United States Government Accountability Office
Report to Congressional Committees

NASA

Assessments of Major Projects

Accessible Version

April 2020

GAO-20-405

GAO Highlights

Highlights of GAO-20-405, a report to congressional committees

April 2020

NASA

Assessments of Major Projects

Why GAO Did This Study

This report provides GAO's annual snapshot of how well NASA is planning and executing its major acquisition projects. In May 2019, GAO found that the cost of NASA's major projects had grown by almost 28 percent since they were baselined with an average launch delay of 13 months.

Congressional conferees included a provision for GAO to prepare status reports on selected large-scale NASA programs, projects, and activities. This is GAO's 12th annual assessment. This report assesses (1) the cost and schedule performance of NASA's portfolio of major projects and (2) progress NASA has made identifying and addressing challenges that contribute to acquisition risk, among other objectives. This report also includes assessments of 24 major projects, each with a life-cycle cost of over $250 million using 2020 data. To conduct its review, GAO analyzed cost, schedule, technology maturity, and other data; reviewed project status reports; and interviewed NASA officials.

What GAO Recommends

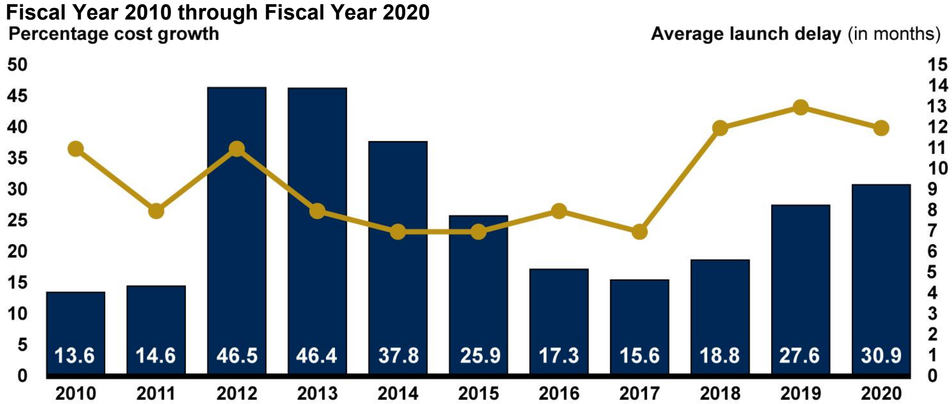
GAO has made a number of recommendations over the last 5 years to improve NASA's acquisition of major projects. NASA has implemented changes in response to many of these recommendations, although 17 recommendations have not yet been fully addressed. NASA generally agreed with the findings in this report.

View GAO-20-405. For more information, contact Cristina T. Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

The National Aeronautics and Space Administration's (NASA) portfolio of major projects continued to experience significant cost and schedule growth this year and the performance is expected to worsen. Since GAO last reported on the portfolio in May 2019, cost growth was approximately 31 percent over project baselines—the third consecutive year that cost growth has worsened after a period of decline. The average launch delay was 12 months, compared to 13 months last year. See figure.

Development Cost Performance and Average Launch Delay for Major NASA Projects from Fiscal Year 2010 through Fiscal Year 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Additional cost growth and schedule delays are likely after NASA establishes a new launch date for Artemis I—an uncrewed test flight of the Space Launch System, Orion crew capsule, and associated ground systems. Further, in 2019, GAO found that the Space Launch System (SLS) and Orion programs have underreported cost growth. GAO recommended that SLS calculate cost growth based on costs that are currently included in the first mission and that the Orion program update its cost estimate to reflect the schedule agreed to in its baseline. Both recommendations still require action to address. Looking ahead, NASA will continue to face significant cost and schedule risks as it undertakes complex efforts to return to the moon under an aggressive time frame.

NASA has taken actions to identify and address challenges contributing to its chronic difficulty meeting cost and schedule goals. For example, in response to a GAO recommendation, NASA plans to broaden its use of a project management process known as earned value management. In addition, NASA plans to assess and update its cost and schedule estimates at more points in the acquisition process and bolster its training for analysts who oversee projects. Such actions will help to provide a better foundation for decision-making, but it will take time to assess the extent to which these efforts are having an effect. Further, GAO's work has found that success also hinges on leadership commitment, accountability, and demonstrated progress.

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Abbreviations

AEPS	Advanced Electric Propulsion System
AMU	Antenna Management Unit
ASI	Italian Space Agency
CCP	Commercial Crew Program
CDR	Critical Design Review
CGI	Coronagraph Instrument
CNES	Centre National d'Etudes Spatiales
DART	Double Asteroid Redirection Test
EGS	Exploration Ground Systems
ESA	European Space Agency
EVM	Earned Value Management
FTIS	Flight Test Instrumentation System
GFAS	Ground Flight Application Software
GN&C	Guidance, Navigation, and Control System
GRNS	Gamma Ray and Neutron Spectrometer
GSLV	Geosynchronous Satellite Launch Vehicle
HEO	Human Exploration and Operations
ICON	Ionospheric Connection Explorer
ICPS	Interim Cryogenic Propulsion Stage
IFS	Integral Field Spectrograph
IMAP	Interstellar Mapping and Acceleration Probe
IPAO	Independent Program Assessment Office
ISRO	Indian Space Research Organisation
ISS	International Space Station
JCL	joint cost and schedule confidence level
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KaRIn	Ka-Band Radar Interferometer
KASI	Korea Astronomy and Space Science Institute
KDP	key decision point
LBFD	Low Boom Flight Demonstrator
LCRD	Laser Communications Relay Demonstration
LICIACube	Light Italian CubeSat for Imaging of Asteroids
LIDAR	Light Detection and Ranging
MDR	Mission Definition Review
NASA	National Aeronautics and Space Administration
NEXT-C	NASA's Evolutionary Xenon Thruster-Commercial
NISAR	NASA ISRO – Synthetic Aperture Radar
NPR	NASA Procedural Requirements
OCI	Ocean Color Instrument
OLI-2	Operational Land Imager 2

Orion	Orion Multi-Purpose Crew Vehicle
PACE	Plankton, Aerosol, Cloud ocean Ecosystem
PDP	Plasma Diagnostics Package
PDR	preliminary design review
PIXL	Planetary Instrument for X-ray Lithochemistry
PPE	Power and Propulsion Element
PSP	Parker Solar Probe
SCaN	Space Communication and Navigation
SCCS	Spaceport Command and Control System
SCS	Sampling and Caching Subsystem
SDO	Solar Dynamics Observatory
SDR	System Definition Review
SEP	Solar Electric Propulsion
SLS	Space Launch System
SGSS	Space Network Ground Segment Sustainment
SHERLOC	Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals
SIR	System Integration Review
SLS	Space Launch System
SPHEREx	Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer
SPIDER	SPace Infrastructure DExterous Robot
SRB	Standing Review Board
STMD	Space Technology Mission Directorate
SWOT	Surface Water and Ocean Topography
SwRI	Southwest Research Institute
TIRS-2	Thermal Infrared Sensor 2
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
USRA	Universities Space Research Association
WFI	Wide Field Instrument
WFIRST	Wide-Field Infrared Survey Telescope

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April 29, 2020

Congressional Committees

The National Aeronautics and Space Administration (NASA) is planning to invest at least $65 billion over the life cycle of its current portfolio of 25 major projects, which we define as those projects or programs that have a life cycle cost of over $250 million. These projects aim to continue exploring Earth and the solar system and extend human presence beyond low Earth orbit, among other things. This report provides an overview of NASA's planning and execution of these major acquisitions—an area that has been on GAO's high-risk list since 1990.[1] It includes assessments of NASA's key projects across mission areas, such as the Space Launch System (SLS) for human exploration, Mars 2020 for planetary science, Plankton, Aerosol, Cloud ocean Ecosystem (PACE) for Earth science, and the Wide Field Infrared Survey Telescope (WFIRST) for astrophysics.

The explanatory statement of the House Committee on Appropriations accompanying the Omnibus Appropriations Act, 2009 included a provision for us to prepare project status reports on selected large-scale NASA programs, projects, and activities.[2] This is our 12th annual report responding to that mandate. This report assesses (1) the cost and schedule performance of NASA's portfolio of major projects; (2) NASA's progress developing and maturing technologies and achieving design stability; and (3) NASA's progress identifying and addressing challenges that contribute to acquisition risk. This report also includes individual assessments of 24 major NASA projects. When NASA determines that a project has an estimated life cycle cost of over $250 million, we include that project in our annual review up through launch or completion. We did not complete an individual project assessment for the 25th project,

[1]GAO, *High-Risk Series: Substantial Efforts Needed to Achieve Greater Progress on High-Risk Areas,* GAO-19-157SP (Washington, D.C.: Mar. 6, 2019).

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

Ionospheric Connection Explorer (ICON), which launched in October 2019, during our review.

To assess the cost and schedule performance, technology maturity, and design stability of NASA's major projects, we collected information on these areas from projects using a questionnaire, analyzed projects' monthly status reports, interviewed NASA project and headquarters officials, and reviewed project documentation. Information available for each project depends on where a project is in its life cycle.[3] For the 18 projects in the implementation phase we compared current cost and schedule estimates as of January 2020 to their original cost and schedule baselines, identified the number of technologies being developed, and compared technology maturity levels at the program's preliminary design review to those levels identified in GAO acquisition best practices and NASA policy.[4] We also compared each project's progress with design drawings at the critical design review against GAO-identified acquisition best practices and analyzed subsequent design drawings changes. We reviewed historical data on cost and schedule performance, technology maturity, and design stability for major projects from our prior reports and compared these data to the performance of NASA's current portfolio of major projects. To assess progress NASA made identifying and addressing challenges that contribute to acquisition risk, we identified and assessed NASA's progress in addressing challenges affecting the portfolio raised in prior GAO work, NASA's Corrective Action Plan to address GAO's high-risk designation, and interviews with senior NASA officials.

To complete our project assessments, we analyzed monthly status reports, analyzed data questionnaires, and interviewed project officials to identify major sources of risk and the strategies that projects are using to

[3]Six projects were in an early stage of development called formulation when there are still unknowns about requirements, technology, and design. For those projects, we reported preliminary cost ranges and schedule estimates. The Commercial Crew Program has a tailored project life cycle and project management requirements. As a result, it was excluded from our cost and schedule performance, technology maturity, and design stability analyses.

[4]GAO, *Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects [Reissued with revisions on Feb. 11, 2020.],* GAO-20-48G (Washington, D.C.: Jan. 7, 2020). National Aeronautics and Space Administration, *NASA Systems Engineering Processes and Requirements,* NASA Procedural Requirement (NPR) 7123.1C (Feb. 14, 2020).

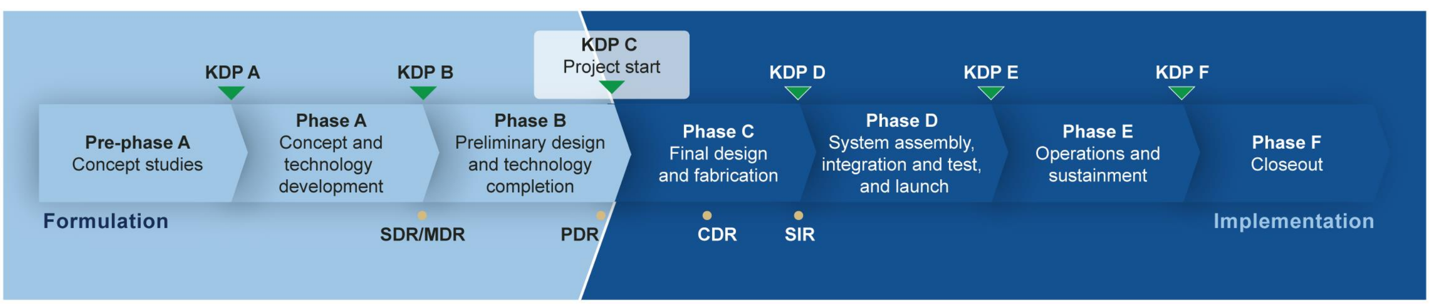
mitigate them. Appendix I contains detailed information on our scope and methodology.

We conducted this performance audit from May 2019 to April 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The life cycle for NASA space flight projects consists of two phases—formulation, which takes a project from concept to preliminary design, and implementation, which includes building, launching, and operating the system, among other activities. NASA further divides formulation and implementation into phase A through phase F. Major projects must get approval from senior NASA officials at key decision points before they can enter each new phase. Figure 1 depicts NASA's life cycle for space flight projects.

Figure 1: NASA's Life Cycle for Space Flight Projects



Management decision reviews

KDP = key decision point

Technical reviews

- SDR/MDR = system definition review/mission definition review
- PDR = preliminary design review
- CDR = critical design review
- SIR = system integration review

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Project formulation consists of phases A and B, during which the projects develop and define requirements, cost and schedule estimates, and the system's design for implementation. NASA Procedural Requirements 7120.5E, NASA Space Flight Program and Project Management Requirements, specifies that during formulation, the project must complete a formulation agreement to establish the technical and acquisition work that needs to be conducted during this phase and define the schedule and funding requirements for that work. The formulation agreement should identify new technologies and their planned development, the use of heritage technologies, risk mitigation plans, and testing plans to ensure that technologies will work as intended in a relevant environment.[5] Prior to entering phase B, projects develop a range of the projects' expected cost and schedule which are used to inform the budget planning for that project. During phase B, the project also develops programmatic measures and technical leading indicators, which track various project metrics such as requirement changes, staffing demands, and mass and power utilization. Near the end of formulation, leading up to the preliminary design review, the project team completes technology development and its preliminary design.

Formulation culminates in a review at key decision point C, where cost and schedule baselines are established, documented, and confirmed in the decision memorandum. The decision memorandum outlines the management agreement and the agency baseline commitment. The management agreement can be viewed as a contract between the agency and the project manager. The project manager has the authority to manage the project within the parameters outlined in the agreement. The agency baseline commitment includes the cost and schedule baselines against which the agency's performance on a project may be measured.

To inform the management agreement and the agency baseline commitment, each project with a life cycle cost estimated to be greater than $250 million must also develop a joint cost and schedule confidence level (JCL). The JCL initiative, adopted in January 2009, produces a point-in-time estimate that includes, among other things, all cost and

[5]Heritage technologies are technologies that have been used successfully in operation. Such technologies may be used in new ways where the form, fit, or function is changed; the environment to which it will be exposed in its new application is different than those for which it was originally qualified, or process changes have been made in its manufacture.

