# SUBCOMMITTEE ON SPACE AND AERONAUTICS
# COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
# U.S. HOUSE OF REPRESENTATIVES

# HEARING CHARTER

## *Developing Core Capabilities for Deep Space Exploration: An Update on NASA's SLS, Orion, and Exploration Ground Systems Programs*

Wednesday, September 18, 2019
10:00 a.m.
2318 Rayburn House Office Building

## PURPOSE

The purpose of the hearing is to assess the status, including the progress, challenges, and other issues, of NASA's Exploration Systems Development programs (the Space Launch System, Orion Multipurpose Crew Vehicle, and Exploration Ground Systems).

## WITNESSES

- **Mr. Kenneth Bowersox,** Associate Administrator (Acting), Human Exploration and Operations, National Aeronautics and Space Administration
- **Ms. Cristina Chaplain,** Director, Contracting and National Security Acquisitions, U.S. Government Accountability Office
- **Mr. Doug Cooke**, Owner, Cooke Concepts and Solutions; Former Associate Administrator, Exploration Systems, National Aeronautics and Space Administration

## OVERARCHING QUESTIONS

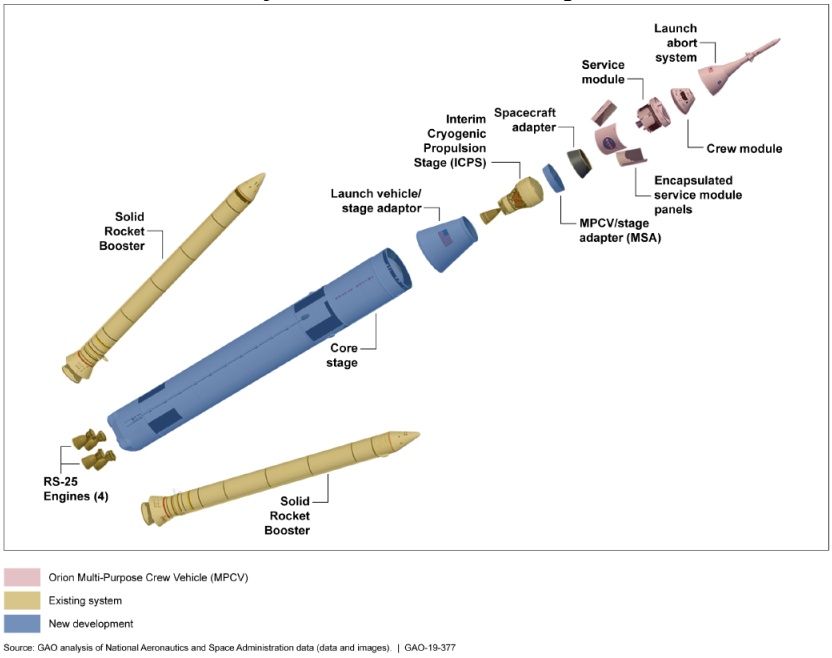
- *What are current challenges and upcoming milestones for the Space Launch System (SLS), Orion, and Exploration Ground Systems (EGS) programs?*
- *What are the biggest drivers of cost growth and schedule challenges for the SLS, Orion, and EGS programs?*
- *How can Congress best ensure that schedule pressure does not compromise safety in the SLS, Orion, and EGS programs?*
- *What are NASA's plans for SLS and Orion after sending humans to the Moon in 2024?*

## BACKGROUND

NASA is developing a new heavy-lift rocket and crew vehicle capable of returning humans to deep space—generally defined as anywhere beyond low Earth orbit (LEO), about 1,200 miles above the Earth's surface—for the first time since the last Apollo astronauts landed on the Moon

in 1972. The agency is working under the directives of the NASA Authorization Act of 2010[1] to build a Space Launch System (SLS), "*the follow-on government-owned civil launch system developed, managed, and operated by NASA to serve as a key component to expand human presence beyond low Earth orbit,*" and continue building the Orion Multi-Purpose Crew Vehicle (Orion), "*to be available as soon as practicable, and no later than for use with the Space Launch System."* Concurrently, through the Exploration Ground Systems (EGS) program, NASA is upgrading Kennedy Space Center (KSC) infrastructure and developing software for SLS and Orion integration, processing, and operations. SLS and Orion development has drawn on work from the Constellation program[2] and used some existing and refurbished Space Shuttle hardware.

