technology development phase in June 2016 with a cost cap of $805 million for the mission. The project office has been allocated $705 million for portions of the development and acquisition of the spacecraft and instruments, and launch costs. NASA headquarters was allocated $100 million for science-related activities, such as the calibration and validation of instrument data and processing of science data. The project completed its system requirements and mission definition review in January 2017 and plans to enter the preliminary design and technology completion phase in late March 2017. In March 2017, the President's 2018 Budget Blueprint proposed canceling PACE.

Design

The PACE project is using a unique design-to-cost process to determine what set of baseline capabilities is achievable within the project's $705 million cost cap at the 65 percent confidence level. NASA headquarters selected PACE as the first project to use this process and hopes to use it for other missions directed by NASA as a way to control cost, while maximizing mission capabilities. NASA already uses cost caps for missions it initiates through competitions, such as those conducted under the Discovery program. The PACE project has defined a set of notional baseline capabilities and a preferred mission concept; however, it will continue to analyze mission, spacecraft, and instrument concepts up through project confirmation, which is later than the typical project. During that time, the project will continue to look for ways to maximize its science capabilities and minimize costs.

NASA has made several key decisions about PACE's spacecraft and payload. In August 2016, NASA held an acquisition strategy meeting and decided to build the spacecraft in-house at the Goddard Space Flight Center, rather than buy it commercially, and add a secondary instrument, a polarimeter. PACE project officials preferred an in-house spacecraft build because they said their analysis indicated it would cost less and enable synergies with its primary instrument, the Ocean Color Instrument (OCI), which will also be built in-house with industry support. An independent review board has previously noted that the project's schedule would be aggressive for an in-house spacecraft build.

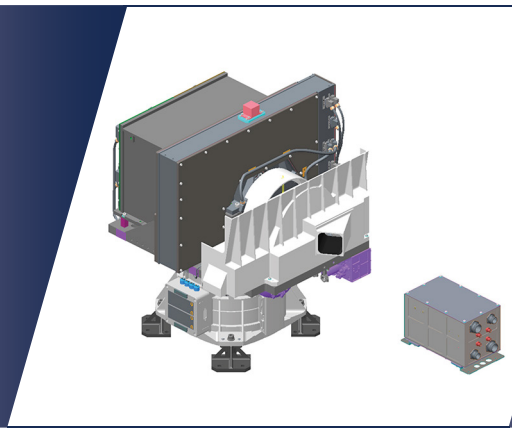
Launch

One of the PACE project's top risks is that its launch vehicle will cost more than initially estimated, which could cause it to exceed its cost cap or have to reduce its science capabilities. The project is working with NASA's Launch Services Program to explore options to reduce its launch costs, such as arranging for a foreign partner to contribute a launch vehicle or sharing a launch vehicle with another mission. The project does not expect NASA to select a launch vehicle until 2019.

PROJECT OFFICE COMMENTS

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

Radiation Budget Instrument



The Radiation Budget Instrument (RBI) is a scanning radiometer that will launch on the National Oceanic and Atmospheric Administration's (NOAA) Joint Polar Satellite System 2 (JPSS-2). RBI will 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 represents one of two key sets of measurements needed to determine whether the Earth is warming or cooling. RBI will also extend unique global climate measurements made by the Clouds and the Earth's Radiant Energy System instrument since 1998.

Source: Harris Corporation. | GAO-17-303SP

FORMULATION

- **07/14** Formulation start
- **12/14** System requirements review
- **05/16** Preliminary design review
- **07/16** Project confirmation

IMPLEMENTATION

- **01/17** **GAO review**
- **06/17** Critical design review
- **04/19** Target delivery date
- **12/19** Committed delivery date

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Not applicable (Marshall Islands)**

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

Mission Duration: **7 years**

Requirement Derived from: **2007 Decadal Survey in Solar Space Physics**

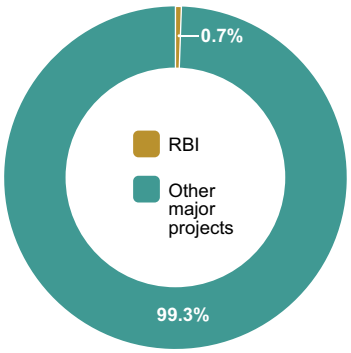
Budget Portfolio: **Science, Earth Science**

PROJECT SUMMARY

The RBI project has met key best practices for reducing product development risk, but it may be unable to meet its aggressive schedule goals. In July 2016, the project entered implementation and NASA committed to deliver RBI to NOAA's JPSS-2 program by December 2019—8 months later than the April 2019 JPSS-2 need date. The project is working to meet the need date, but it appears to be unrealistic. NASA's joint cost and schedule confidence level analysis indicated that the likelihood of the project meeting the date is low and the project's independent review board described the schedule as optimistic when compared to similar instruments. The project has taken steps to reduce development risks by maturing its critical technologies and stabilizing its design, but it is still falling behind schedule. The prime contractor has experienced delays in completing the engineering development unit that proves out the design before the flight instrument is built, as well as continual cost overruns as it consumes more resources than planned to try to stay on schedule.

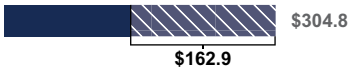
PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