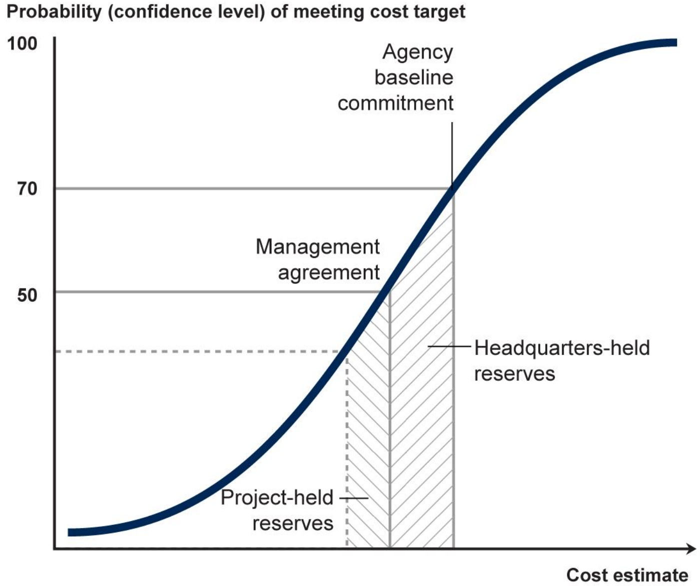
schedule elements in phases A through D, incorporates and quantifies known risks, assesses the effects of cost and schedule to date, and addresses available annual resources. NASA policy requires that projects be baselined and budgeted at the 70 percent confidence level and funded at a level equivalent to at least the 50 percent confidence level.[6]

The management agreement and agency baseline commitment include cost and schedule reserves held at the project and NASA headquarters levels, respectively.[7] Cost reserves are for costs that are expected to be incurred—for instance, to address project risks—but are not yet allocated to a specific part of the project. Schedule reserves are extra time in project schedules that can be allocated to specific activities, elements, and major subsystems to mitigate delays or address unforeseen risks. Project-held cost and schedule reserves are within the project manager's control. If the project requires additional time or money beyond the management agreement—for example, if a project needs additional funds for an issue outside of the project's control—NASA headquarters may allocate headquarters-held reserves. Figure 2 notionally depicts how NASA would distribute cost reserves for a project that was baselined in accordance with its JCL policy.

[6]National Aeronautics and Space Administration, *NASA Space Flight Program and Project Management Requirements* paras 2.4.4 and 2.4.4.2, NASA Procedural Requirements (NPR) 7120.5E (Aug. 14, 2012) (hereinafter cited as NPR 7120.5E (Aug. 14, 2012)). The decision authority for a project can approve it to move forward at less than the 70 percent confidence level. That decision must be justified and documented.

[7]NASA refers to cost reserves as unallocated future expenses.

Figure 2: Notional Distribution of Cost Reserves for a Project Budgeted at the 70 Percent Confidence Level



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

The total amount of cost and schedule reserves held at the project level varies based on where the project is in its life cycle. Seven centers or laboratories are responsible for managing 24 NASA major projects. Of these, two centers or laboratories manage 16 major projects and require or recommend that projects hold a certain level of cost and schedule reserves at key project milestones.[8] For example, at the Goddard Space Flight Center, mission flight projects are required to hold cost reserves equal to at least 25 percent of the estimated cost remaining at the project confirmation review, and 10 percent at the time of delivery to the launch site. Projects track their reserves between phases to help ensure they hold reserves consistent with these requirements. The final major project,

[8]National Aeronautics and Space Administration, *Schedule and Budget Margins for Flight Projects,* Goddard Procedural Requirements 7120.7B (Sep. 17, 2018); *Marshall Space Flight Center Engineering and Program/Project Management Requirements,* Marshall Procedural Requirements 7120.1 (Aug. 26, 2014); Langley Research Center, *Space Flight Project Practices Handbook*, LPR 7120.5 B-2 (Mar. 17, 2014); and Jet Propulsion Laboratory, *Flight Project Practices*, *Rev. 8* (Oct. 6, 2010). The Kennedy Space Center and Johnson Space Center do not have center-specific guidance for reserves. The Johns Hopkins University Applied Physics Laboratory manages the Double Asteroid Redirect Test (DART) and Dragonfly projects and has guidelines for schedule reserves, but not for cost reserves. The Johns Hopkins University Applied Physics Laboratory SD-QP-012, Rev. b, *Space Exploration Sector (SES) Quality Procedure: Earned Value Management System (EVMS) Project Management Control System (PMCS)* (Apr. 4, 2017).

the Low Boom Flight Demonstrator (LBFD), does not have a lead center because it is using a virtual project office with project members located in different NASA centers. The project office uses a mix of center policies in managing the LBFD acquisition.

After a project is confirmed, it begins implementation, consisting of phases C, D, E, and F. In this report, we refer to projects in phase C and D as being in development. A critical design review is held during the latter half of phase C in order to determine if the design is mature enough to support proceeding with the final design and fabrication. After the critical design review and just prior to beginning phase D, the project completes a system integration review to evaluate the readiness of the project and associated supporting infrastructure to begin system assembly, integration, and test. In phase D, the project performs system assembly, integration, test, and launch activities. Phases E and F consist of operations and sustainment and project closeout.

NASA Projects Reviewed in GAO’s Annual Assessment

NASA’s portfolio of major projects includes satellites equipped with advanced sensors to study the Earth, a rover that plans to collect soil and rock samples on Mars, telescopes intended to explore the universe, and spacecraft to transport humans and cargo beyond low-Earth orbit. When NASA determines that a project will have an estimated life cycle cost of more than $250 million, we include that project in our annual review. After a project launches or reaches full operational capability and holds its key decision point E, we no longer include an assessment of it in our annual report.

Table 1 includes a list of all projects included in this report. Four projects are being assessed for the first time this year: 1) Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx), 2) Dragonfly, 3) Power and Propulsion Element (PPE), and 4) Solar Electric Propulsion (SEP). For a list of all the projects and their current cost and schedule estimates, see appendix II. Appendix III includes a list of all the projects that we have reviewed from 2009 to 2020.

Table 1: Major NASA Projects Reviewed in GAO's 2020 Assessment

Category	Category members
Projects in formulation	Dragonfly
	Interstellar Mapping and Acceleration Probe (IMAP)
	Power and Propulsion Element (PPE)
	Restore-L
	Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx)
	Wide Field Infrared Survey Telescope (WFIRST)
Projects in implementation	Commercial Crew Program (CCP)
	Double Asteroid Redirection Test (DART)
	Europa Clipper
	Exploration Ground Systems (EGS)
	Ionospheric Connection Explorer (ICON)[a]
	James Webb Space Telescope (JWST)
	Landsat 9
	Laser Communications Relay Demonstration (LCRD)
	Low Boom Flight Demonstrator (LBFD)
	Lucy
	Mars 2020
	NASA ISRO Synthetic Aperture Radar (NISAR)
	Orion Multi-Purpose Crew Vehicle (Orion)
	Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)
	Psyche
	Solar Electric Propulsion (SEP)
	Space Launch System (SLS)
	Space Network Ground Segment Sustainment (SGSS)
	Surface Water and Ocean Topography (SWOT)

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

[a]The ICON project launched in 2019.

Over the past 8 years, we have issued several reports assessing NASA's progress in acquiring its largest projects and programs in more depth.[9] For example, in December 2019, we found that NASA had quickly refocused its acquisition plans to support accelerated plans to land astronauts on the moon by 2024. We reported, however, that some decisions related to requirements, cost, and schedule for the lunar mission were lagging.[10] We recommended that NASA define and

[9]See related GAO products at the end of this report.

[10]GAO, *NASA Lunar Programs: Opportunities Exist to Strengthen Analyses and Plans for Moon Landing,* GAO-20-68 (Washington, D.C.: Dec. 19, 2019).

schedule reviews that align requirements across lunar programs and create a cost estimate for the first lunar mission. NASA agreed with these and other recommendations and outlined steps to implement them with expected completion dates ranging from April 2020 to September 2021.

Further, key to NASA's plans to return to the moon are three programs—Space Launch System (SLS), Orion crew capsule, and the associated ground systems at Kennedy Space Center—that have been under development for several years. After a series of delays, NASA is reevaluating the planned June 2020 launch date for the first integrated test flight of these systems, an uncrewed mission known as Artemis I. We have made 20 recommendations in prior reports to strengthen NASA's acquisition management of these three programs. NASA generally agreed with our recommendations and has implemented eight of the recommendations. Further action is needed to fully implement the remaining recommendations. For example, in 2019, we recommended that NASA direct the SLS and Orion programs to reevaluate their strategies for incentivizing contractors and determine whether they could more effectively incentivize contractors to achieve the outcomes intended as part of ongoing and planned contract negotiations.[11] NASA agreed with the intent of this recommendation and stated that the SLS and Orion program offices will reevaluate their strategies for incentivizing contract performance as part of contracting activities, including contract restructures, contract baseline adjustments, and new contract actions. We will continue to follow up on the actions the agency is taking to address this recommendation.

We have also reported for several years on the James Webb Space Telescope (JWST) project, which has experienced significant cost increases and schedule delays. Prior to being approved for development, cost estimates for JWST ranged from $1 billion to $3.5 billion, with expected launch dates ranging from 2007 to 2011. Before 2011, early technical and management challenges, contractor performance issues, low levels of cost reserves, and poorly phased funding levels caused JWST to delay work after confirmation, which contributed to significant cost and schedule overruns, including launch delays. Following an independent review that found JWST was executing well from a technical standpoint, but that the baseline cost estimate did not reflect the most

[11]GAO, *NASA Human Space Exploration: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs,* GAO-19-377 (Washington, D.C.: June 19, 2019).

probable cost with adequate reserves in each year of project execution, Congress placed an $8 billion cap on the formulation and development costs for the project in November 2011. NASA rebaselined JWST with a life cycle cost estimate of $8.835 billion that included additional funding for operations and a planned launch in October 2018.[12]

Subsequently, problems discovered during testing caused multiple delays that led NASA to replan the project in June 2018. Now estimated at $9.7 billion, the project's costs have increased by 95 percent and its launch date has been delayed by over 6.5 years since its cost and schedule baselines were established in 2009. In January 2020, we found that the JWST project had made significant progress, including completing testing of the observatory's individual elements and integrating them together, but the project estimates only a 12 percent likelihood of meeting its most recent planned March 2021 launch date.[13]

NASA's Major Project Portfolio's Cost and Schedule Performance Expected to Worsen and Challenging Lunar Programs Beginning

The cost performance of NASA's portfolio of major projects has worsened for the third consecutive year, while the average schedule delay has decreased. Since we last reported in May 2019, cost growth has increased from 27.6 percent to approximately 31 percent. The average launch delay decreased from 13 months to approximately 12 months.[14] Our analysis shows that NASA's cost and schedule performance is expected to deteriorate as a result of several factors, including likely Artemis I delays and understated cost growth for the Orion and SLS

[12]A rebaseline is a process initiated if the NASA Administrator determines the development cost growth is more than 30 percent of the estimate provided in the baseline of the report, or if other events make a rebaseline appropriate. When the NASA Administrator determines that development cost growth is likely to exceed the development cost estimate by 15 percent or more, or a program milestone is likely to be delayed from the baseline's date by 6 months or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. 51 U.S.C § 30104(e)(2)(reporting requirement).

[13]GAO, *James Webb Space Telescope: Technical Challenges Have Caused Schedule Strain and May Increase Costs,* GAO-20-224 (Washington, D.C.: Jan. 28, 2020).

[14]GAO, *NASA: Assessments of Major Projects,* GAO-19-262SP (Washington, D.C.: May 30, 2019).

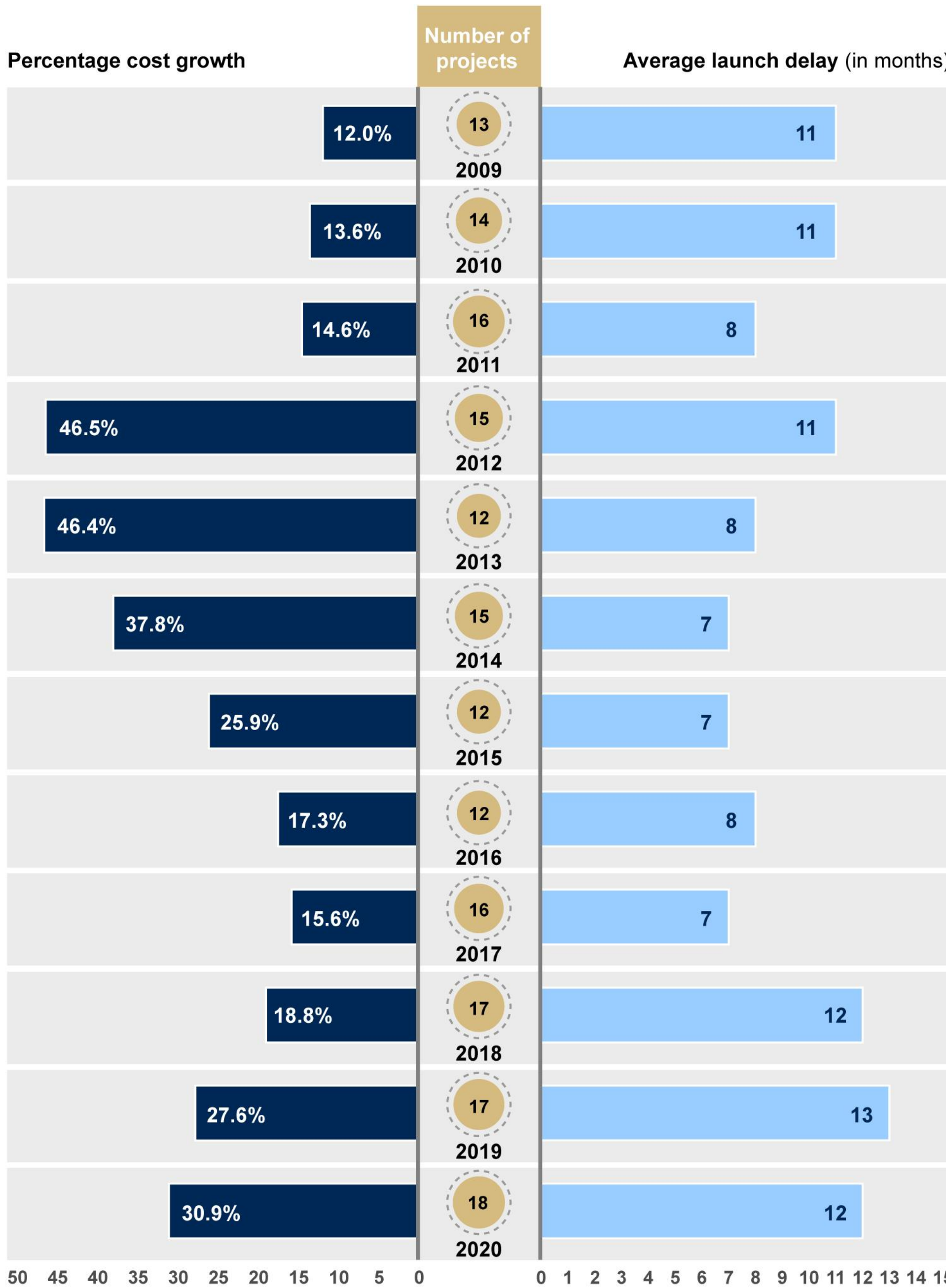
programs. According to NASA officials, the partial government shutdown that occurred between December 2018 and January 2019 did not affect projects' cost and schedule baselines, but these officials identified varying other effects including the use of cost and schedule reserves. Looking forward, programs that will be part of NASA's plans to conduct a lunar landing in 2024 will begin to enter the portfolio and present additional cost and schedule risks as NASA works toward this aggressive target date.

Negative Cost and Schedule Performance Will Be Further Exacerbated by Pending Artemis I Delay

The cost performance of NASA's portfolio of major projects continues to deteriorate for the third consecutive year and both cost and schedule performance are expected to worsen when NASA announces a new schedule for the Artemis I mission.[15] Overall development cost growth was approximately 31 percent, compared with 27.6 percent cost growth reported last year, and the average launch delay was approximately 12 months, compared with the 13 month delay that we reported last year (see fig. 3).

[15]GAO-19-377.The Artemis I mission is the first planned uncrewed demonstration mission of the Space Launch System, Orion Multi-Purpose Crew Vehicle, and Exploration Ground Systems programs. The Artemis II mission is the first planned crewed demonstration mission of these programs.