According to NASA, Orion will be the "*only spacecraft capable of carrying and sustaining crew on missions to deep space, providing emergency abort capability, and safe re-entry from lunar return velocities,*" and SLS will be "*the only rocket with the power and capability required to carry astronauts to deep space on board the Orion spacecraft.*"[3] More than 3,800 suppliers and 60,000 workers across all 50 states support the SLS, Orion, and EGS programs. The figure below[4] identifies major SLS and Orion components, to be discussed further in what follows.




*SLS and Orion Hardware. Source: Government Accountability Office (GAO)*

The first fully integrated test of the SLS, Orion, and EGS system will be an uncrewed flight known as Exploration Mission 1 (EM-1, since Artemis 1). The SLS re-named rocket will launch the uncrewed Orion capsule to lunar orbit for a three-week mission; Orion will orbit the Moon for six days before returning to Earth.[5] The second flight, Exploration Mission 2 (EM-2, or Artemis 2), will carry up to four astronauts on board Orion to lunar orbit before returning them safely to Earth. The two flights will take different trajectories to demonstrate the full range of capabilities of SLS and

[1] Pub. L. No. 111-267, "National Aeronautics and Space Administration Authorization Act of 2010," Title II, Section 302. October 11, 2010. Available at: https://www.congress.gov/bill/111th-congress/senate-bill/3729

[2] NASA began the Constellation Program in response to President Bush's Vision for Space Exploration, and work included initial development of the Ares heavy-lift rockets and the Orion Crew Exploration Vehicle. In 2010, President Barack Obama proposed to cancel Constellation after an independent review found that the program was unsustainable given funding constraints, schedule realities, and goals of the agency.

[3] https://www.nasa.gov/sites/default/files/atoms/files/america_to_the_moon_2024_artemis_20190523.pdf

[4] GAO, "NASA HUMAN SPACE EXPLORATION: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs," June 2019. GAO-19-377. Available at: https://www.gao.gov/products/GAO-19-377

[5] https://www.nasa.gov/feature/around-the-moon-with-nasa-s-first-launch-of-sls-with-orion

Orion. In 2014 and 2015, NASA committed to launch EM-1 no later than November 2018 and EM-2 no later than April 2023, but later delayed EM-1 to no later than June 2020. However, in testimony to the House Subcommittee on Space and Aeronautics on May 8, 2019, NASA officials reported that June 2020 would no longer be possible.[6]

After the test flights, NASA intends to be able to launch human or large cargo payloads to deep space at a frequency of about once per year.[7] In the FY 2020 budget request submitted to Congress in March 2019, NASA outlined plans for multiple SLS/Orion/EGS missions to a Lunar Gateway, eventually leading to a 2028 lunar landing as part of establishing a sustainable human exploration infrastructure on and around the Moon. Two weeks after releasing the proposal, the Trump administration directed NASA to return humans to the lunar surface sooner, by 2024. NASA now plans to land humans on the Moon in 2024 on the third launch of SLS and Orion [the second crewed launch of Orion]. NASA has not released a definitive plan (schedule and/or destinations) for future SLS launches.