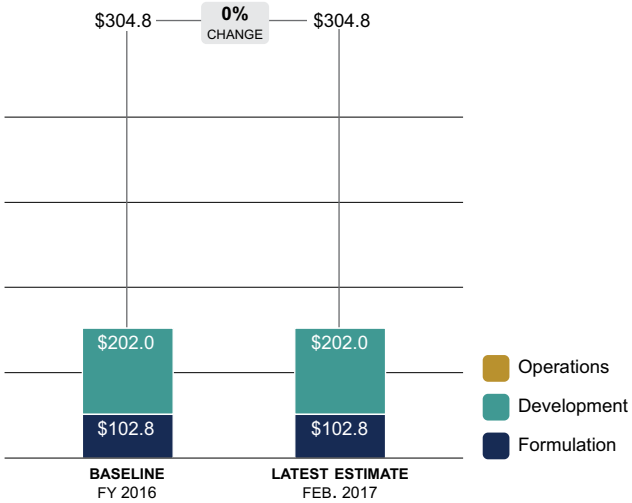
TOTAL NEEDED TO BE FUNDED

then-year dollars in millions

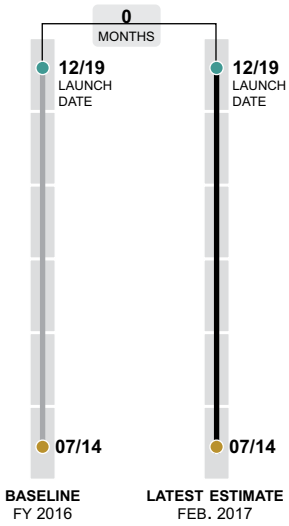


COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The RBI project entered the implementation phase in July 2016 and formally established its cost and schedule baselines. In the baseline, NASA committed to deliver RBI to the JPSS-2 program in December 2019, which is 8 months later than the April 2019 JPSS-2 need date. The project is working to meet the April 2019 date, but it appears to be unrealistic. NASA has calculated the joint cost and schedule confidence level, which is the likelihood a project will meet its cost and schedule estimate, for that date at 42 percent, which is lower than the 50 percent generally required by NASA policy. The project's independent review board also described the RBI schedule as optimistic when compared against historical data for similar instruments.

RBI project officials stated that the schedule is aggressive, but still feasible. The project has evaluated actions it could take to try to preserve its schedule, such as using extended or double shifts. If the RBI project cannot meet the need date, JPSS-2 can fly without the instrument because RBI is not required to meet JPSS-2's science requirements. The project could also get some relief if the JPSS-2 project experiences delays.

Technology and Design

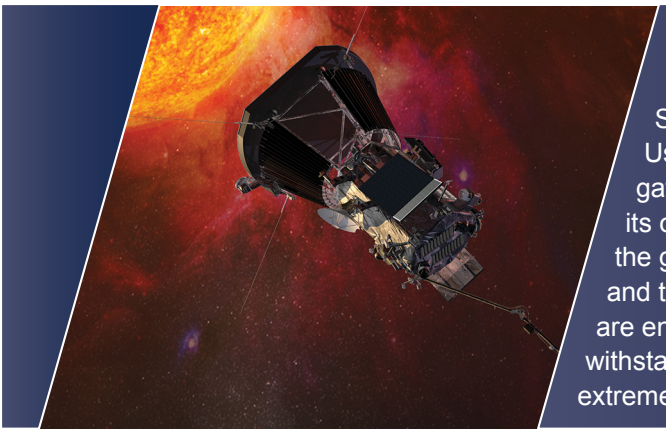
The RBI project has met key best practices for reducing product development risk; however, it is still having difficulty maintaining its aggressive schedule. The project matured its three critical technologies to a technology readiness level 6, the level recommended by best practices, prior to its May 2016 preliminary design review. The project also released all of its expected design drawings in advance of its critical design review, which is an indicator of design stability. However, the project delayed its planned April 2017 critical design review by 2 months to June 2017 because components of its engineering development unit—a model of the system used to help validate the design and its performance—have taken longer to complete than expected. For example, the project expects the engineering development unit's telescopes to be delivered 4 months late because the project had to repair telescope mirrors that were damaged during the process of hardening the coating on other areas of the telescopes. The project is assessing these delays on its overall schedule.

Contractor

The RBI project's prime contractor Harris continues to experience cost overruns. The project awarded a cost-plus award fee contract to Harris in May 2014. In May 2015, the prime contractor notified the project that its estimated costs had significantly increased. Langley Research Center issued a stop work order and the contract was renegotiated in March 2016. By the time the project entered implementation, the value of the Harris contract had grown by $62 million, or 59 percent, from its original value, primarily due to higher than expected subcontractor costs. The project added a deputy project manager and increased site visits and meetings with Harris to improve subcontractor oversight. However, the contractor has continued to incur more costs than planned as it tries to meet the aggressive instrument development schedule. The project currently estimates that Harris will overrun the renegotiated contract by $16 million. The project has cost reserves to cover the projected overrun, but using those reserves would leave it with less than the Langley recommended level of reserves for the remainder of the project. As a result of the continual overruns, the project plans to re-evaluate its schedule, reserve levels, and risks, and identify potential areas to descope.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, RBI project officials noted that they were taking multiple actions to contain project costs and maintain schedule. For example, the project recently reduced the scope of the engineering development unit to preserve cost and schedule. However, a NASA official noted that reducing the scope of the engineering development unit may also increase technical and programmatic risks to the RBI flight instrument. Project officials also provided technical comments, which were incorporated as appropriate.



Solar Probe Plus

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

Source: Johns Hopkins University/Applied Physics Lab. | GAO-17-303SP

FORMULATION

- **11/09** Formulation start
- **11/11** System requirements/ mission definition review
- **01/14** Preliminary design review
- **03/14** Project confirmation

IMPLEMENTATION

- **03/15** Critical design review
- **05/16** System integration review
- **01/17** **GAO review**
- **08/18** Committed launch readiness date

PROJECT INFORMATION

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

International Partner: **None**

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

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

Mission Duration: **7 years**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar and Space Physics**

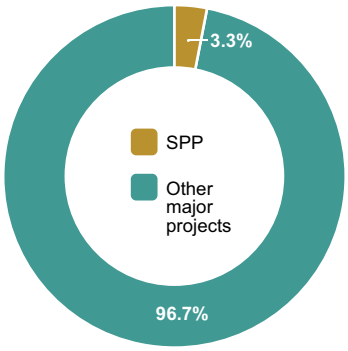
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The SPP project remains on track to launch during its planetary launch window in 2018, even as it has experienced delays in its system integration and testing activities. The delays have not affected the overall project schedule, in part, because the project has had sufficient cost and schedule reserves to mitigate them. In July 2016, the project started system integration and testing, but delays in the delivery of key spacecraft components, such as a flight avionics box that serves as a communications hub, has affected its progress. The project has developed workarounds to try to mitigate the effect of the delays. The SPP project is also working to address spacecraft computer processor issues that could degrade mission performance. The performance margins for the processor, which could affect both the recording and transmission of science data, is lower than expected. The project is incorporating software changes and considering other strategies for increasing the margins, and it may ultimately have to take other actions, such as making software updates after launch.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