Figure 3: Development Cost Growth Performance and Average Launch Delay for Major NASA Projects from 2009 to 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Note: The years in the figure are the year we issued the report. Cost and schedule performance is compared across each report period (i.e., from one year to the next). In 2018, we were not able to determine the full extent of portfolio cost growth as NASA did not have an updated cost estimate for the Orion program at that time.

Since we last reported, our analysis found that six projects reported development cost growth, with four of these projects also reporting schedule delays. Two projects reported a development cost decrease. The remaining projects stayed within cost and schedule estimates since we last reported. Table 2 provides data on the cost and schedule performance of the 18 major projects in development that have cost and schedules baselines since our last assessment.[16]

Table 2: Development Cost and Schedule Performance of Selected Major NASA Projects Currently in Development

Na	Na	na	Cumulative performance from original baseline through current assessment		Changes between last GAO assessment and current assessment	
Overall performance	Project	Year confirmed	Cost (millions of dollars)	Schedule (months)	Cost (millions of dollars)	Schedule (months)
Lower than expected cost	NISAR	2016	-20.6	0	-42.6	0
Lower than expected cost	Lucy	2018	-8.0	0	-8.0	0
Within baseline	DART	2018	0.0	0	0.0	0
Within baseline	Europa Clipper	2019	0.0	0	N/A	N/A[f]
Within baseline	Landsat 9	2017	0.0	0	0.0	0
Within baseline	LBFD	2018	0.0	0	0.0	0
Within baseline	PACE	2019	0.0	0	N/A	N/A[f]
Within baseline	Psyche	2019	0.0	0	N/A	N/A[f]
Within baseline	SEP	2020	0.0	0	N/A	N/A[f]
Within baseline	SWOT	2016	0.0	0	0.0	0
Higher than expected cost	ICON[a]	2014	9.4	24	7.2	10
Higher than expected cost	Orion[b]	2015	918.2	0	539.2	0
Replan[c]	EGS[d]	2014	485.5	28	64.1	9
Replan[c]	Mars 2020	2016	359.3	0	310.9	0
Replan[c]	SLS[d]	2014	1,728.8	28	700.2	9
Rebaseline[e]	LCRD	2017	36.8	14	36.8	14
Rebaseline[e]	SGSS	2013	589.2	48	0.0	0
Rebaseline[e]	JWST	2008	4,421.5	81	0.0	0
	Total		**$8,520.1**	**223**	**$1,607.8**	**42**

[16]GAO-19-262SP.

Legend: DART Double Asteroid Redirection Test;: NISAR: NASA Indian Space Research Organisation – Synthetic Aperture Radar; LBFD: Low Boom Flight Demonstrator; PACE: Plankton, Aerosol, Cloud, ocean Ecosystem; SEP Solar Electric Propulsion; SWOT: Surface Water and Ocean Topography; ICON: Ionospheric Connection Explorer; Orion: Orion Multi-Purpose Crew Vehicle; EGS: Exploration Ground Systems; SLS: Space Launch System; LCRD: Laser Communications Relay Demonstration; SGSS: Space Network Ground Segment Sustainment; JWST: James Webb Space Telescope.

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Notes: Positive values indicate cost growth or launch delays. Negative values indicate cost decreases or earlier than planned launch dates.

[a]ICON launched in 2019.

[b]The Orion program's cost and schedule baseline is tied to the crewed Artemis II mission.

[c]A replan is a process generally initiated if development costs increase by 15 percent or more. NASA replanned the SLS program even though development costs did not increase by 15 percent or more. A replan does not require a new project baseline to be established.

[d]The SLS and EGS programs' cost and schedule baselines are tied to the uncrewed Artemis I mission.

[e]A rebaseline is a process initiated if the NASA Administrator determines that development costs increase by 30 percent or more or if other events make a rebaseline appropriate. When the NASA Administrator determines that development cost growth is likely to exceed the development cost estimate by 15 percent or more, or a program milestone is likely to be delayed from the baseline's date by 6 months or more, NASA must submit a report to the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate. 51 U.S.C § 30104(e)(2)(reporting requirement).

[f]Project crossed from formulation to implementation during our review period.

Cost growth and schedule delays since our last assessment occurred for the following reasons:

- The Orion program reported $539.2 million in development cost growth since our last assessment due to effects from the Artemis I uncrewed test flight's schedule slipping and poor contractor performance. The program reported no schedule delays because it has not delayed its launch readiness date of April 2023 for the crewed Artemis II test flight. This test flight is the milestone against which NASA assesses the Orion program's schedule performance.
- The SLS and EGS programs reported a combined $764.3 million in development cost growth since our last assessment due to poor SLS program performance and schedule delays. Both programs are now estimating costs to achieve a launch readiness date of March 2021. This represents an additional 9 months of delay since our last assessment, but, as of January 2020, this date was still under review by NASA leadership.
- The Mars 2020 program reported development cost growth of $310.9 million due to multiple development difficulties, delayed deliveries, and higher than anticipated procurement costs. The program reported no schedule delays as it continues to work towards its July 2020 launch readiness date.
- The Laser Communications Relay Demonstration (LCRD) program reported development cost growth of $36.8 million due to a slip in the

launch readiness date of its host spacecraft from November 2019 to January 2021 and unexpected work on a key component.

- The Ionospheric Connection Explorer's (ICON) program reported $7.2 million cost growth and experienced an additional 10-month delay due to delays related to its launch vehicle. The project successfully launched in October 2019.

Two projects reported a cost decrease since the last update:

- Lucy reported $8 million less in development costs due the launch vehicle procurement cost being less than originally estimated when NASA approved the project's cost and schedule baseline.
- The NASA Indian Space Research Organisation Synthetic Aperture Radar (NISAR) reported a development cost decrease. NASA reduced NISAR's reserves by $20.6 million because it had assessed that the project's risk posture had improved and these reserves were no longer necessary. We previously reported that NISAR was not meeting its cost baseline because of $30 million in cost growth associated with plans to collect additional soil moisture and natural hazard data of value to other federal agencies and the science community.[17] While NISAR is continuing to develop the capabilities to collect these additional data, NASA has subsequently made a decision to no longer include these costs as part of NISAR's cost estimate because they were not part of the baseline plan.

While our analysis reflects the status of cost and schedule for these major programs as of January 2020, it does not account for expected changes to the portfolio's cost and schedule performance due to pending schedule revisions and underreported costs for human exploration programs. Specifically, the portfolio analysis does not reflect an agency-approved schedule for the Artemis I mission because it had not been finalized at the time of our review. In July 2019—following the reassignment of key leadership that oversees the programs—the NASA Administrator stated that one of the first tasks once new leadership is in place would be to reexamine the Artemis I schedule. According to officials, the new Associate Administrator for Human Exploration and Operations joined NASA on December 2, 2019. As of January 2020, this schedule revision was still pending and both programs were estimating costs to a March 2021 launch date. In June 2019, we found the date could be as late as

[17]GAO, *NASA: Assessments of Major Projects,* GAO-18-280SP (Washington, D.C.: May 1, 2018).

June 2021 when all risks at that time were taken into account.[18] Further delays beyond March 2021 would lead to further cost growth.

In addition, the SLS and Orion programs are underreporting their cost growth. Specifically, in 2019, we found that the Orion program was not estimating costs to its committed Artemis II baseline launch date of April 2023.[19] Rather, at that time, the program was estimating costs to an October 2022 launch date. We recommended that NASA direct the Orion program to update its cost estimate to reflect the later schedule. NASA partially concurred with this recommendation stating that the program followed standard estimation processes. Further action is needed to implement this recommendation. Similarly, while NASA acknowledges cost growth for the SLS program, the amount is understated. In 2019, we found this gap resulted because NASA shifted some planned SLS scope to future missions but did not reduce the program's cost baseline accordingly. At that time, when we reduced the baseline to account for the reduced scope, the cost growth was about $1.8 billion or approximately 29 percent. We recommended that SLS update its development cost to be consistent with costs and scope, including costs NASA determined are not in the scope of the first flight. NASA agreed with this recommendation and said it would update the SLS development cost estimate as it proceeds with lunar planning efforts, but this effort is not yet complete.

Government Shutdown Had Various Effects on Projects but Did Not Affect Cost and Schedule Baselines

For 35 days between December 2018 and January 2019, NASA was subject to a partial government shutdown due to a lapse in fiscal year 2019 appropriations. The shutdown resulted in varying effects on NASA's major projects. Effects included delaying key milestone reviews and procurements, but, according to a senior NASA project official, it did not

[18]GAO-19-377.

[19]GAO-19-377.

result in breaches of cost and schedule baselines for any projects in the major project portfolio.[20]

Fourteen of 23 projects continued work during the shutdown. Of these 14 projects, seven projects are managed at the Applied Physics Laboratory—a University Affiliated Research Center—and the Jet Propulsion Laboratory (JPL)—a Federally Funded Research and Development Center—both of which continued operations throughout the shutdown.[21] NASA granted exceptions to the remaining seven projects to continue work, but not all projects received immediate exceptions and officials stated that there were still effects from the shutdown. For example, Landsat 9 was granted an exception approximately 2 weeks into the shutdown. Project officials stated that they accommodated schedule delays by adjusting projected delivery dates for two instruments and using project cost reserves to address cost impacts. The project still plans to launch by its committed launch readiness date. Additionally, officials from various projects that continued to operate noted that NASA was closed, which delayed key meetings and normal coordination with civil-service personnel.

The remaining nine projects in the portfolio that did not operate during the shutdown experienced varying effects from the shutdown, including delaying key milestone reviews, procurements, and hiring, as well as the inability to process invoices and loss of critical skills. Specific examples reported to us from projects in the implementation phase at the time of the shutdown include:

- LBFD delayed several of the project's key milestone dates, including the project's critical design review and flight readiness review, by approximately 5 weeks. Project officials stated they used $5.4 million in cost reserves to absorb the effects of the shutdown. However, officials noted that the decrease of the project's reserves increases risk going forward. The project requested the restoration of the $5.4 million in funds expended as a result of the shutdown through NASA's annual budget process. NASA officials told us a decision will not be made before spring 2020.

[20]This discussion includes 23 of the 25 projects in the major-project portfolio. SPHEREx and Dragonfly are not included because they entered the portfolio after the government shutdown.

[21]The projects that had funding ahead of the shutdown to continue working included DART, Europa Clipper, IMAP, Mars 2020, NISAR, Psyche, and SWOT.

- EGS, according to project officials, experienced a schedule delay of around 27 days to Multi-element Verification and Validation. This is a test process to ensure that systems at Kennedy Space Center can operate together to successfully process and launch the integrated SLS and Orion Systems. NASA officials estimated a $2 million cost associated with this delay. In addition, officials noted that, while construction activities were allowed to proceed, some critical skills such as iron and tubing workers were lost due to uncertainty regarding the duration of the government shutdown and the inability to process contractor invoices.
- SGSS—a project that has reported long-standing issues with contractor performance—reported cost and schedule impacts caused by the project not having access to NASA's White Sands Complex, the government shutdown, and a decline in contractor performance. As a result, the project was unable to perform integration and testing activities that were on the project's critical path, affecting the date for the project's first operational readiness review.
- Orion and SLS received partial exceptions to continue critical path work on Artemis I. However, both projects reported effects from the shutdown beyond Artemis I work including delays to procurement activities.

Specific examples reported to us among projects in the formulation phase at the time of the shutdown include:

- PACE established its cost and schedule baselines in August 2019, at which time it included approximately $34 million in costs above its preliminary cost estimate due to delays resulting from the government shutdown.
- WFIRST had to revise its schedule to accommodate 5 weeks of schedule impacts, but the project has not yet established a cost or schedule baseline so the government shutdown did not affect a launch readiness date. Project officials stated they used cost reserves to address $25 million of cost impacts.
- Restore-L incurred a 1-month delay to the project's overall schedule, the consumption of 1-month of schedule margin, and the use of $14 million of the project's cost reserves. The shutdown also resulted in delayed hiring of key positions.
- PPE delayed its planned contract start date from March 2019 to the end of May 2019, which also resulted in a delay to the project's preliminary launch readiness date.

Portfolio Analysis Does Not Yet Reflect New, Large Lunar Projects

Because our cost and schedule analysis in this report is as of January 2020, it does not include new, large lunar projects that will support NASA's efforts to return to the moon. The initial effect will be a reduction in cost and schedule growth because new projects are less likely to have experienced cost and schedule growth, but there is a longer-term risk because the programs themselves are risky. Six new lunar projects are likely to enter the implementation phase soon to meet a human lunar landing by 2024, which we have previously identified as an aggressive schedule.[22] NASA expects four lunar projects to exceed the $250 million major project threshold. However, not all cost estimates are finalized, and none of these projects have established cost and schedule baselines. These efforts include three projects that compose a small platform in lunar orbit called Gateway— PPE, Habitation and Logistics Outpost, and Logistics—and the Human Landing System. NASA has not yet determined whether two other lunar projects—Volatiles Investigating Polar Exploration Rover and Space Suits—will exceed the $250 million threshold.

NASA originally planned a lunar landing for 2028. However, as we have reported, in March 2019, the White House directed NASA to accelerate its plans and return astronauts to the lunar surface by 2024. This timeline was established, in part, to create a sense of urgency regarding returning American astronauts to the Moon. NASA senior officials have acknowledged the aggressiveness of this accelerated schedule. In December 2019, we found that effectively executing the Artemis III mission will require extensive coordination within NASA and its commercial partners, and for each individual program to meet aggressive development time frames. We recommended using program management tools and practices to set these new programs up for success.

Further, the complexity of these efforts present additional cost and schedule risks for NASA's major project portfolio over the next couple of years. An example of one high-risk project is the PPE project, which is being designed to provide Gateway with power, communications, attitude control, orbit maintenance, and the ability to change orbits. The PPE contractor must deliver a solar electric propulsion system as part of PPE's

[22]GAO-20-68.

space flight demonstration. NASA maintains a separate project, SEP, which is developing and qualifying the solar electric propulsion system. According to NASA, the contractor completing the development and qualification work has struggled with its performance, which led NASA to modify the development contract and reduce technical requirements for the Solar Electric Propulsion project. For PPE, NASA will be faced with either schedule delays or the need to reduce technical requirements if development challenges continue with solar electric propulsion. Given that NASA plans to launch PPE in less than 3 years—December 2022—this is an area that we will continue to monitor as changes could have implications for both cost and schedule, and the extent of risk NASA will face in executing the mission.