Overview of the Space Launch System (SLS)

SLS will be NASA's first deep space rocket since the Apollo-era Saturn V, and its most powerful. The minimum requirements set in the NASA Authorization Act of 2010 include:[8]

- An initial capability to lift payloads between 64 and 91 metric tons (mt) to LEO
- An eventual capability, with an enhanced upper stage, to lift payloads of 118 mt to LEO
- The capability to lift the multipurpose crew vehicle
- The capability to serve as a backup system for ISS crew and cargo delivery
- Flexibility in design to allow evolution in capability to carrying heavier payloads

NASA has designed SLS as a two-stage, super heavy-lift rocket that will evolve over three configurations with incrementally increasing capacity. The Block 1 configuration will be capable of lifting payloads of 70 mt to LEO (24 mt to the Moon, 20 mt to Mars). A planned Block 1B configuration will use an Exploration Upper Stage (EUS) to be capable of lifting 105 mt to LEO (40 mt to the Moon, 33 mt to Mars). Finally, the planned Block 2 configuration will use both the EUS and advanced solid rocket boosters and be capable of lifting 130 mt to LEO (52 mt to the Moon, 41 mt to Mars). SLS Block 1 will produce 8.8 million pounds of thrust at launch, 13 percent more than the Space Shuttle and 15 percent more than the Apollo-era Saturn V during liftoff and ascent.[9]

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[6] Prepared Statement of William H. Gerstenmaier and Mark Sirangelo, "Keeping Our Sights on Mars: A Review of NASA's Deep Space Exploration Programs and Lunar Proposal," May 8, 2019. Available at: https://science.house.gov/imo/media/doc/Joint%20Gerstenmaier-Sirangelo%20Testimony.pdf

[7] IDA Science & Technology Policy Institute, "Evaluation of a Human Mission to Mars by 2033," March 2019. Available at: https://www.ida.org/-/media/feature/publications/e/ev/evaluation-of-a-human-mission-to-mars-by-2033/d-10510.ashx

[8] Title 42, U.S. Code, Section 18322, The Space Launch System as a follow-on launch vehicle to the Space Shuttle. Available at: https://www.law.cornell.edu/uscode/text/42/18322

[9] NASA, "NASA's Space Launch System: Meet the Rocket," July 21, 2014. Available at: https://www.nasa.gov/sls/multimedia/gallery/sls-infographic3.html

The SLS program is managed out of the Marshall Space Flight Center in Huntsville, Alabama, which reports to the Exploration Systems Development (ESD) division at NASA Headquarters. Manufacturing and testing of components are conducted at NASA's Michoud Assembly Facility in Louisiana and Stennis Space Center in Mississippi. SLS major components include:

- Four RS-25 rocket engines originally designed and built for the Space Shuttle, refurbished for use on SLS by Aerojet Rocketdyne.[10]
- Two five-stage solid rocket boosters built by the Northrop Grumman Corporation[11] based on the Shuttle design, with some refurbished Shuttle components
- A core stage being built by the Boeing Corporation (Boeing).
- An upper stage built by Boeing, initially the Interim Cryogenic Propulsion Stage (ICPS) and then the EUS (Block 1B and Block 2). Both use Aerojet Rocketdyne RL-10 engines.

The RS-25 engines, solid rocket booster segments, and ICPS for EM-1 were successfully delivered to NASA and have undergone qualifications testing, and they are ready for final assembly and integration upon completion of the core stage. In August 2019, NASA and Boeing announced a major development milestone for the core stage: the completed assembly of the engine section, the most complex element of the core stage, which houses the four RS-25 engines and includes the vital systems that govern delivery of propellant to those engines.[12]

NASA plans to launch EM-1 and EM-2 on an SLS Block 1 (70 mt to LEO). NASA had notionally planned to debut the Block 1B (105 mt to LEO) in 2024 on EM-3 and Block 2 (70 mt to LEO) on EM-8 in 2028;[13] however, the agency has not updated that schedule since receiving the directive to land astronauts on the Moon in 2024. The President's FY 2020 budget request did not propose funding for continued EUS development, which would be used on the Block 1B and Block 2 variants of the SLS.