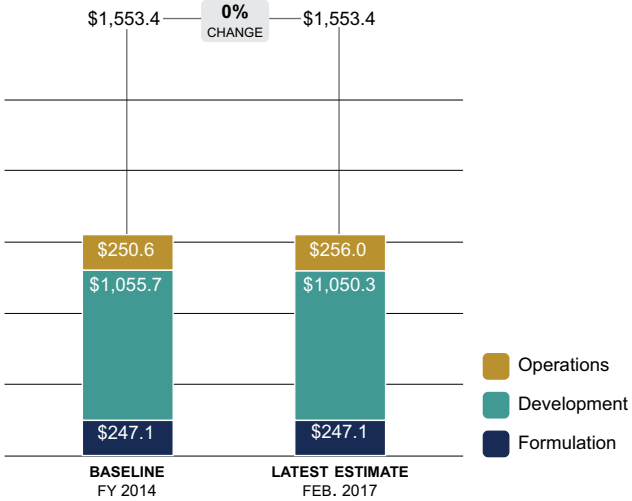


TOTAL NEEDED TO BE FUNDED

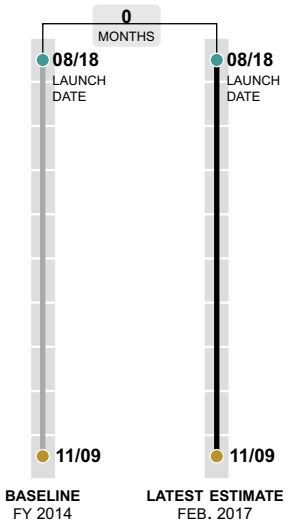
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The SPP project remains on track to launch during its planetary launch window in 2018, even as it has experienced delays in its system integration and testing activities. Maintaining the project's 2018 planetary launch window is important because the window only opens every 10 months and subsequent launch windows would result in a longer mission duration and require more fuel. The project has used cost and schedule reserves to address delivery delays for multiple spacecraft components. The project has low cost reserves because it consumed reserves quicker than expected, but is still holding schedule reserves at the level recommended by the Johns Hopkins University Applied Physics Laboratory guidance.

Technology

The SPP project is working to address spacecraft computing issues, which could affect mission performance. The performance of its spacecraft computer processor is lower than expected and it is currently operating below its required performance margin for this stage in the project. The processor performance affects both the recording and transmission of science data. If the available processor margin continues to erode, then the project risks losing science data during solar encounters. According to project officials, the project has incorporated software changes that have significantly increased the performance margins for the processor. However, if these efforts do not fully mitigate the problem, the project may need to re-write portions of its flight software or make software updates after launch.

Integration and Test

The SPP project experienced delivery delays with multiple spacecraft components, which has affected its system-level integration and test schedule. The delays have not affected the overall project schedule, in part, because the project has had sufficient reserves to mitigate them. The redundant electronics module, a flight avionics box, was delivered for system-level integration and testing in February 2017—3 months later than planned. The module serves as a communications hub for other spacecraft components. To mitigate the effect of the delay, the project used an engineering model to practice test procedures before the flight version was delivered. The solar array cooling system was delivered for system-level integration and testing in February 2017—4 months later than planned—due to a number of issues, including a test failure on one of its components and delayed deliveries from vendors. For example, the project received two flight platens—which transport water within the system to cool the spacecraft's solar cells—5 months later than expected, due primarily to manufacturing difficulties. The cooling system issues also caused a corresponding delay in another part of the project—the manufacturing of the thermal protection system. In addition to these delays with spacecraft components, the project is tracking a number of instrument-related risks that could cause integration and testing delays.

Design

The SPP project demonstrated it had a stable design at its system integration review in May 2016—over one year after its critical design review, the point at which product development best practices recommend having a stable design. Last year, we reported that the project held its critical design review with only 34 percent of its design drawings released, significantly lower than the best practice of 90 percent. Our work on product development best practices shows that releasing at least 90 percent of engineering drawings by this review lowers the risk of subsequent cost and schedule growth.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, SPP project officials stated that they agreed with the assessment. They 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 eventually to 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 advanced boosters.

Source: NASA. | GAO-17-303SP

FORMULATION

- **11/11** Formulation start
- **05/12** Mission/system design review
- **07/13** Preliminary design review
- **08/14** Project confirmation

IMPLEMENTATION

- **07/15** Critical design review
- **01/17** **GAO review**
- **11/18** Committed launch readiness date

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Kennedy Space Center, Florida (Marshall Islands)**

Launch Vehicle: **Pegasus**

Mission Duration: **Varies based on destination**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar and Space Physics**

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

Budget Portfolio: **Science, Heliophysics**

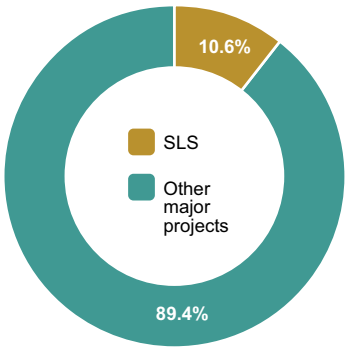
Budget Portfolio: **Exploration, Exploration Systems Development**

PROJECT SUMMARY

The SLS program's schedule is deteriorating and it is at increased risk of exceeding its cost baseline and missing its November 2018 launch readiness date. The program has delayed its internal launch readiness goal and has less cost and schedule reserves available than recommended by NASA center policy to address known and unknown development risks. The program is working to resolve known issues with hardware components, including the core stage and booster. Program officials stated that they have also replanned software development to accommodate more testing, among other reasons. Furthermore, the integration of SLS into a complete launch vehicle and the phase when the launch vehicle will be integrated with ground systems and the Orion crew capsule could reveal unforeseen challenges leading to cost growth and schedule delays.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