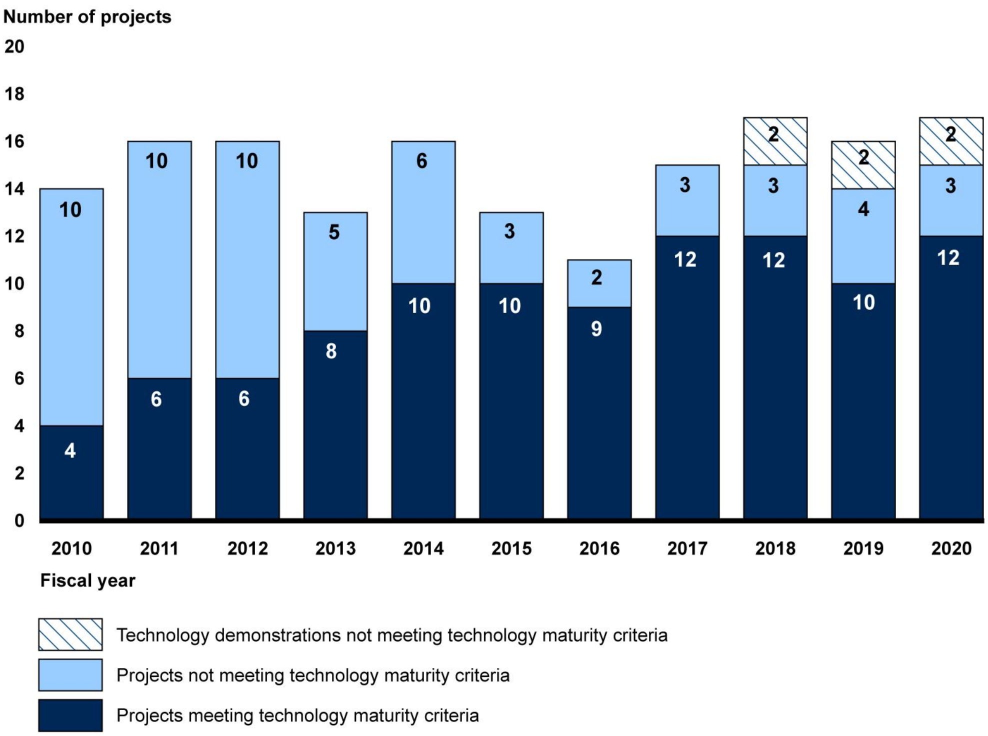
NASA Has Generally Maintained Portfolio Progress in Demonstrating Technology Maturity and Design Stability

NASA has generally maintained its progress over the years demonstrating the technology and design maturity of its major projects. For example, most NASA major projects have met the best practice of maturing technologies by a preliminary design review and NASA has maintained the number of projects with stable designs at critical design review. With respect to technologies, NASA continues to report low number of critical technologies on its projects compared to several years ago, which may be an indication that projects are taking on less technical risk. But we have also found that there is subjectivity in the process NASA uses to identify critical technologies that could also be a factor in this change. NASA has started to take steps to address concerns regarding subjectivity in the critical technology identification process, and this will be an area we continue to monitor.

NASA Projects Generally Maintain Technology Maturity Levels

We found that most of NASA's major projects in development—12 of 17—met the best practice of maturing all technologies to technology readiness level (TRL) 6 by preliminary design review. This review demonstrates that the preliminary design meets all system requirements with acceptable risk and within the cost and schedule constraints and establishes the basis for proceeding with detailed design. (App. IV provides a description of technology readiness levels, which are the metrics used to assess technology maturity). NASA's technology maturity levels in 2020 were generally consistent with recent years (see fig. 4). We did not include the LBFD and SEP projects, which are technology demonstrations, because the projects do not intend to mature their technologies until operations or qualification testing before hand-off to the PPE project, respectively. Two other technology demonstrations—LCRD and Restore-L—are included in the analysis because both projects intended to mature the technologies before launch. Our best practices work has shown that reaching a TRL 6—which includes demonstrating a representative prototype of the technology in a relevant environment that simulates the harsh conditions of space—by preliminary design review can minimize risks for the systems entering product development.[23]

Figure 4: Number of NASA's Major Projects Attaining Technology Maturity by Preliminary Design Review from 2010 to 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

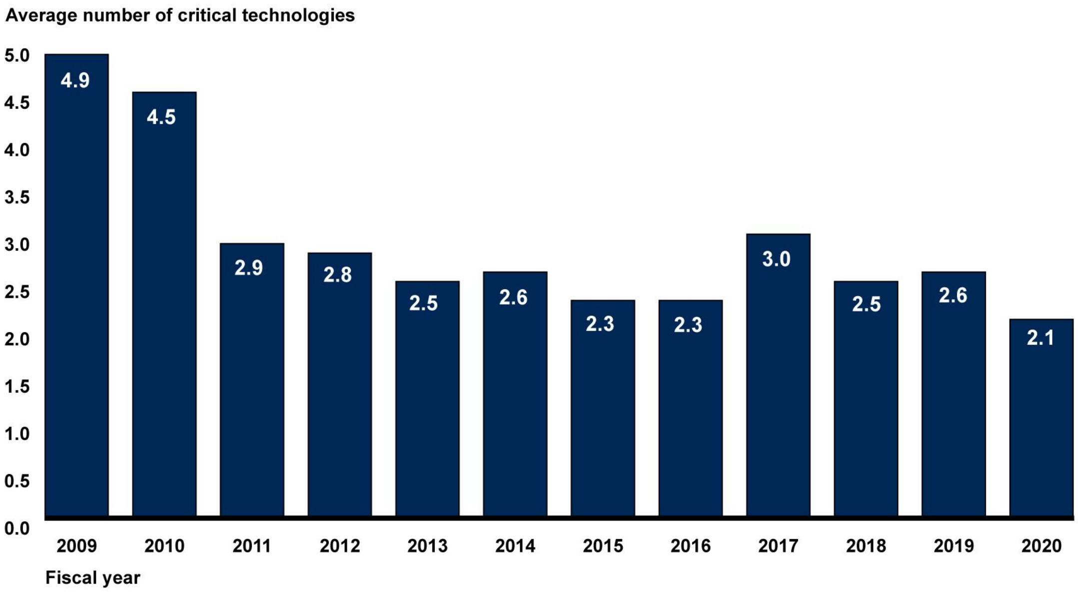
[23]Appendix V contains information about GAO's product development best practices and the project attributes and knowledge-based metrics that we assess projects against at each stage of a system's development.

Note: Includes projects that completed preliminary design review and identified critical or heritage technologies. We included two technology demonstration missions in our analysis—LCRD and Restore-L—because officials had told us that, while these technology demonstration missions are not required to mature technologies before launch, both of these projects intended to do so. The years in the figure are the years we issued the report.

Of the four projects we added to our technology maturity analysis this year, three—Europa Clipper, PACE, and Psyche—matured all of their technologies to a TRL 6. The WFIRST project assessed the maturity of 23 technologies at its preliminary design review (PDR) and determined three were not yet mature. Two heritage technologies were not assessed because changes to their design required further development. The third technology did not need to be matured by PDR because it is a technology demonstration.

The 18 projects in the current portfolio that were in development as of January 2020—meaning the project held both a PDR and a confirmation review—reported an average of 2.1 critical technologies, which is generally consistent with the number projects have self-reported over the past 9 years (see fig. 5). Of the four projects added to the analysis this year—Europa Clipper, PACE, Psyche, and SEP—only PACE and SEP reported having critical technologies. PACE and SEP reported two critical technologies each. One project that left the portfolio this year, Parker Solar Probe, had 10 critical technologies, which contributed to a decrease from 2019 to 2020.

Figure 5: Average Number of Critical Technologies Reported by NASA's Major Projects in Development from 2009 to 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Note: Includes all projects that held a preliminary design review (PDR) and key decision point C as of January 2020, except for the Restore-L project. Restore-L held a PDR by this time frame, but has continued to delay its key decision point C review. The years in the figure are the years we issued the report.

As seen in figure 5, an average of 2.1 critical technologies is a marked decrease from the 4.9 and 4.5 average numbers of critical technologies reported in 2009 and 2010, respectively. We have previously observed that the decline in the average number of critical technologies may be an indication that recent projects are taking on less technology risk than their predecessors by incorporating fewer new critical technologies into their design.[24] Last year, however, we reported that subjectivity exists in the processes NASA uses to identify and assess critical technologies, which could also be a factor in the changes in the average number of critical technologies and has the potential to affect a comparison of the average number of technologies from year to year.[25]

NASA has continued to take steps to address some of these concerns and is currently drafting a Technology Readiness Assessment (TRA) Best

[24]GAO, *NASA: Assessments of Selected Large-Scale Projects,* GAO-13-276SP (Washington, D.C.: Apr. 17, 2013).

[25]GAO-19-262SP.

Practices document as part of the agency's High-Risk Corrective Action Plan. An initial draft was prepared at the end of 2019 and is continuing through agency review and revision. NASA intends this document to be a best practices guide that will gather high-level information regarding TRA best practices into a single source with citations to governing documents from across the agency providing information on how to conduct an assessment. We will continue to monitor NASA's efforts in this area.[26]

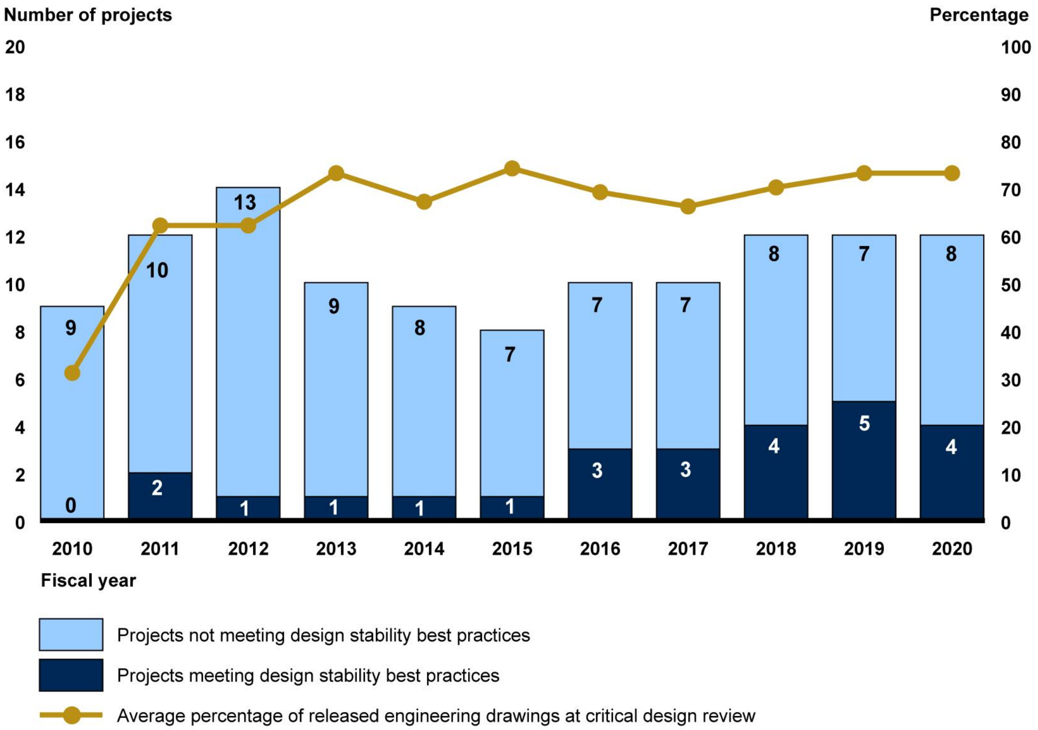
NASA Has Generally Maintained the Number of Projects Meeting the Design Stability Best Practice, but Most Projects Have Late Design Drawing Growth

NASA has maintained the number of projects with stable designs at critical design review, but most projects still do not meet this best practice. The critical design review is the time in a project's life cycle when the integrity of the project design and its ability to meet mission requirements are assessed. Our work on product development best practices has shown that releasing at least 90 percent of engineering drawings by the time of the critical design review lowers the risk of projects experiencing design changes and manufacturing problems that can lead to cost and schedule growth. Engineering drawings are considered to be a good measure of the demonstrated stability of a product's design because the drawings represent the language used by engineers to communicate to the manufacturers the details of a new product design—what it looks like, how its components interface, how it functions, how to build it, and what critical materials and processes are required to fabricate and test it. Once the design of a product is finalized, the drawing is "releasable."

Of the 12 projects that held a critical design review as of January 2020, four projects met the best practice of releasing 90 percent of design drawings by critical design review, which is similar to recent years. The average percentage of drawings releasable at critical design review is 73 percent, the same percentage as last year. While most projects are not meeting the best practice, this still represents an improvement since 2010 (see fig. 6).

[26]For more information on technology readiness assessments, see GAO-20-48G.

Figure 6: NASA Major Projects Releasing at Least 90 Percent of Engineering Drawings and Average Percentage of Released Drawings by Critical Design Review from 2010 to 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Note: The years in the figure are the years we issued the report.

This year, we removed three projects from our analysis—Interior Exploration using Seismic Investigations, Geodesy and Heat Transport; Ice, Cloud and land Elevation Satellite-2; and Parker Solar Probe. None of these projects met the best practices as of our analysis in 2019. This year, we added three new projects—DART, LBFD, and Lucy—none of which met the best practice. In addition, the Landsat 9 project experienced drawing growth such that it no longer met the best practice as it did in 2019.

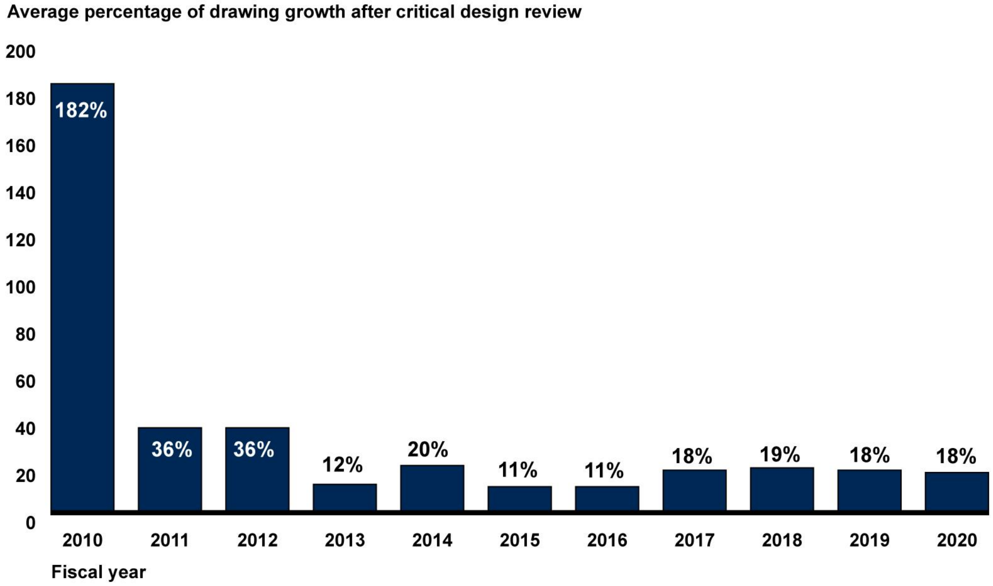
Of the three new projects, the LBFD project released the fewest engineering drawings—37 percent—at its critical design review. Project officials explained that they never anticipated meeting the 90 percent best practice because the contractor is using a rapid prototyping process, which enables the contractor to initiate early fabrication of the vehicle as key design drawings are completed. As a result, the project had been targeting a release of 60 to 70 percent of drawings by critical design review, but the project also did not meet that target. LBFD project officials stated that drawing releases were delayed due to a lack of experienced stress analysts dedicated to the project at the contractor, which was exacerbated by delays from vendors whose parts and specifications are required to complete certain drawings. Officials reported that the contractor's management has taken steps to address these issues. Furthermore, they noted that the project has released drawings for the aircraft's primary structures to allow manufacturing to begin, with the remaining drawings mostly representing the secondary structures and subsystems. For these reasons, despite not meeting the best practice of releasing 90 percent of design drawings by critical design review, project officials expressed confidence in their approach.

Design drawing growth has remained relatively steady, however, certain projects continue to experience such growth.[27] Experiencing a large amount of design drawing growth after critical design review may be an indicator of instability in a project's design late in the development cycle. Design changes at this point can be costly to the project in terms of time and funding because hardware may need to be reengineered or reworked as a result.