Overview of the Orion Multipurpose Crew Vehicle

Under the Constellation program, NASA undertook its first major crew vehicle development effort since building the Space Shuttle in the 1970s. The NASA Authorization Act of 2010 directed the agency to continue work on a crew vehicle with minimum requirements including:[14]

- The capability to serve as the primary crew vehicle for missions beyond LEO

[10] Aerojet Rocketdyne is contracted to refurbish sixteen Shuttle RS-25 engines for the first four SLS flights; on a separate contract, the company is restarting production in 2018 in order to manufacture six new engines for a fifth.
[11] Originally contracted to Alliant Techsystems, which merged with Orbital Science Corporation to become Orbital ATK in 2015, which was purchased by the Northrop Grumman Corporation in 2018. Contract includes three flight sets of boosters and one test set.
[12] Sloss, Phillip, "Boeing Completes First NASA SLS Engine Section, Getting Ready for Final Core Stage Mate," *NASASpaceFlight*, August 25, 2019. Available at: https://www.nasaspaceflight.com/2019/08/sls-engine-section-ready-final-core-mate/
[13] IDA Science & Technology Policy Institute, "Evaluation of a Human Mission to Mars by 2033," March 2019. Available at: https://www.ida.org/-/media/feature/publications/e/ev/evaluation-of-a-human-mission-to-mars-by-2033/d-10510.ashx
[14] Title 42, U.S. Code, Section 18323, Multi-purpose crew vehicle. Available at: https://www.law.cornell.edu/uscode/text/42/18323

- The capability to conduct regular in-space operations in conjunction with payloads delivered by the SLS or other vehicles
- The capability to serve as a backup crew and cargo vehicle for the ISS
- The capacity for efficient and timely evolution

The Orion multipurpose crew vehicle comprises three primary components: the Launch Abort System (LAS), the Crew Module (CM), and the Service Module (SM). The LAS is intended to safely propel the crew module away from the SLS prior to or in the first several minutes after launch in case of any threat to the astronaut crew. The crew capsule can provide habitation and life support for up to four astronauts for up to 21 days. The service module will provide propulsion, air, water, and power to the crew module.

The Orion program is managed out of the Johnson Space Center (JSC), which reports to the ESD division at NASA Headquarters. Lockheed Martin is the prime contractor for the Orion crew spacecraft (including both the LAS and the CM). NASA and Lockheed Martin recently reached a major milestone with the successful demonstration of the LAS in-flight abort capability in the Ascent Abort test on July 2, 2019. The European Space Agency (ESA) developed and produced the European Service Module (ESM) for EM-1 and EM-2; NASA accepted the delivery of the EM-1 ESM from ESA in November 2018 and mated the CM and ESM in July 2019 to form the completed, combined system, the Crew and Service Module (CSM). NASA plans to deliver the CSM to its Plum Brook facility at the Glenn Research Center in Ohio for thermal vacuum testing in September 2019.

Overview of the Exploration Ground Systems (EGS) Program

All SLS launches will use the facilities of NASA's KSC. EGS is a development and operations program for the systems and facilities KSC will use to process and launch modern and next-generation vehicles and spacecraft, including SLS and Orion. EGS activities include modernizing computational hardware and software, developing new ground systems, and upgrading or refurbishing existing infrastructure. The EGS program is managed out of KSC, which reports to the ESD division at NASA Headquarters.

EGS software development efforts include the Space Command and Control System and Ground Flight Application Software. Key facilities of the EGS program include the Vehicle Assembly Building (VAB), the Mobile Launcher and Crawler-Transporter, and Launch Pad 39B. During final integration for launch, SLS will be assembled ("stacked") on the mobile launcher in the VAB. The Crawler-Transporter will then move the stacked SLS and mobile launcher at a top speed of one mile per hour to Launch Pad 39B, 4.2 miles away.