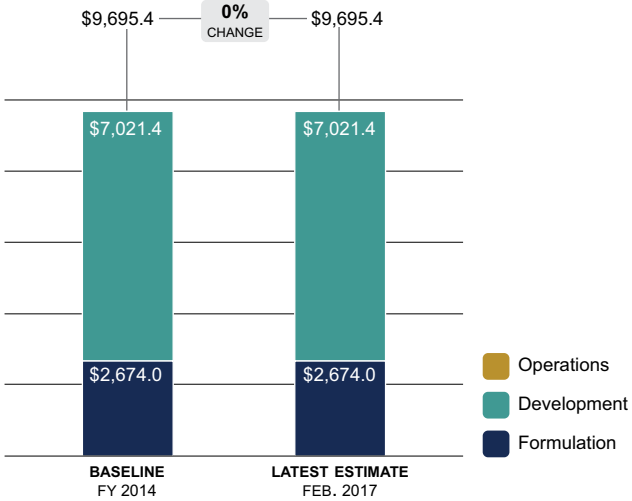


TOTAL NEEDED TO BE FUNDED

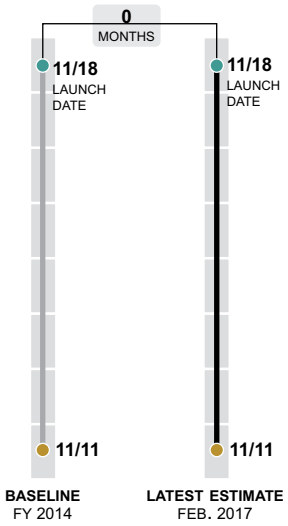
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The SLS program's schedule is deteriorating and it is at increased risk of exceeding its cost baseline and missing its November 2018 launch readiness date. In May 2016, the SLS program delayed its internal goal for launch readiness from July 2018 to September 2018, which means the program only has 2 months of schedule reserve remaining. This is lower than the amount of schedule reserve that is standard for this stage of a program according to Marshall Space Flight Center guidance. The program was also baselined with a lower than recommended level of cost reserves. As a result, the program has less time and money than recommended to address known and unknown risks without affecting its baseline.

The core stage development is the pacing item for the SLS program and its schedule is aggressive. For example, there is no schedule reserve remaining for core stage development leading up to the "green run" test scheduled for October 2017. This test is the culmination of the development effort and includes the core stage flight article integrated with four RS-25 engines that NASA plans to fire for about 500 seconds in a simulated flight profile. If the test does not occur as scheduled or the stage does not perform as expected, core stage delivery to Kennedy Space Center could be delayed beyond the currently scheduled date of March 2018. The program only has 20 days of reserve between the end of the test and the date the core stage is needed at Kennedy Space Center for the start of integration.

Design

In July 2016, we reported that the SLS program had matured the launch vehicle's design, but it is still working to address known hardware and software challenges.[a] The program's current hardware challenges include the strength of the core stage tank welds and booster-related issues. NASA officials indicated they have identified and corrected the root cause of low strength welds in the core stage tanks and that welding of test articles has resumed. NASA is also determining the extent to which new materials within the booster can withstand the structural stress of the SLS launch environment due to effects of long-term storage prior to launch. In addition, the SLS program is assessing the potential risk of damage from booster debris impacting the engines during launch. The program has efforts underway to further analyze or mitigate these and other issues. The SLS program also has encountered delays with the development of SLS flight software due to the late delivery of core stage avionics models needed for testing. These development delays consumed software schedule reserves and affected the maturity of the 12th software release. The program has 14 planned software releases. Program officials said that the final software release was moved from 2017 to 2018 to allow for more testing, among other reasons.

[a]GAO, *NASA Human Space Exploration: Opportunity Nears to Reassess Launch Vehicle and Ground Systems Cost and Schedule*, GAO-16-612 (Washington, D.C.: July 27, 2016).

Integration and Test

The SLS program must complete two distinct levels of integration—integration of the SLS launch vehicle and cross-program integration of SLS with Orion and ground support systems—before it can achieve launch readiness in 2018. The integration period often reveals unforeseen challenges leading to cost growth and schedule delays.

Contractor

The value of the SLS core stage development contract increased by $962 million in February 2017. The SLS program and Boeing reached agreement to modify the scope of the contract to develop, test and deliver a new exploration upper stage for the vehicle that the program plans to use during Exploration Mission-2.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, the SLS program stated that it had made progress resolving challenges, including determining the effects of long-term storage on new booster materials and developing software. Program officials also provided technical comments, which were incorporated as appropriate.

Space Network Ground Segment Sustainment

The Space Network Ground Segment Sustainment (SGSS) project plans to develop and deliver a new ground system for three Space Network sites, which provide 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-17-303SP

FORMULATION

- **09/10** Formulation start
- **11/11** Mission/system definition review
- **09/12** Preliminary design review
- **04/13** Project confirmation

IMPLEMENTATION

- **06/13** Critical design review
- **06/15** Project rebaseline
- **01/17** **GAO review**
- **TBD** System integration review
- **09/19** Committed final acceptance review
- **TBD** Projected final acceptance review

PROJECT INFORMATION

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

International Partner: **None**

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

Launch Vehicle: **N/A**

Launch Vehicle: **Pegasus**

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

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar and Space Physics**

Budget Portfolio: **Science, Heliophysics**

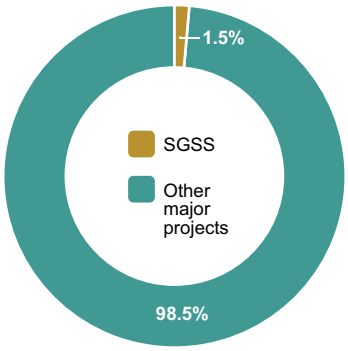
Budget Portfolio: **Space Operations, Space and Flight Support**