This year, nine out of 12 projects experienced design drawing growth after critical design review, compared to nine of 12 projects last year. The average percentage of design drawing growth after critical design review remained the same as last year at 18 percent (see fig. 7).

[27]Design drawing growth is measured as the number of design drawings projects expected at their respective critical design reviews compared to the updated number of design drawings projects expected as reported in data received by GAO each year.

Figure 7: Average Percentage of Engineering Drawing Growth after Critical Design Review among NASA Major Projects from 2010 to 2020



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Note: Drawing growth in 2010 was primarily attributed to the Solar Dynamics Observatory (SDO) because it did not have a stable design at its critical design review and drawings for SDO's instruments were not included in this review. The project launched in 2010 and exited the portfolio. The years in the figure are the years we issued the report.

Of the projects experiencing design drawing growth after critical design review this year, growth ranged from 2 percent to 70 percent. Of the projects experiencing the highest growth in design drawings—JWST, LCRD, Mars 2020, and Orion—none had met the best practice of releasing 90 percent of design drawings by critical design review.

As we have previously reported, NASA has raised concerns about our use of the design drawing best practice to assess design stability because, among other reasons, they view it as a legacy standard developed prior to the use of computerized drawings and NASA officials no longer think it is applicable for modern NASA projects.[28] In discussing this concern with project managers, we found that there are a variety of potential tools to measure design stability and no clear consensus on the topic. Some projects still used design drawings, even if they also used computerized drawings and modelling, while others cited mass and power margins, growth in requirements, and projects' schedule performance as

[28]GAO-19-262SP.

other metrics they use to assess stability. In other GAO work in this area, we have seen use of engineering models and prototyping to test design stability.[29]

Traditionally, we have used engineering design drawings released by critical design review because this metric can be applied commonly across most of NASA's portfolio of major projects and because it was among several metrics identified by a panel of experts convened by the National Academy of Sciences for GAO in 2013, which included former NASA officials. However, we understand that several years have passed since the completion of this work and plan to look more broadly at the metric as a part of our ongoing work with both NASA, the Department of Defense, and the Department of Homeland Security. As part of that work, we will continue to follow up with NASA on ongoing efforts it has in this area.

NASA Has Actions Underway to Identify and Address Challenges Contributing to Acquisition Risk

NASA has acknowledged recent challenges in cost and schedule growth and is taking steps to identify and address areas contributing to acquisition risk. GAO has designated NASA's management of acquisitions as a high-risk area for almost 3 decades. In our 2019 High-Risk Assessment, we found that NASA had taken steps to build capacity to reduce acquisition risk, including updating tools aimed at improving cost and schedule estimates but continued to experience challenges.[30] For example, NASA has not always followed best practices in areas such as estimating costs and schedules and earned value management, and projects are reluctant to update their cost and schedule estimates as new risks emerge. Further, in our May 2018 assessment of major projects, we found that several NASA major projects experienced workforce challenges, including not having enough staff or staff with the right skills.[31]

[29] GAO, *Weapon Systems: Prototyping Has Benefited Acquisition Programs, but More Can Be Done to Support Innovation Initiatives,* GAO-17-309 (Washington, D.C.: June 27, 2017)

[30] GAO-19-157SP.

[31] GAO-18-280SP.

NASA has also identified capability gaps in areas such as scheduling, earned value management, and cost estimating.

In December 2018, NASA completed a Corrective Action Plan to address NASA's inclusion in GAO's biennial High-Risk Report and after several of its highest-profile missions experienced cost and schedule growth. This plan identifies a range of initiatives that will help to provide a foundation for making better management decisions, but it will take time to assess the extent to which these efforts are having an effect. Further, our high-risk work has also found that success hinges on leadership commitment, accountability, and demonstrated progress.[32]

The Corrective Action Plan covers a number of initiatives and we identified three that relate to GAO's capacity criteria for high-risk, which is the extent to which the agency has the people and resources to resolve the risk.[33] An update on the status of NASA's progress implementing each initiative follows.

- **Enhance Earned Value Management (EVM) Implementation.** EVM is a key project management tool that integrates information on a project's cost, schedule, and technical efforts for management and decision makers. It measures the value of work accomplished in a given period and compares it with the planned value of work scheduled for that period and the actual cost of work accomplished. EVM is part of the agency's efforts to understand project development needs and to reduce cost and schedule growth. NASA requires EVM for major space flight projects unless waived. This initiative also addresses EVM surveillance, which is a review of a contractor's EVM system with the intention of understanding how well the contractor uses EVM data to manage cost, schedule, and performance.

  The goal of the EVM implementation initiative is to roll out EVM capability to all relevant centers, include EVM data in status meetings, increase surveillance, and reduce errors in EVM data. NASA reported that its four centers with the most EVM projects—Kennedy Space Center, Johnson Space Center, Marshall Space Flight Center, and

[32]GAO, *High-Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others*, GAO-17-317 (Washington, D.C.: Feb. 15, 2017); and GAO-19-157SP.

[33]Other initiatives to implement in the Corrective Action Plan include: Improve Human Exploration and Operations Mission Directorate Portfolio Insight and Status, Include Original Agency Baseline Commitments for Performance-Driven Re-baselined Projects, Enhance Annual Strategic Review Process, and Create Technology Readiness Assessment Best Practices Document.

Goddard Space Flight Center—have EVM capability, and that it plans to expand in-house EVM surveillance capability in 2020. While the centers with the most EVM projects have EVM capability, NASA officials explained there is some cultural resistance to the EVM process due to its perception as expensive, which leads projects and programs to request waivers and deviations from EVM requirements. To address the culture around EVM and promote its use, officials said senior NASA leaders have increased emphasis on EVM at agency-level project reviews from senior leadership, which emphasizes the importance of EVM to projects.

Since at least 2012, NASA struggled with resource constraints regarding EVM surveillance capability. But, according to officials, the agency is now targeting the beginning of 2020 to implement its in-house surveillance plans. Officials explained conducting EVM surveillance is the main approach for NASA's plans to enhance EVM implementation. In November 2012, GAO recommended that NASA update its procedural requirements to implement a formal EVM surveillance program in order to improve the reliability of EVM data collected by NASA programs. NASA agreed with the recommendation but cited concerns about affordability for implementation. NASA currently uses Defense Contract Management Agency (DCMA) to conduct EVM surveillance on some large contracts. However, for contractors without a DCMA presence—such as Applied Physics Laboratory and Southwest Research Institute—NASA validated the EVM system, but has not performed EVM surveillance. Officials expect in-house surveillance to improve the quality of compliance monitoring, and NASA has added three contracted work year equivalents to complete in-house EVM surveillance. NASA plans to add one additional full-time employee or work year equivalent to focus on the initiative to enhance EVM implementation in 2020.

- **Joint Cost and Schedule Confidence Level (JCL) Policy.** A JCL produces a point-in-time estimate that includes all cost and schedule elements in phases A through D, incorporates and quantifies known risks, assesses the impacts of cost and schedule to date, and addresses available annual resources, among other things. NASA originally implemented a JCL policy to help reduce the cost and schedule growth in its portfolio and improve transparency, and increase the probabilities of meeting those expectations.

  NASA has completed this initiative through an update to its JCL policy that now requires projects with life cycle costs over $1 billion to conduct JCLs at key decision points (KDP) B and C, critical design review, and potentially at KDP-D if development costs are 5 percent or more over the agency baseline commitment. Additionally, NASA will require any project with a life cycle cost of $250 million or more that rebaselines its cost and schedule to recalculate its JCL. Previously, a JCL was only required at KDP-C for all projects with a life cycle cost estimate over $250 million, and NASA policy did not require projects to update their JCL as they progressed through development. Figure 8 provides an overview of how JCL requirements have evolved at NASA from 2009 to 2019.

Figure 8: Joint Cost and Schedule Confidence Level (JCL) Policy 2009-2019

2009 JCL Policy

- JCLs required for projects exceeding $250 million at KDP-C
- Requires projects to be baselined at the 70 percent confidence level
- Requires funding the project at least to the 50 percent confidence level

→

2012 NASA JCL Policy

- JCLs required for all projects exceeding $250 million at KDP-C
- JCL suggested for projects over $250 million that rebaseline
- Requires projects to be baselined at the 70 percent confidence level
- Requires funding the project at least to the 50 percent confidence level

→

2019 NASA JCL Policy Update

- JCLs required for all projects exceeding $250 million at KDP-C
- JCL required for projects over $250 million that rebaseline
- If the project costs over $1 billion, JCL also required at KDP-B
- If the project costs over $1 billion, the JCL from KDP-C is required to be updated at critical design review
- If the project costs over $1 billion and costs are 5 percent or more over the development agency's baseline commitment, a JCL is also required at KDP-D
- Requires projects to be baselined at the 70 percent confidence level
- Requires funding the project at least to the 50 percent confidence level

JCL = Joint Cost and Schedule Confidence Level

KDP = Key Decision Point

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Although the JCL policy has been updated, no projects have gone through the new process yet. NASA is waiting for a project that meets the updated policy's criteria—a life cycle cost estimate over $1 billion and passing one of the KDPs—to implement the new aspects of the policy. Based on the schedules of NASA major projects, officials anticipate either a Gateway project, Human Landing System, or the Mars Sample Return will be the first to implement the new policy of conducting a JCL at KDP-B. NASA officials explained that they expect the JCL data collected at KDP-B will be lower quality compared to JCLs completed later in development due to the availability of data at that stage in the project's life cycle. According to officials, Europa Clipper will likely be the first project with a life cycle cost over $1 billion to pass the critical design review milestone, which now requires an update to the KDP-C JCL. Officials reported the Orion program will be doing a JCL at KDP-D because they are more than 5 percent over the agency baseline commitment. Orion's new JCL analysis is in response to the updated JCL policy.

- **Curriculum Development for Programmatic Analysts.** NASA is establishing an updated training curriculum for its analysts to strengthen the agency's programmatic capabilities and promote consistency of the agency's best practices and processes. NASA has started drafting course content for 10 of 28 new courses, and one existing course has been significantly updated. Some of these courses will be piloted by programmatic analysts in fiscal year 2020. Courses cover NASA programmatic policy, JCL implementation, independent assessments, scheduling, cost estimating, and project integration and communication. NASA initiated these new training courses in response to a NASA-conducted study of its programmatic workforce, which found an inadequate number of analysts with proficient skills and limited resources. The training courses aim to strengthen NASA's programmatic capability by emphasizing agency best practices and methods. While new courses are being developed, officials explained NASA has not yet determined expectations for class participation requirements but plan to consider employee experience, demand, and potential classes to serve as "refreshers."

In addition to the Corrective Action Plan, an effort to restructure NASA's Independent Program Assessment Office (IPAO) also aimed to strengthen the programmatic analyst workforce. Restructuring started in October 2015 and was completed in December 2017. Under the restructuring, NASA devolved the responsibility for conducting independent assessments to mission directorates. NASA completed its decentralization of the independent assessment function in an effort to better use its programmatic analyst workforce by deploying staff to the agency's centers to meet program needs in areas such as program management, cost estimating, and resource analysis, and to fill gaps in program analysis skills at the center level. Table 3 shows some of the changes in selected topic areas.

Table 3: Selected Changes from NASA's Independent Program Assessment Office (IPAO) Decentralization, as of June 2016

Topic	From:	To:
Responsibility	• Independent Assessment organized and performed by a central organization (IPAO) • IPAO Reports to Associate Administrator for Independent Assessment	• Independent Assessments continue under the responsibility of the Mission Directorate with support from the Centers • Mission Directorates report to Associate Administrator for Independent Assessment
Review Teams	• Independent assessments performed by Standing Review Boards (SRBs).	No change

Topic	From:	To:
SRB Member Independence	• Come from separate chain of command • Funded from source other than project under review • No conflict of interest	No change
SRB Selection	• SRB chair selection and technical membership facilitated by IPAO working with Convening Authorities. • Cost and schedule analysts and Review Manager assigned by IPAO. • Decision Authority approves SRB.	• SRB chair selected by Mission Directorate and Centers with assistance from Office of the Chief Engineer for technical members and the Office of the Chief Financial Officer for cost and schedule analytical expertise. • Review management facilitation provided by Mission Directorate or Center. • Decision Authority approves membership (no change).

Source: GAO analysis of NASA documentation. | GAO-20-405

With respect to the programmatic workforce assigned to independent assessment teams, the Office of the Chief Financial Officer has a key role in identifying resources across the agency to help mission directorates fulfill this need. Officials within this office told us that one area they have to actively manage is ensuring there are sufficient schedule analysts and civil servants to serve on Standing Review Boards (SRB). According to these officials, the skill set required by schedule analysts is in high demand across the government and is a difficult area to recruit and retain talent, especially when competing with the private sector. Officials explained that they have the option to hire contracted support to serve on SRBs when needed.

NASA also identified SRB civil servant staffing as an area to monitor. In an effort to increase the number of programmatic analysts, NASA staffed SRBs with more junior staff and paired them with more experienced analysts. NASA officials noted this provides a learning experience for junior analysts and has potential to create a pipeline of qualified analysts to serve on SRBs. Mission Directorate officials responsible for assembling the independent assessment teams stated that the Office of the Chief Financial Officer and the Office of the Chief Engineer have provided assistance in this area and there has been no difficulty meeting these staffing needs.

In March 2016, we highlighted three areas that could be negatively affected by the reorganization of the independent assessment function—independence, the robustness of reviews, and information sharing.[34] As of

[34]GAO, *NASA: Assessments of Major Projects,* GAO-16-309SP (Washington, D.C.: Mar. 30, 2016).

January 2020, at least 10 of the projects in our portfolio have set up a SRB through their respective Mission Directorates. In speaking with Mission Directorates, selected projects, and select Standing Review Board chairs, multiple officials told us that the transition was transparent and that the process is now more efficient. For example, one official stated the new process requires less time for tasks like giving presentations, completing paperwork, and attending meetings. One Mission Directorate new to the SRB process reported the reviews are working well and SRBs provided additional insights to the independent reviews the Mission Directorate was already conducting.

However, officials from another Mission Directorate noted there is an ongoing challenge in the consistency of interpreting SRB conflict of interest rules across the centers. Previously, one center was responsible for vetting all conflicts of interest and now the process is decentralized. According to officials, the decentralization may be contributing to varying strictness of the rules, which can cause efficiency problems because of inconsistent rejections of potential SRB members. For example, very strict vetting can make SRB staffing difficult in specialized areas, where there are only a handful of experts to choose from. According to officials, NASA headquarters and General Counsel are aware of this challenge.

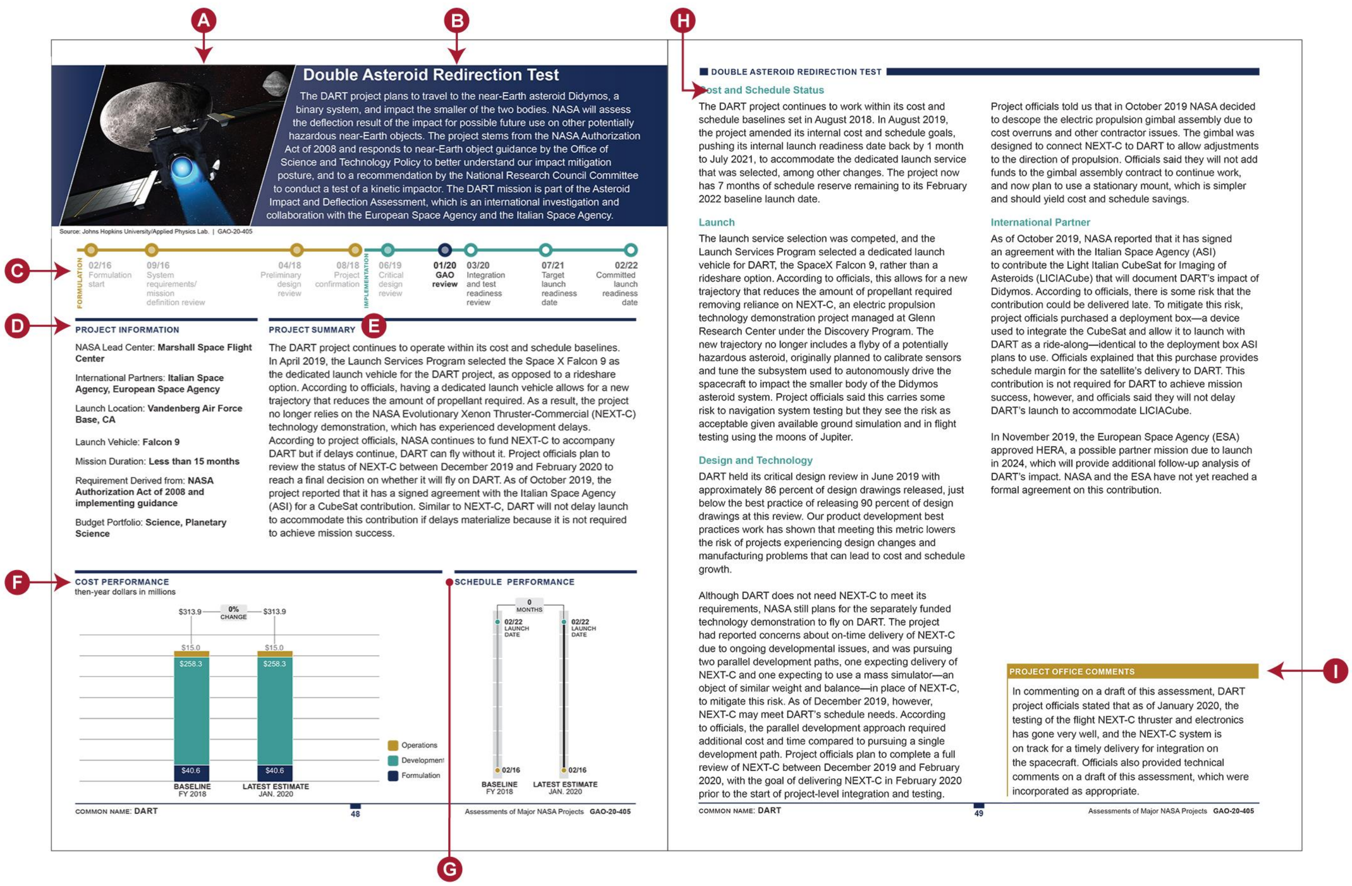
It is too early to tell if the decentralization of IPAO will improve the quality of reviews or address skill gaps in the workforce. This is in part due to the frequency with which SRBs are held. According to NASA policy, SRBs must be conducted at various points in a project's life cycle. However, with some projects taking years to complete, it is possible a project has had limited exposure to the new independent assessment function since it has not passed many, if any, of these key points since the dissolution of IPAO in 2015. As time passes, more projects will conduct more SRBs under the new model, and its effectiveness could be better evaluated at that time. We will continue to monitor the transition through future reviews, including of NASA's lunar programs.

Project Assessments

In the following section, we summarize the individual assessments of the 24 projects we reviewed in a two-page or one-page profile of each project. Each assessment includes a description of the project's objectives, information about the NASA centers and international partners involved in the project, the project's cost and schedule performance, a timeline identifying key project dates, and a brief narrative describing the current status of the project. Twenty-one assessments describe the challenges we identified as well as challenges that we have identified in the past. On the first page, the project profile presents the standard information listed above. On the second page of the assessment, we provide an analysis of the project challenges, and outline the extent to which each project faces cost, schedule, or performance risks because of these challenges, if applicable. Three of the assessments do not provide an in-depth review of program challenges because the projects had few, if any, challenges to report. The information presented in these assessments was obtained from NASA documentation, answers to our questionnaire by NASA officials, interviews with project staff, and includes our analysis of project cost and schedule information. NASA project offices were provided an opportunity to review drafts of the assessments prior to their inclusion in the final product, and the projects provided both technical corrections and more general comments. We integrated the technical corrections as appropriate and summarized the general comments at the end of each project assessment.

See figure 9 for an illustration of a sample assessment layout.

Figure 9: Illustration of a Sample Project Assessment



- **A** Illustration of the spacecraft, instrument, aircraft, launch vehicle, or ground system.
- **B** General description of the mission's objectives.
- **C** Timeline identifying key dates for the project including when the project began formulation, held major design reviews, began implementation, and launched or fielded an operating capability.
- **D** **Project Information:** Information on the responsible NASA center, international partners, launch plans, mission duration, the source of mission's requirements, and budget portfolio.
- **E** **Project Summary:** Brief narrative describing the current status of the project.
- **F** **Cost:** For projects in formulation, the preliminary cost estimate. For projects in implementation, the approved cost baseline and latest estimate.
- **G** **Schedule:** For projects in formulation, the preliminary launch readiness target date or range of dates. For projects in implementation, the approved schedule baseline and latest estimate.
- **H** The second page of the assessment is an analysis of the project challenges and the extent to which each project faces cost, schedule, or performance risks because of these challenges.
- **I** **Project Office Comments:** General comments provided by the cognizant project office.

Source: GAO analysis. | GAO-20-405

Assessments of Projects in the Formulation Phase

Dragonfly

BLANK

Interstellar Mapping and Acceleration Probe (IMAP)

BLANK

Power and Propulsion Element (PPE)

Restore-L

Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx)

BLANK

Wide-Field Infrared Survey Telescope (WFIRST)

Assessments of Projects in the Implementation Phase

Commercial Crew Program (CCP)

Double Asteroid Redirection Test (DART)

Europa Clipper

Exploration Ground Systems (EGS)

James Webb Space Telescope (JWST)

Landsat 9

Laser Communications Relay Demonstration (LCRD)

Low Boom Flight Demonstrator (LBFD)

Lucy

NASA ISRO – Synthetic Aperture Radar (ISRO)

Orion Multi-Purpose Crew Vehicle (Orion)

Plankton, Aerosol, Cloud, ocean Ecosystem (PACE)

Psyche

Solar Electric Propulsion (SEP)

Space Launch System (SLS)

Space Network Ground Segment Sustainment (SGSS)

Surface Water and Ocean Topography (SWOT)

Agency Comments

We provided a draft of this report to NASA for comment. In written comments, NASA generally agreed with the findings of the report. The comments are reprinted in appendix VI. NASA also provided technical comments, which have been addressed in the report, as appropriate.

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

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

Cristina T. Chaplain
Director, Contracting and National Security Acquisitions

List of Committees

The Honorable Jerry Moran
Chairman
The Honorable Jeanne Shaheen
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Ted Cruz
Chairman
The Honorable Kyrsten Sinema
Ranking Member
Subcommittee on Aviation and Space
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable José Serrano
Chairman
The Honorable Robert Aderholt
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Kendra Horn
Chairwoman
The Honorable Brian Babin
Ranking Member
Subcommittee on Space and Aeronautics
Committee on Science, Space, and Technology
House of Representatives

Appendix I: Objectives, Scope, and Methodology

The objectives of our review were to assess (1) the cost and schedule performance of the National Aeronautics and Space Administration's (NASA) portfolio of major projects; (2) NASA's progress developing and maturing technologies and achieving design stability; and (3) progress NASA has made identifying and addressing challenges that contribute to acquisition risk. We also described the status and assessed the risks and challenges faced by NASA's 24 major projects, each with life cycle costs more than $250 million. When NASA determines that a project has an estimated life cycle cost of over $250 million, we include that project in our annual review up through launch or completion. We did not complete an individual assessment for one project, Ionospheric Connection Explorer (ICON), which launched during our review, but included data from this project in other analyses, as appropriate.

This is our 12th annual report assessing selected large-scale NASA programs, projects, and activities. To complete our annual assessments, we typically compare cost and schedule performance of NASA's portfolio across each of our reporting periods. The reporting period is the year we issue our report, and we have typically used cost and schedule data that NASA provided to us early in that calendar year. For example, for our 2018 assessment, we based the reporting period on data NASA provided to us in January and February 2018.[1] For our last assessment, due to the partial government shutdown, which occurred between December 2018 and January 2019 due to a lapse in appropriations for fiscal year 2019, we included data current as of December 2018, unless otherwise noted.[2] The current reporting period uses data NASA provided to us in January 2020.

To respond to the objectives of this review, we developed several standard data questionnaires. We developed multiple questionnaires, which were completed by NASA's Office of the Chief Financial Officer, to gather data on each project's cost and schedule. We used another questionnaire, which was completed by each project office, to gather data

[1] GAO-18-280SP.

[2] GAO-19-262SP.

on projects' technology and design maturity and development partners. The information available on individual projects depends on where a project is in its life cycle. For example, for projects in an early stage of development—called formulation—there are still unknowns about requirements, technology, and design. We also analyzed questionnaire data from our prior reviews.

To assess the cost and schedule performance of NASA's major projects, we compared cost and schedule data as of January 2020 provided on questionnaires by NASA for the 18 projects in the implementation phase during our review to previously established cost and schedule baselines.[3] The Commercial Crew Program has a tailored project life cycle and project management requirements, so it was excluded from some analyses. In addition, we assessed development cost and schedule performance for NASA's portfolios of major projects from 2009 to January 2020 to examine longer-term trends. To determine cost performance, we compared the projects' baseline development costs and development costs as of January 2020. We included the Solar Electric Propulsion (SEP) project in our analysis even though NASA did not sign the baseline memo until February 2020 because the SEP project briefed NASA headquarters for its baseline approval in June 2019. We did not include the Wide Field Infrared Survey Telescope (WFIRST) project, whose baseline was also approved in February 2020, because this project did not brief headquarters or have a signed memo until February 2020. This was past our data cutoff date of January 2020. For projects that had launched, we used the final development cost data from the project's Key Decision Point E memorandum.

All cost information in this report is presented in nominal then-year dollars for consistency with budget data. Current baseline costs for all projects are adjusted to reflect the cost accounting structure in NASA's fiscal year 2009 budget estimates. For the fiscal year 2009 budget request, NASA changed its accounting practices from full-cost accounting to reporting only direct costs at the project level. To determine schedule performance, we compared the project's baseline launch readiness or completion date and current launch readiness or completion date as of January 2020. We also spoke to officials about the effects of the government shutdown to determine whether projects received an exception to continue operation or not, and to determine if projects experienced any cost or schedule

[3]For the purpose of this review, cost performance is defined as the percentage of total development cost growth over the development cost baseline.

impacts as a result of the shutdown. We used project reported data to characterize the effect of the shutdown. We also spoke to officials about NASA's plans for upcoming lunar efforts and the extent to which these efforts may become major projects in the future.

To assess technology maturity, we asked project officials to complete a questionnaire that provided the technology readiness levels of each of the project's critical and heritage technologies at various stages of project development including the preliminary design review. We did not verify or validate project office supplied data on the technology readiness level of technologies or the classification of technologies as critical or heritage.

For the 17 projects in development that identified critical or heritage technologies, we compared those levels against our technology maturity best practice to determine the extent to which the portfolio was meeting the criteria. Our work has shown that reaching a technology readiness level 6—which indicates that the representative prototype of the technology has been demonstrated in a relevant environment that simulates the harsh conditions of space—by the preliminary design review is the level of maturity needed to minimize risks for space systems entering product development. Originally developed by NASA, technology readiness levels are measured on a scale of one to nine, beginning with paper studies of a technology's feasibility and culminating with a technology fully integrated into a completed product. See appendix IV for the definitions of technology readiness levels. We compared this year's results against those in prior years to assess whether NASA was improving in this area.

We did not assess technology maturity for those projects that had not yet reached the preliminary design review at the time of this assessment or for projects that reported no critical or heritage technologies. We also excluded 2009 from our analysis since the data were only for critical technologies and did not include heritage technologies. This year, our analysis of technology maturity included two technology demonstration projects. The two technology demonstration projects were the Laser Communication Relay Demonstration (LCRD) and Restore-L. LCRD and Restore-L are managed by Goddard Space Flight Center. The Mission Directorate in charge of technology demonstration projects policy does not require technology demonstrations to mature all of their technologies to a technology readiness level (TRL) 6 by preliminary design review.[4] NASA officials explained that this is because the purpose of some technology demonstration projects is to mature new technologies to TRL 6 or higher by the end of the demonstration, making it not feasible for these projects to achieve this level by preliminary design review (PDR). However, we included LCRD and Restore-L in our analysis because they planned to mature their technologies prior to launching or reaching completion. Therefore, the same risks of subsequent technical problems that can result in cost growth and schedule delays identified in our best practices work apply to these projects. We excluded two other technology demonstrations from our analysis—Solar Electric Propulsion and Low Boom Flight Demonstrator—because they did not plan to mature technologies before operations or qualification testing.

For our analysis of critical technologies, we compared the number of these technologies being developed per project with those in prior years to determine how the number of critical technologies developed per project had changed. We also collected information on the use of heritage technologies in the projects, including what heritage technologies were being used; what effort was needed to modify the form, fit, and function of the technology for use in the new system; and whether the project considered the heritage technology as a risk to the project.

To assess design stability, we asked project officials to complete a questionnaire that provided the number of engineering drawings completed or projected for release by the preliminary and critical design reviews and as of our current assessment.[5] We did not verify or validate project office supplied data on the number of released and expected engineering drawings. However, we collected the project offices' rationale for cases where it appeared that only a small percentage of the expected drawings were completed by the time of the design reviews or where the project office reported significant growth in the number of drawings released after the critical design review. In accordance with best

[4]NASA's technology demonstration missions program, which began in 2010, aims to mature new technologies from a technology readiness level 5 to technology readiness level 7 or greater. After the technologies are matured, they are to be transferred or infused into other NASA, partner, or commercial projects.

[5]In our calculation for the percentage of total number of drawings projected for release, we used the number of drawings released at the critical design review as a fraction of the total number of drawings projected, including where a growth in drawings occurred. Therefore, the denominator in the calculation may have been larger than what was projected at the critical design review. We believe that this more accurately reflected the design stability of the project.

practices, projects were assessed as having achieved design stability if at least 90 percent of projected drawings were released by the critical design review. We compared this year's results against those in prior years to assess whether NASA was improving in this area. For this year's assessment, 12 projects had held a critical design review and reported data on design drawings. We did not assess the design stability for those projects that had not yet reached the critical design review at the time of this assessment.

To assess challenges—in addition to cost and schedule performance—NASA faces in reducing acquisition risk for major projects and what progress has been made, we reviewed prior work including our High-Risk report, NASA's Corrective Action Plan in response to high-risk, and NASA identified risks.[6] From there, we determined that programmatic workforce and tools and NASA's independent assessment function were priority with respect to acquisition risk at NASA, but acknowledged that success also hinges on leadership commitment, accountability, and demonstrated progress. To assess the status of NASA's transition to its new independent project assessment process, we analyzed relevant transition documentation such as the agency's white paper and mission directorate implementation plans. We also interviewed officials at multiple levels—such as officials from the Office of the Chief Financial Officer and the Office of the Chief Engineer, mission directorates, projects, and standing review boards—to determine the status of the transition, including the benefits and outstanding challenges. To assess potential challenges that pertain to programmatic workforce and tools, we analyzed the relevant initiatives from NASA's 2018 Corrective Action Plan. We then interviewed officials in the Office of the Chief Financial Officer to determine the progress made in relation to milestones cited in the plan and reviewed relevant documentation provided by NASA.