PROJECT SUMMARY

The SGSS project has exceeded the new cost and schedule baseline NASA set for it in June 2015 and further cost and schedule growth is likely. In December 2016, the project estimated that it would exceed its new cost baseline by more than $53 million and its committed completion date by at least 2 months. These cost increases and schedule delays have occurred even as the scope of the project has decreased from upgrading three Space Network sites to one site. The project attributes the new cost and schedule growth to the contractor's incomplete understanding of its requirements, which led to poor contractor plans and late design changes. This is the latest in a series of contractor performance problems on the project. The project's oversight of the contractor has also been an issue and it is taking steps to fill staff shortfalls in key areas. The project has developed a cost and schedule baseline to track the project through fiscal year 2017 and plans to present a new cost estimate and completion date to NASA by August 2017.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

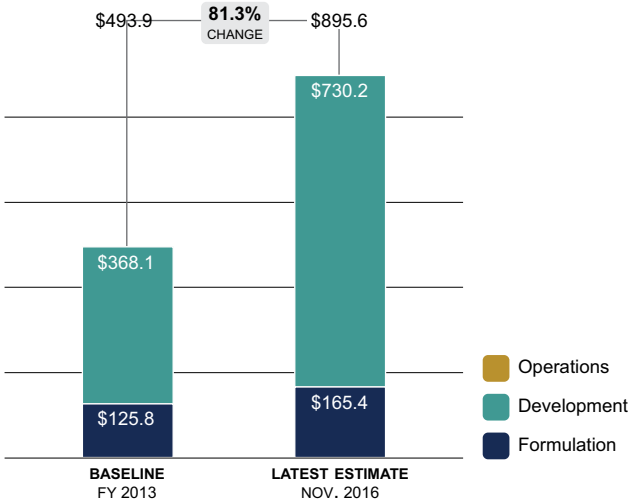


TOTAL NEEDED TO BE FUNDED

then-year dollars in millions

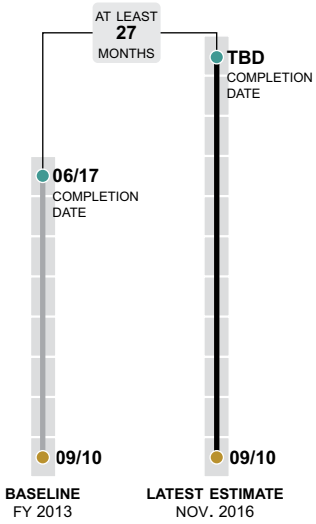
COST PERFORMANCE

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

The SGSS project has exceeded the new cost and schedule baseline NASA set for it in June 2015 and further cost and schedule growth is likely. The 2015 rebaseline increased SGSS's estimated costs by $345 million and delayed its estimated completion by 27 months. In December 2016, the project estimated that its development costs exceeded its new baseline by more than $53 million and its final acceptance review would occur at least 2 months later than NASA's committed date. These cost increases and schedule delays have occurred even as the scope of the project has decreased from upgrading nine Space Network terminals at three sites to six terminals at one site. The project attributes the latest cost and schedule growth to the contractor's incomplete understanding of its requirements, which led to poor contractor plans and late design changes. The project has developed a cost and schedule baseline to track the project through fiscal year 2017 and plans to present a new cost estimate and completion date to NASA by August 2017.

Contractor

The SGSS project continues to experience contractor performance problems. The contractor is not adhering to its cost and schedule to deliver the fifth, final, and most complex software increment. For example, the project estimates completion of this increment to occur in June 2017, 6 months later than planned, with nearly $20 million in contract cost growth. The cost and schedule growth is due to the contractor moving a large portion of the software's required functionality into this increment after experiencing problems with earlier increments, the need to address a growing backlog of defects, and late design changes that were not identified in the contractor's plan. According to a NASA official, there have recently been some positive changes in the contractor's performance. For example, the contractor has provided an improved schedule and is providing better real time data on delays. The contractor also replaced its project manager.

The project is developing a plan to try to address contractor performance problems, although it might not have the resources needed to provide sufficient oversight. The project is working with the contractor to develop a reliable schedule to measure progress. In addition, project officials said they may change contractor performance incentives—which in the past had focused on timeliness, rather than technical quality. The project also has a new NASA project manager, an increased physical presence at the contractor facility, and more staff focused on validation and verification activities, but according to the project, there are staff shortfalls in key areas, such as business, systems engineering, and development management, which the project is working to address.

Funding

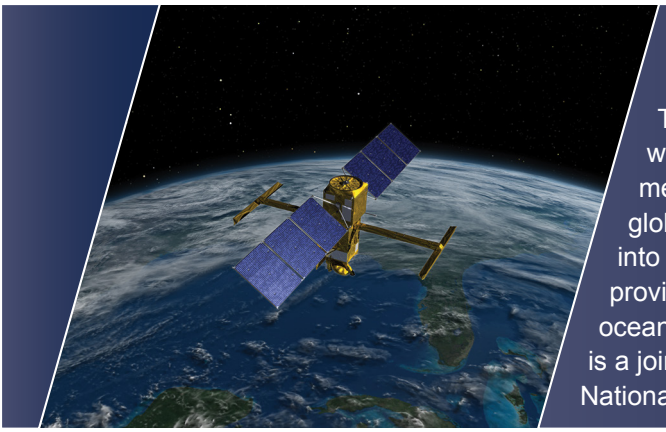
The SGSS project experienced a funding shortfall in fiscal year 2017, in part due to contract cost overruns, that led the SCaN program to indefinitely defer work on two of SGSS's three planned sites. The delays in the SGSS project and the deferral of work at certain sites will result in increased operations and maintenance costs for the Space Network.

Other Issues to Be Monitored

In 2016, NASA announced it was reclassifying SGSS as a hybrid sustainment project for the Space Network, which has implications for project oversight. A hybrid sustainment effort is a sustainment effort that still includes development work. A SCaN program official told us that NASA's inability to fund the project to its 2015 rebaseline agreement drove the reclassification of the SGSS project. As a result of no longer being considered a major project, NASA does not plan to maintain its 2015 project rebaseline, update the joint cost and schedule confidence level analysis, or report on the project's cost and schedule in its Major Program Annual Report to Congress.