Our work was performed primarily at NASA headquarters in Washington, D.C. In addition, we and other GAO teams working on related reviews visited Goddard Space Flight Center in Greenbelt, Maryland; the Jet Propulsion Laboratory in Pasadena, California; Kennedy Space Center in Merritt Island, Florida; Johnson Space Center in Houston, Texas; and Marshall Space Flight Center in Huntsville, Alabama.

[6]GAO-19-157SP.

Project Profile Information on Each Individual Project Assessment

This year, we developed individual project assessments for 24 projects in the portfolio with an estimated life cycle cost greater than $250 million. We did not complete individual assessments for projects that launched during our review. For each project assessment, we included a description of each project's objectives; information concerning the NASA center, and international partners involved in the project, if applicable; the project's cost and schedule performance; a schedule timeline identifying key project dates; and a brief narrative describing the current status of the project. We also provided a detailed discussion of project challenges for selected projects as applicable.

To assess the cost and schedule changes of each project, we obtained data directly from NASA's Office of the Chief Financial Officer through our questionnaire. For the Commercial Crew program, we obtained cost and schedule data directly from the program. When applicable, we compared the level of cost and schedule reserves held by the project to the level required by center policy.

Project timelines are based on acquisition cycle time, which is defined as the number of months between the project's start, or formulation start, and the projected or actual launch date. Formulation start generally refers to the initiation of a project; NASA refers to a project's start as key decision point (KDP)-A, or the beginning of the formulation phase. The preliminary design review typically occurs toward the end of the formulation phase, followed by a review at KDP-C, known as project confirmation, which allows the project to move into the implementation phase. The critical design review is generally held during the latter half of the final design and fabrication phase of implementation and demonstrates that the maturity of the design is appropriate to support continuing with the final design and fabrication phase. The manifested launch date is the launch date that the project is working toward, and when a launch vehicle is available to launch the project. This date is only a goal launch date for the project, not a commitment that it will launch on this date. The committed launch readiness date is determined through a launch readiness review that verifies that the launch system, spacecraft, and payloads are ready for launch. The implementation phase includes the operations of the mission and concludes with project disposal.

Project Challenges Discussion on Each Individual Project Assessment

To assess the status, risk, and challenges for each project, we submitted a questionnaire to each project office. In the questionnaire, we requested information on the maturity of critical and heritage technologies, the number of releasable design drawings at project milestones, and international partnerships.[7] We also held interviews with representatives from all of the projects to discuss the information on the questionnaire. We then reviewed project documentation—including monthly status reports, project plans, schedules, risk assessments, and major project review documentation—to corroborate any testimonial evidence we received in the interviews. These reviews led to identification of further challenges faced by NASA projects. The second page of our project assessments highlights key challenges facing that project that have or could affect project performance. For this year's report, we identified challenges across the projects we reviewed in the categories of cost, schedule, launch, contractor, development partner, design, technology, and integration and test. These challenges do not represent an exhaustive or exclusive list and are based on our definitions and assessments, not those of NASA.

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

Data Limitations

NASA provided preliminary estimated life cycle cost ranges and associated schedules for the six projects that had not yet entered implementation, which are generally established at KDP-B. NASA formally establishes cost and schedule baselines, committing itself to cost and schedule targets for a project with a specific and aligned set of planned mission objectives at KDP-C, which follows a preliminary design

[7]We did not collect this information for the Commercial Crew Program.

review. KDP-C reflects the life cycle point where NASA approves a project to leave the formulation phase and enter into the implementation phase. NASA explained that preliminary estimates are generated for internal planning and fiscal year budgeting purposes at KDP-B, which occurs midstream in the formulation phase, and hence, are not considered a formal commitment by the agency on cost and schedule for the mission deliverables. Due to changes that occur to a project's scope and technologies between KDP-B and KDP-C, the estimates of project cost and schedule can be significantly altered between the two KDPs.

We conducted this performance audit from May 2019 to April 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Major NASA Projects Assessed in GAO's 2020 Report

In 2020, we assessed 25 major National Aeronautics and Space Administration (NASA) projects. Figure 10 shows the preliminary launch readiness data and cost estimates for projects in the formulation phase and the current launch readiness dates and cost estimates for projects in the implementation phase.

Figure 10: Cost and Schedule of Major NASA Projects Assessed in GAO's 2020 Report by Phase

Phase	Acronym	Project name	Preliminary launch readiness date	Preliminary cost estimate (in millions)
Formulation	Dragonfly	Dragonfly	2026	Not to exceed $850
Formulation	IMAP	Interstellar Mapping and Acceleration Probe	October 2024 – December 2024	$707.7 - $776.3
Formulation	PPE	Power and Propulsion Element	December 2022	$375[a]
Formulation	Restore-L	Restore-L	December 2023	Under revision
Formulation	SPHEREx	Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer	2nd quarter fiscal year 2024	$394.9 – 426.9
Formulation	WFIRST	Wide Field Infrared Survey Telescope[b]	September 2026	$3,193.2 – $3,798.2

Phase	Acronym	Project name	Current launch readiness date	Current cost estimate (in millions)
Implementation	CCP	Commercial Crew - Boeing[c]	Under revision	$7,157.2
Implementation	CCP	Commercial Crew - SpaceX[c]	Under revision	
Implementation	DART	Double Asteroid Redirection Test	February 2022	$313.9
Implementation	EGS	Exploration Ground Systems	Under revision *(cost tied to March 2021 planning LRD)*	$3,303.7
Implementation	Clipper	Europa Clipper	September 2025	$4,250.0
Implementation	ICON	Ionospheric Connection Explorer	October 2019	$260.1
Implementation	JWST	James Webb Space Telescope	March 2021	$9,662.7
Implementation	LBFD	Low Boom Flight Demonstrator	January 2022	$582.4
Implementation	LCRD	Laser Communications Relay Demonstration	January 2021	$310.5
Implementation	L9	Landsat 9	November 2021	$885.0
Implementation	Lucy	Lucy	November 2021	$981.1
Implementation	Mars 2020	Mars 2020	July 2020	$2,725.8
Implementation	NISAR	NASA-Indian Space Research Organisation Synthetic Aperture Radar	September 2022	$846.3
Implementation	Orion	Orion Multi-Purpose Crew Vehicle	April 2023	$12,197.0
Implementation	PACE	Plankton, Aerosol, Cloud, ocean Ecosystem	January 2024	$889.7
Implementation	Psyche	Psyche	August 2022	$996.4
Implementation	SEP	Solar Electric Propulsion	December 2024	$335.6
Implementation	SGSS	Space Network Ground Segment Sustainment[d]	June 2021	$1,123.0
Implementation	SLS	Space Launch System	Under revision *(cost tied to March 2021 planning LRD)*	$11,424.1
Implementation	SWOT	Surface Water and Ocean Topography	April 2022	$754.9

Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

Note: The life cycle for NASA space flight projects consists of two phases—formulation, which takes a project from concept to preliminary design, and implementation, which includes building, launching, and operating the system, among other activities. For projects in implementation, the current launch readiness date and cost estimate are the project's established cost and schedule baseline or the latest cost estimate and schedule if the project has experienced cost or schedule growth above the project's baseline.

[a]This is the contract value for the PPE project. A full life cycle cost estimate that includes costs above the contract will be higher when the project establishes a cost and schedule baseline.

[b]The cost range for the WFIRST project represents the Science Mission Directorate contribution. The Space Technology Mission Directorate will also contribute an additional $134 million to the project.

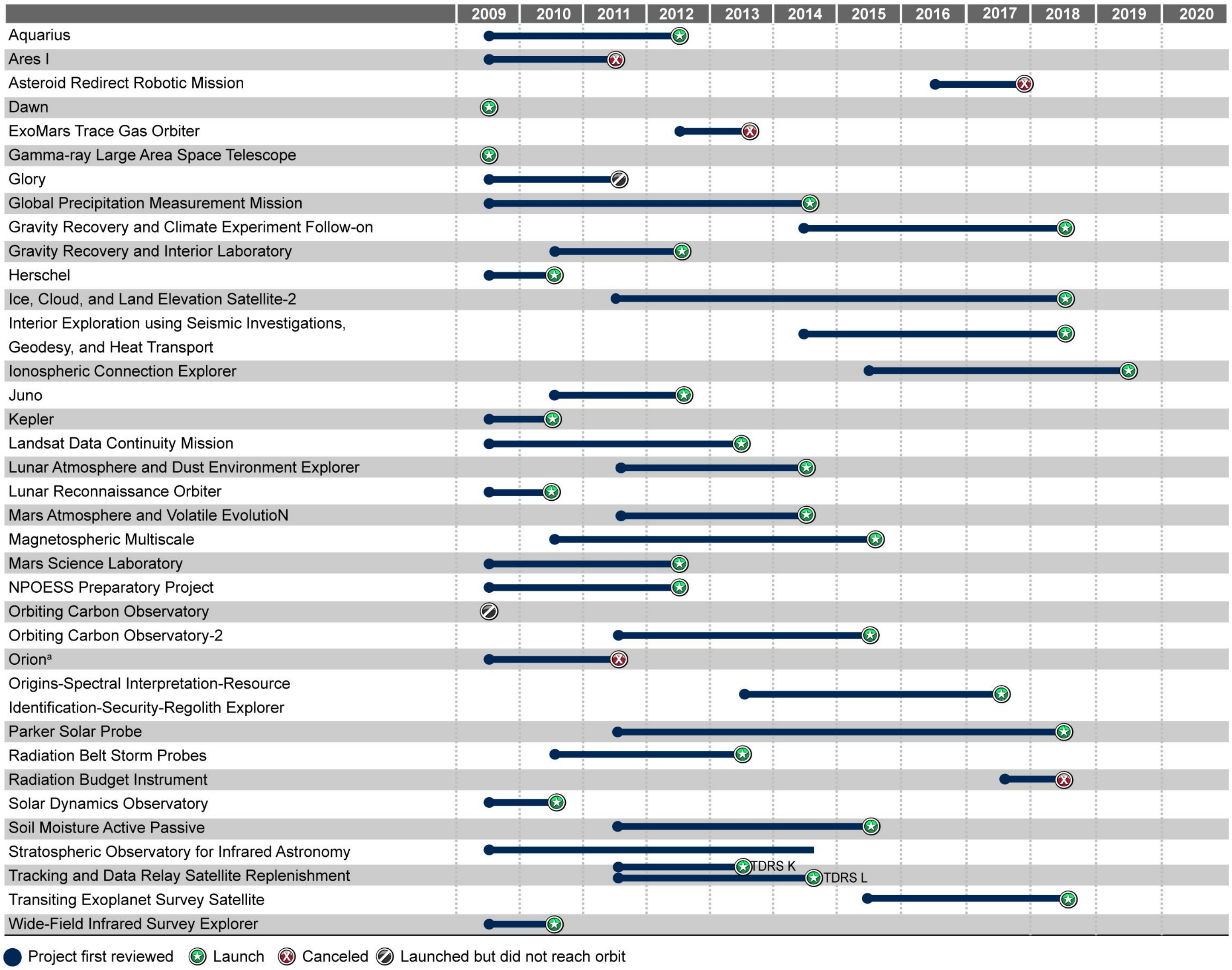
[c]The launch readiness date for the Commercial Crew Program is for the certification reviews for Boeing and SpaceX. The Commercial Crew Program is implementing a tailored version of NASA's space flight project life cycle, but it is currently completing development activities typically associated with implementation.

[d]In 2016, NASA reclassified Space Network Ground Segment Sustainment (SGSS) as a hybrid sustainment effort, rather than a major project. A hybrid sustainment effort still includes development work. As a result, we continue to include SGSS in our assessment.

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

We have reviewed 59 major National Aeronautics and Space Administration (NASA) projects or programs since our initial review in 2009. See figure 11 below for a list of projects included in our assessments from 2009 to 2019. These projects were not included in the 2020 review because they launched, were canceled, or launched but failed to reach orbit.

Figure 11: Major NASA Projects Reviewed in GAO's Annual Assessments from 2009-2019

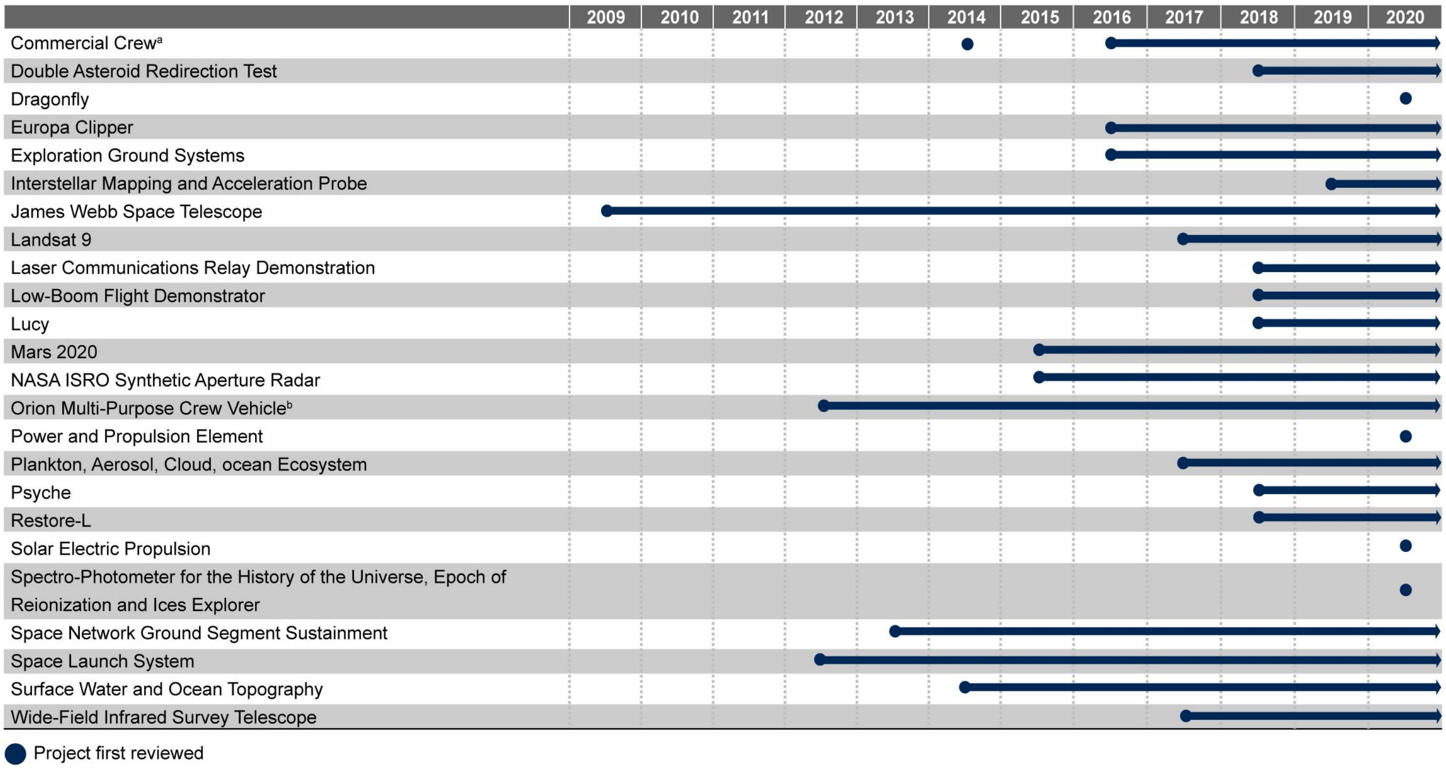


Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

[a]In 2014, NASA adopted Orion as the common name for Orion Multi-Purpose Crew Vehicle (MPCV); the project did not change. This Orion project stems from the original Orion project that was canceled in June 2011 when the Constellation program was canceled after facing significant technical and funding issues. During the closeout process for the Constellation program, NASA identified elements of the Ares I and Orion projects that would be transitioned for use on the new Space Launch System and Orion Multi-Purpose Crew Vehicle programs.