PROJECT OFFICE COMMENTS

SGSS project officials provided technical comments on a draft of this assessment, 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: Caltech/JPL (artist depiction). | GAO-17-303SP

FORMULATION

- 11/12 Formulation start
- 05/14 System requirements/ mission definition review
- 04/16 Preliminary design review
- 05/16 Project confirmation

IMPLEMENTATION

- 01/17 GAO review
- 02/18 Critical design review
- 07/19 System integration review
- 04/21 Manifested launch readiness date
- 04/22 Committed launch readiness date

PROJECT INFORMATION

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

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

Launch Vehicle: **Falcon 9**

Requirement Derived from: **2013 - 2022 Decadal Survey in Solar Space Physics**

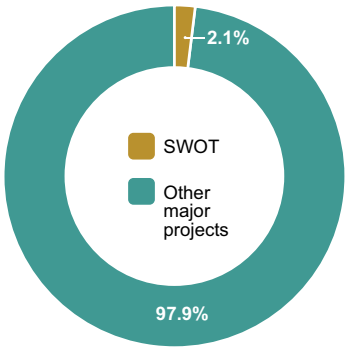
Budget Portfolio: **Science, Heliophysics**

PROJECT SUMMARY

The SWOT project took steps to reduce its development risk prior to entering implementation in May 2016. SWOT's cost baseline is within preliminary estimates, but its planned launch date is 6 months later than previously expected. The project added the 6 months to account for potential delivery delays with a component of its main instrument, the Ka-Band Radar Interferometer (KaRIn), and to take actions to increase SWOT's reliability. These and other steps help to reduce project risk in implementation. For example, the project matured its four critical technologies to the level recommended by best practices by its preliminary design review. The KaRIn instrument is the most challenging development effort and biggest schedule driver for the project. The project is tracking a risk that schedule delays could occur because multiple international partners are contributing components. We have previously reported that integrating contributions from multiple partners may complicate development efforts and contribute to cost and schedule growth.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



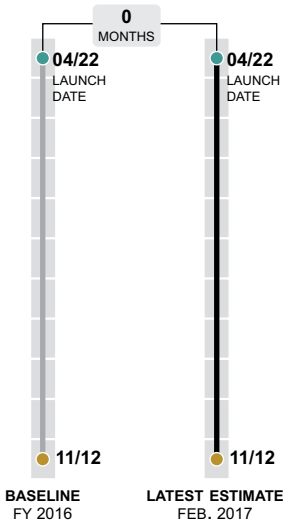
TOTAL NEEDED TO BE FUNDED

then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions

SCHEDULE PERFORMANCE



Cost and Schedule Status

The SWOT project entered the implementation phase in May 2016 and formally established its cost and schedule baselines. SWOT's cost baseline is within the preliminary estimates for the project, but its planned launch date is 6 months later than previously expected. The project added the extra time to account for potential delivery delays with the Radio Frequency Unit (RFU), a key component of SWOT's main instrument, the Ka-Band Radar Interferometer (KaRIn), and to take actions to increase SWOT's reliability. The project received NASA headquarters-held reserves, which is funding that may be used to address issues outside of a project's control, to cover the costs of the delay and reliability efforts.

Technology

The SWOT project met a key best practice by maturing its four critical technologies to a technology readiness level 6 by its preliminary design review. Maturing critical technologies to this level helps minimize risks for space systems entering product development.

Development Partner

The KaRIn instrument, which involves multiple international partners, is the most complicated development effort and biggest schedule driver for the project. Before the project established its schedule baseline, CNES, which is contributing the KaRIN RFU, requested and received an additional 4 months to complete risk reduction activities and allow more time for parts procurement. The project added an additional 2 months of schedule reserves to account for risks, such as the need to repeat testing. Project officials said that contractor performance has been an ongoing concern for the RFU, and CNES is closely managing the responsible contractor in close coordination with NASA. The project is also tracking a risk that schedule delays could occur due to the complexity of having multiple partners contributing components of KaRIn. GAO and the NASA Office of Inspector General have previously found that receiving and integrating contributions from multiple partners may complicate development efforts and contribute to cost and schedule growth. To mitigate the risk, the project plans to mature key interfaces early and conduct a full instrument-level integration and test phase for the KaRIn engineering model, among other actions.

Design

The SWOT project is taking steps to increase the reliability of its spacecraft and instruments after the failure of the Soil Moisture Active Passive (SMAP) mission. The project has not identified any areas of commonality related to SMAP's failure. However, it has taken actions to reduce its probability of experiencing a single-point failure, which, if it occurs, can threaten the mission. For example, the project is making design improvements, using higher quality parts, and conducting additional testing to ensure similar problems do not occur.

Other Issue to Be Monitored

The project has 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. AirSWOT is an airborne sensor that collects data on ocean and surface water phenomena. These data can be used to calibrate and validate the KaRIN instrument. However, AirSWOT's ocean measurements to date showed features that were not fully understood and therefore degraded its utility as a calibration and validation tool. The project has performed analysis to explain the phenomena, updated its algorithm for ocean data processing, and identified alternate ocean calibration and validation methods that could be used if needed.

PROJECT OFFICE COMMENTS

SWOT project officials provided technical comments on a draft of this assessment, 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. The mission's goal is to discover exoplanets—or planets in other solar systems—during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth. 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-17-303SP

FORMULATION

- **04/13** Formulation start
- **02/14** System requirements/ mission definition review
- **09/14** Preliminary design review
- **10/14** Project confirmation

IMPLEMENTATION

- **08/15** Critical design review
- **01/17** **GAO review**
- **05/17** System integration review
- **03/18** Manifested launch readiness date
- **06/18** Committed launch readiness date

PROJECT INFORMATION

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

International Partner: **None**

Launch Location: **Kwajalein Marshall Islands**

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

Launch Vehicle: **Pegasus**

Mission Duration: **2 years**

Requirement Derived from: **2010 Decadal Survey in Solar Space Physics**

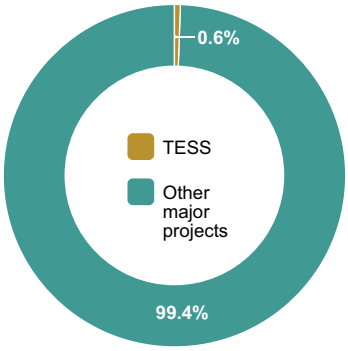
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

The TESS project still plans to launch before its committed launch date and within its cost baseline, despite a series of launch vehicle and instrument-related delays. The project delayed its launch by 7 months from August 2017 to March 2018 because SpaceX required additional time to certify its upgraded launch vehicle and the project required additional time to complete the development of its instrument. Prior to moving the launch date, the project faced schedule pressures due to development delays on its data handling unit (DHU), a primary component of the TESS instrument. To mitigate DHU delays, the project used cost reserves to buy an alternative DHU with a different design from a different supplier. The project plans to select a DHU design by May 2017, in time for the start of system integration and test. The project's primary concerns leading up to system integration are spacecraft-related delays involving its solar arrays and one of its transmitters, among other components.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years

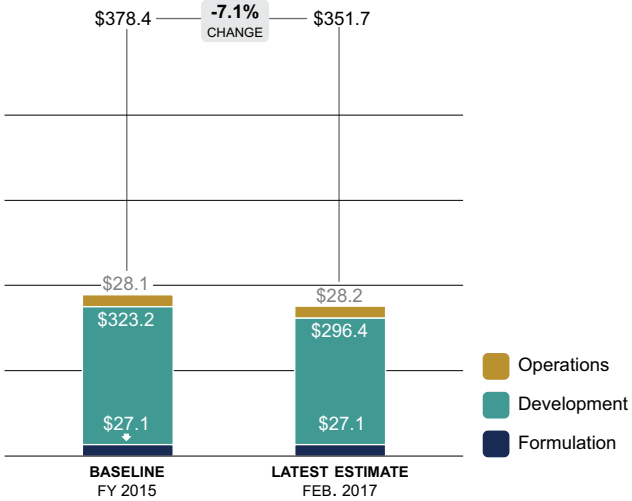


TOTAL NEEDED TO BE FUNDED

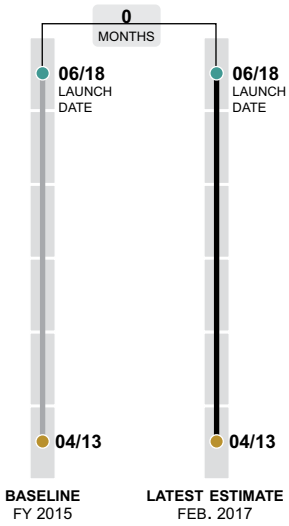
then-year dollars in millions

COST PERFORMANCE

then-year dollars in millions



SCHEDULE PERFORMANCE



Cost and Schedule Status

The TESS project delayed its launch readiness date by 7 months from August 2017 to March 2018 due to launch vehicle and instrument-related delays, but it still plans to launch before its committed launch date and within its cost baseline. The project plans to use NASA headquarters-held reserves, which is funding that may be used to address issues outside of a project's control, to cover the cost of the delay. The project has made progress on test and integration of its spacecraft, which began in March 2016, but it has delayed its system integration review twice. The project plans to hold this review in May 2017—7 months later than originally planned—after it completes the development of its science instrument.

Launch

According to NASA officials, several launch vehicle-related issues led to the delay in TESS's planned launch date. First, SpaceX required additional time to certify its upgraded Falcon 9 through NASA's Launch Services Program since it will be the first time that NASA will use this version of the vehicle. The certification process includes criteria, such as having six successful launches. In addition, SpaceX needed time to investigate and resolve an anomaly that caused a September 2016 launch mishap. NASA has renegotiated its launch contract with SpaceX to account for these delays. SpaceX continues to upgrade the Falcon 9 and, as part of the negotiation process, NASA gained the right not to be the first launch on the planned Block 5 version of the vehicle.

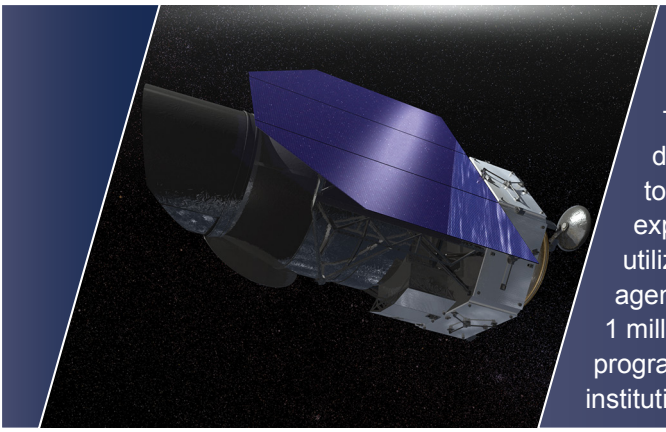
Technology and Design

The TESS project's primary concerns leading up to its system integration review are spacecraft-related delays. In August 2016, the project found faulty slip rings within the TESS solar array drive assembly, which delayed the assembly's integration with the spacecraft by 6 months—the length of time it takes to build the rings—to February 2017. The project told us that the electrical circuits in the slip rings, which allow electrical energy to pass from the rotating solar arrays into the spacecraft body, were not properly isolated, causing interruptions in electrical conductivity during testing. The project has been unable to determine a root cause, but identified cracks in insulation materials and potential over-testing as contributing causes. To help mitigate the problem, the project made manufacturing process improvements for the new slip rings. According to project officials, delays in the completion of the spacecraft's Ka-band transmitter, which transmits the mission's science data to the ground, is also a risk. The transmitter will be the last spacecraft component delivered for system-level integration and test. The project expects delivery in June 2017. If there are additional problems with these or other spacecraft components, it could result in changes or delays in the project's system-level integration and test schedule.