See figure 12 below for a list of projects included in our 2020 assessment, including when the projects were first included in the review.

Figure 12: Major NASA Projects Reviewed in GAO's 2020 Assessment



Source: GAO analysis of National Aeronautics and Space Administration data. | GAO-20-405

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

[b]In 2014, NASA adopted Orion as the common name for Orion MPCV; the project did not change. This Orion project stems from the original Orion project that was canceled in June 2011 when the Constellation program was canceled after facing significant technical and funding issues. During the closeout process for the Constellation program, NASA identified elements of the Ares I and Orion projects that would be transitioned for use on the new Space Launch System and Orion Multi-Purpose Crew Vehicle programs.

Appendix IV: Technology Readiness Levels

Table 4: Characteristics of Technology Readiness Levels

Technology readiness level	Description	Hardware	Demonstration environment
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.	None (paper studies and analysis)	None
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.	None (paper studies and analysis)	None
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.	Analytic studies and demonstration of nonscale individual components (pieces of subsystem)	Lab
4. Component and/or breadboard Validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of ad-hoc hardware in a laboratory.	Low fidelity breadboard (demonstrates function without considering form or fit) Integration of nonscale components to show pieces will work together. Not fully functional or form or fit but representative of technically feasible approach suitable for flight articles.	Lab
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in a simulated environment. Examples include high-fidelity laboratory integration of components.	High-fidelity breadboard Functionally equivalent but not necessarily form and/or fit (size, weight, materials, etc.). Should be approaching appropriate scale. May include integration of several components with reasonably realistic support elements/subsystems to demonstrate functionality.	Lab demonstrating functionality but not form and fit. May include flight demonstrating breadboard in surrogate aircraft. Technology ready for detailed design studies.

Technology readiness level	Description	Hardware	Demonstration environment
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for technology readiness level 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high-fidelity laboratory environment or in simulated realistic environment.	Prototype. Should be very close to form, fit, and function. Probably includes the integration of many new components and realistic supporting elements/subsystems if needed to demonstrate full functionality of the subsystem.	High-fidelity lab demonstration or limited/restricted flight demonstration for a relevant environment. Integration of technology is well defined.
7. System prototype demonstration in a realistic environment.	Prototype near or at planned operational system. Represents a major step up from technology readiness level 6, requiring the demonstration of an actual system prototype in a realistic environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.	Prototype. Should be form, fit, and function integrated with other key supporting elements/subsystems to demonstrate full functionality of subsystem.	Flight demonstration in representative realistic environment such as flying test bed or demonstrator aircraft. Technology is well substantiated with test data.
8. Actual system completed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this technology readiness level represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.	Flight qualified hardware	Developmental Test and Evaluation in the actual system application.
9. Actual system "flight - proven" through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.	Actual system in final form	Technology assessed as fully mature. Operational Test and Evaluation in operational mission conditions.

Source: GAO analysis and representation of National Aeronautics and Space Administration TRLs from NPR 7123.1B, Appendix E. | GAO-20-405

Appendix V: Elements of a Sound Business Case

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

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

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

project will generally enter development after completing the preliminary design review, at which time a business case should be in hand.

- Then, about midway through the project's development, its design should be stable and demonstrate it is capable of meeting performance requirements. The critical design review takes place at that point in time because it generally signifies when the program is ready to start building production-representative prototypes. If project development continues without design stability, costly redesigns to address changes to project requirements and unforeseen challenges can occur.
- Finally, by the time of the production decision, the product must be shown to be producible within cost, schedule, and quality targets and have demonstrated its reliability, and the design must demonstrate that it performs as needed through realistic system-level testing. Lack of testing increases the possibility that project managers will not have information that could help avoid costly system failures in late stages of development or during system operations.

Appendix VI: Comments from the National Aeronautics and Space Administration

National Aeronautics and
Space Administration

Office of the Administrator
Washington, DC 20546-0001

April 13, 2020

Ms. Cristina T. Chaplain
Director
Contracting and National Security Acquisitions
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to comment on the Government Accountability Office (GAO) draft report entitled, "NASA: Assessments of Major Projects" (GAO-20-405SP). This assessment provides NASA with a valued independent perspective on our major acquisitions. We appreciate the open and constructive dialogue between NASA and the GAO engagement team, and we look forward to continuing to work with the GAO to identify and address any challenges that may enable cost and schedule improvements in our current and future projects. While a portion of our major project portfolio enables sustained scientific observations and improves upon legacy missions, the diversity of novel missions has notably expanded. NASA is redoubling its efforts to enable human expansion across the solar system and bring new knowledge and opportunities back to Earth. It is imperative to seek efficiencies wherever possible to enable this bold endeavor.

This year's report represents the 12th annual iteration of the GAO's legislatively mandated assessment of NASA's major acquisitions. Since the inaugural report's issuance in 2009, the GAO has provided NASA with several highly valued insights into various aspects of our acquisition approaches, many of which have resulted in programmatic improvements and enhancements. NASA has worked closely with GAO to find and implement improvements in our programs. However, as the NASA portfolio expands mirroring increasing appropriated funding, the number of major projects in this annual engagement is expected to continue to grow. The 2020-2021 engagement cycle has the potential to include as many as 37 projects, which would represent a greater than 50 percent increase over this past year. NASA is concerned with this expansion and the associated demands it places on management and coordination of the audit. We may have to institute additional strategies going forward to phase in reviews on a more doable or realistic basis, given the growing scope of activities assigned to the Agency by the Administration. We want to work closely with GAO to identify any options for streamlining the process without sacrificing the net result: safe and efficiently managed programs.

NASA recognizes the inherent challenges in managing large, complex space flight and aeronautical programs that are uniquely designed to expand the boundaries of science and technology and achieve unprecedented capabilities and accomplishments. Therefore,

1

NASA has accordingly worked over many years to improve policies and procedures that control cost and schedule while ensuring mission success. In December 2018, NASA established the Corrective Action Plan (CAP) in response to GAO's continued designation of NASA's acquisition management practices on its High-Risk List. The CAP contains nine key initiatives designed to strengthen the Agency's cutting-edge program and project management efforts and to improve transparency for NASA's stakeholders. NASA has made substantial progress in the implementation of the CAP and is in the process of updating the document this summer to include new initiatives geared to improving our acquisition outcomes. NASA appreciates the GAO's recognition of these initiatives in the assessment and will continue to provide the GAO with updates on our progress against the CAP; as successful implementation will contribute to improved programmatic performance across the Agency in the years ahead.

NASA has continued development of the Space Launch System (SLS), Orion, and Exploration Ground Systems (EGS) programs, making major progress, including delivery of the SLS core stage to Stennis Space Center and completion of Orion testing at Plum Brook Station. As GAO has observed in audits since 2017, the launch date for Artemis I, which serves as the main development milestone for their life-cycle costs, has been under review pending a formal rebaseline analysis. NASA utilized an Independent Review Team to study the SLS and EGS costs using a joint cost and schedule confidence level (JCL) model. The results are being shared with Agency leadership to inform an Agency decision on a new launch readiness date for Artemis I. Orion's life-cycle costs are anchored around the Artemis II mission, which will receive an independent programmatic assessment, including a JCL model as recommended by the GAO, as part of Orion's upcoming Key Decision Point D review.

The report includes findings on the current state of independent assessment at NASA following the 2015 dissolution of the Independent Program Assessment Office (IPAO), which distributed independent assessment responsibility to the individual Mission Directorates as opposed to a central Agency office. The report focuses on just one of the many goals of this restructuring – programmatic capability improvement. Other drivers behind the restructuring are outlined in documentation provided to the GAO, including Mission Directorates taking greater ownership of the independent assessment for their programs and projects to enhance mission success and to increase management accountability. Under the leadership of the Program Management Improvement Officer (PMIO) and with the support of the Office of the Chief Financial Officer the Agency continues to improve the consistency and effectiveness of independent assessment with a focus on insuring lessons learned are captured and communicated with review chairs and board members.

The report also discusses the feedback GAO received from a Mission Directorate regarding differences in interpretation of Standing Review Board (SRB) conflict of interest rules across the Centers. GAO mentioned that NASA Headquarters and the Office of the General Counsel (OGC) are aware of this challenge. It is important to elaborate that NASA is not only aware but is also taking definitive action to resolve this concern. It is currently being actively worked by the Science Mission Directorate, OGC, and the Program Management Improvement Officer. OGC is examining specific examples to address any perceived differences in vetting standards and resulting updates to the SRB Handbook are in work to further ensure a homogeneous interpretation across the Centers.

2

As NASA previously noted, GAO continues to apply its design stability best practice metric of 90 percent of design drawings completed by the Critical Design Review; however, NASA no longer uses this metric internally to measure design stability. The design drawing release metric is a legacy standard developed prior to the use of computerized drawings and is no longer an applicable standard for modern NASA projects. NASA appreciates that GAO recognizes this and the evolving nature of measuring design stability and looks forward to continuing work in partnership with GAO to reach an acceptable broadly applied design stability metric.

NASA would like to thank the GAO for continuing to work with project subject-matter experts to consider and incorporate technical corrections as part of this audit. We appreciate the consideration of these comments, which is important for an accurate and balanced presentation of the projects' technical status. We look forward to working with the GAO to ensure the technical review process continues to add value in the future.

NASA greatly appreciates the ongoing dialogue with the GAO on this critical engagement and is committed to working jointly to address any questions or concerns related to this effort. Please contact Kevin M. Gilligan at (202) 358-4544 if you have any questions or require additional information.

Sincerely,

Stephen G. Jurczyk
Associate Administrator

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Appendix VII: GAO Contact and Staff Acknowledgments

GAO Contact

Cristina T. Chaplain, (202) 512-4841 or chaplainc@gao.gov.

Staff Acknowledgments

In addition to the contact named above, Molly Traci, Assistant Director, Daniel Singleton, Analyst-in-Charge, Pete Anderson; Tina Cota-Robles; Kurt Gurka; Chad Johnson; Erin Kennedy; Joy Kim; Natalie Logan; Jonathan Munetz; Jose A. Ramos; Carrie Rogers; Zachary Sivo; Juli Steinhouse; Eli Stiefel; Roxanna T. Sun; Tom Twambly; John Warren; Alyssa Weir; Tonya Woodbury; Kristin Van Wychen; and Erin Guinn Villareal made significant contributions to this report

Appendix VIII: Accessible Data

Data Tables

Accessible Data for Development Cost Performance and Average Launch Delay for Major NASA Projects from Fiscal Year 2010 through Fiscal Year 2020

Year	Percentage cost growth	Average launch delay (in months)
2010	13.6	11
2011	14.6	8
2012	46.5	11
2013	46.4	8
2014	37.8	7
2015	25.9	7
2016	17.3	8
2017	15.6	7
2018	18.8	12
2019	27.6	13
2020	30.9	12

Accessible Data for Figure 3: Development Cost Growth Performance and Average Launch Delay for Major NASA Projects from 2009 to 2020

Year	Percentage cost growth	Average launch delay (in months)	Number of projects
2009	12	11	13
2010	13.6	11	14
2011	14.6	8	16
2012	46.5	11	15
2013	46.4	8	12
2014	37.8	7	15
2015	25.9	7	12
2016	17.3	8	12
2017	15.6	7	16

Year	Percentage cost growth	Average launch delay (in months)	Number of projects
2018	18.8	12	17
2019	27.6	13	17
2020	30.9	12	18

Accessible Data for Figure 4: Number of NASA's Major Projects Attaining Technology Maturity by Preliminary Design Review from 2010 to 2020

Fiscal year	Projects meeting technology maturity criteria	Projects not meeting technology maturity criteria	Technology demonstrations not meeting technology maturity criteria
2010	4	10	0
2011	6	10	0
2012	6	10	0
2013	8	5	0
2014	10	6	0
2015	10	3	0
2016	9	2	0
2017	12	3	0
2018	12	3	2
2019	10	4	2
2020	12	3	2

Accessible Data for Figure 5: Average Number of Critical Technologies Reported by NASA's Major Projects in Development from 2009 to 2020

Fiscal year	Average number of critical technologies
2009	4.9
2010	4.5
2011	2.9
2012	2.8
2013	2.5
2014	2.6
2015	2.3
2016	2.3
2017	3
2018	2.5

Fiscal year	Average number of critical technologies
2019	2.6
2020	2.1

Accessible Data for Figure 6: NASA Major Projects Releasing at Least 90 Percent of Engineering Drawings and Average Percentage of Released Drawings by Critical Design Review from 2010 to 2020

Fiscal year	Projects meeting design stability best practices	Projects not meeting design stability best practices	Average percentage of released engineering drawings at critical design review
2010	0	9	31
2011	2	10	62
2012	1	13	62
2013	1	9	73
2014	1	8	67
2015	1	7	74
2016	3	7	69
2017	3	7	66
2018	4	8	70
2019	5	7	73
2020	4	8	73

Accessible Data for Figure 7: Average Percentage of Engineering Drawing Growth after Critical Design Review among NASA Major Projects from 2010 to 2020

Fiscal year	Average percentage of drawing growth after critical design review
2010	182
2011	36
2012	36
2013	12
2014	20
2015	11
2016	11
2017	18
2018	19

Fiscal year	Average percentage of drawing growth after critical design review
2019	18
2020	17

Agency Comment Letter

Accessible Text for Appendix VI Comments from the National Aeronautics and Space Administration

Page 1

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Sincerely,

Stephen G. Jurczyk

Associate Administrator

Related GAO Products

James Webb Space Telescope: Technical Challenges Have Caused Schedule Strain and May Increase Costs, GAO-20-224 (Washington, D.C.: Jan. 28, 2020)

NASA Commercial Crew Program: Significant Work Remains to Begin Operational Missions to the Space Station, GAO-20-121 (Washington, D.C.: Jan. 29, 2020)

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NASA Commercial Crew Program: Schedule Uncertainty Persists for Start of Operational Missions to the International Space Station, GAO-19-504 (Washington, D.C.: June 20, 2019)

NASA Human Space Exploration: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs, GAO-19-377 (Washington, D.C.: June 19, 2019)

James Webb Space Telescope: Integration and Test Challenges Have Delayed Launch and Threated to Push Costs Over Cap, GAO-18-273. Washington, D.C.: Feb. 28, 2018

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James Webb Space Telescope: Project Meeting Commitments but Current Technical, Cost, and Schedule Challenges Could Affect Continued Progress, GAO-14-72. Washington, D.C.: Jan. 8, 2014

James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration, GAO-13-4. Washington, D.C.: Dec. 3, 2012

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