Prior to moving its launch date, the TESS project was also facing schedule pressures due to development delays on its data handling unit (DHU)—which powers the cameras and serves as the instrument data storage and processing computer. The project has completed the development of its cameras, but the DHU is behind schedule because of a series of technical issues related to its complex design and contractor performance issues. To mitigate the DHU delays, the project used cost reserves to buy an alternate DHU from a different supplier. According to the project office, both DHUs are capable of meeting the mission's top-level science requirements. The project plans to make a decision on which DHU to use by May 2017 after it tests engineering development units of both versions. The project plans to use this engineering model to start system-level integration and test and later integrate the flight unit, to help prevent further schedule delays. Project officials said they would continue to develop the other DHU as a backup and would later make it available for use by another mission.

PROJECT OFFICE COMMENTS

In commenting on a draft of this assessment, TESS project officials said they are on track to meet their March 2018 launch date, and are holding a significant amount of schedule reserves. Officials said the completion of certain spacecraft components are the current pacing items for the project, and the prime contractor for the Ka-band transmitter is working to ensure an on-time delivery. Officials also noted that both DHU and alternate DHU vendors delivered their engineering development units and are in the process of completing their flight boxes. Project officials also provided technical comments, 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 utilize 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 where observation time may be made available to academic and other institutions.

Source: NASA. | GAO-17-303SP

PROJECT INFORMATION

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

International Partner: **TBD**

Launch Location: **TBD**

Launch Vehicle: **TBD**

Mission Duration: **6 ¼ years**

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

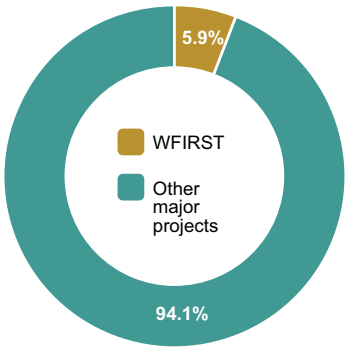
Budget Portfolio: **Science, Astrophysics**

PROJECT SUMMARY

In February 2016, NASA approved the WFIRST project to enter the concept and technology development phase and established preliminary cost and schedule estimates. The current funding profile supports a launch date in the mid to late 2020s. However, if funding is accelerated starting in fiscal year 2018, the project estimates that it could launch in 2024 at a significantly lower cost. The project is evaluating how it plans to work with international partners as it prepares for its system requirements and mission definition review in June 2017. The WFIRST project also continues to mature the detector technology needed for its Wide Field Instrument and to mitigate risks related to detector performance and production. Design trade-offs are also being made. NASA is studying whether to incorporate design features into WFIRST to make it compatible with a starshade, which improves performance by blocking out starlight. The project plans to make a final decision on whether WFIRST will include these features by October 2017.

PROJECT BUDGET INFORMATION

percent of current portfolio over next 5 years



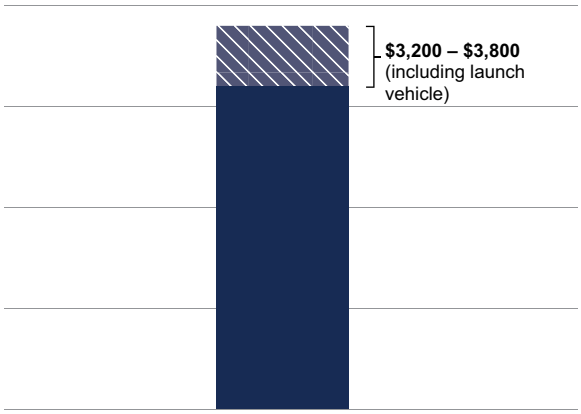
TOTAL FUNDED TO DATE

then-year dollars in millions

$87

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. 2017

Cost and Schedule Status

The WFIRST project entered the concept and technology development phase and established preliminary cost and schedule estimates in February 2016. The project's planned launch date is still being determined and is dependent on the funding it receives. The current funding profile supports a date in the mid to late 2020s. According to the project, WFIRST received more funding than anticipated in fiscal years 2014 through 2016, which the project used to mature technology and increase the fidelity of its design. The project is evaluating the feasibility for an earlier launch in 2024 if it receives significantly more funding starting in fiscal year 2018. According to project officials, the additional funding would allow the project to optimize the development schedule and reduce the cost of the mission.

Design

The WFIRST project has selected its instruments and defined other elements of its design. The current design includes a 2.4 meter telescope and two instruments—the Wide Field Instrument and a technology demonstration instrument, the Coronagraph. The telescope was built and qualified for another federal agency over 10 years ago, so the project is performing an aging assessment to see how the long storage period affected it. The project is also evaluating which components to reuse and which to modify, refurbish, or build new. NASA has also directed WFIRST be designed so that a robotic servicing vehicle can replace various modules while it is on-orbit.

The project is also evaluating other design considerations. For example, the project is studying what design features WFIRST would need to be compatible with current starshade design concepts. 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 expects to make a final decision on these design features by October 2017 after assessing the potential scientific benefits, risks, and resource needs.

Technology

The WFIRST project is continuing to mature its one critical technology—the Wide Field Instrument detectors. The Wide Field Instrument is WFIRST's primary instrument and is intended to measure light from a billion galaxies and perform a survey of the inner Milky Way. The project has assessed the detector to be at a technology readiness level 5, which means that the basic components have been integrated and tested in a simulated environment. The project plans to use detectors evolved from those used on James Webb Space Telescope. According to project officials, these next generation detectors will provide a higher level of performance, which is needed to meet the project's requirement for larger sky surveys. There is a risk that the chosen detectors will not meet all the project's performance specifications, and the detector yield will be low due to limited production experience with the configuration planned for the instrument. The project is conducting additional testing and implementing new manufacturing processes to mitigate these risks. The Coronagraph, which is designed to perform high contrast imaging and spectroscopy of nearby exoplanets, also has new technologies, but their development poses less of a risk since the instrument is not needed to meet the mission's requirements.

Developmental Partner

NASA is discussing possible contributions with various international partners, including the European Space Agency, Canada, Australia, and Japan, for elements of the Wide Field Instrument, Coronagraph, and ground system. These contributions could potentially reduce the project's cost. NASA expects to determine its international partners before the project enters the preliminary design and technology completion phase, which is planned for October 2017.

PROJECT OFFICE COMMENTS

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