NASA has renovated the VAB, Launch Pad 39B, and the Crawler-Transporter-2 (CR-2) under the EGS program. Upgrades to the Mobile Launcher are underway. NASA is also beginning construction of a second mobile launcher (ML2), as directed by Congress in the FY 2018 appropriations legislation,[15] rather than upgrade the existing mobile launcher to be able to support the larger Block 1B and 2 SLS configurations. Without ML2, more extensive upgrades

[15] Pub. L. No. 115-141, "Consolidated Appropriations Act, 2018," Title II. Available at: https://www.congress.gov/bill/115th-congress/house-bill/1625

to the only SLS mobile launcher would have forced a gap between the first SLS launch (EM-1, on a Block 1) and the second (EM-2, then planned on a Block 1B) of 33 months. The President's FY 2020 budget proposal provided no additional funds for the ML2.

Safety

The 2018 Annual Report of the Aerospace Safety Advisory Panel (ASAP)[16] noted "*significant progress in many areas*" by NASA's ESD program, including full-scale structural testing; initial power-on testing, structural qualification, and parachute qualification testing for Orion; and delivery of the ESM. However, ASAP noted several remaining technical challenges and concerns, including whether the Environmental Control and Life Support System (ECLSS) will be "*fully tested, qualified, and ready to support the crew launch for EM-2;*" the ESM's "*serial propellant system design, along with several of the zero-fault-tolerant design aspects of this system;*" the potential for an Orion avionics box failure that could prevent obtaining adequate heat shield performance data in EM-1; and the "*considerable technical risk*" of validation of flight control and ground system software. More generally, the report noted that, even though the ASAP feels that "*technical risks can most directly affect safety,*" the panel observed that "*many of the risks automatically elevated to NASA Headquarters for review seem to be risks that are programmatically oriented (cost, schedule, funding) as opposed to the technical risks that require engineering design or operationally targeted solutions for mitigation.*"

More generally, the ASAP regularly notes the importance to safety and risk reduction of adequate funding profiles and a regular, predictable cadence of development and operational missions. This is consistent with the recommendations of the 2014 National Academies' *Pathways to Exploration* consensus study report,[17] which included "*funding a frequency of flights sufficiently high to ensure the maintenance of proficiency among ground personnel, mission controllers, and flight crews.*" As an example of this principle, the construction of ML2 was directed by Congress in part due to a 2017 warning by ASAP that the extended operational gap while waiting for the modifications would expose the program to significant safety risks.[18]

Budget

NASA funds the development of the Orion, SLS, and EGS programs under the Exploration Systems Development (ESD) division within the Human Exploration and Operations Mission Directorate (HEOMD) budget line. In response to the Trump Administration's directive to accelerate the first human lunar landing to 2024, the Office of Management and Budget released an amended Fiscal Year (FY) 2020 budget request in May 2019 that sought an additional $1.6 billion for NASA. That followed the President's initial FY 2020 request of $21 billion for NASA that was issued in March 2019. Of the additional $1.6 billion in the amended request, $1.375

[16] ASAP, "Annual Report for 2018," January 1, 2019. Available at: https://oiir.hq.nasa.gov/asap/documents/2018_ASAP_Report-TAGGED.pdf
[17] National Research Council, *Pathways to Exploration: Rationales and Approaches for a U.S. Program of Human Space Exploration*, The National Academies Press, 2014. Available at: https://doi.org/10.17226/18801
[18] ASAP, "Annual Report for 2017," January 1, 2018. Available at: https://oiir.hq.nasa.gov/asap/documents/2017_ASAP_Annual_Report.pdf

billion is proposed for Deep Space Exploration Systems, including funding to "*accelerate the development of human-rated lunar lander systems*" and "*to preserve the flight schedule for the Space Launch System rocket and Orion capsule."* Following the release of the budget amendment, NASA identified its plans for allocating $651 million of the proposed amendment for Deep Space Exploration Systems between the SLS and Orion programs.[19]The original FY 2020 budget request for the Orion, SLS, and EGS programs and NASA's plans for the amended budget are shown in the table below.

| | **FY 2018** | | **FY 2019** | | **FY 2020** | | |
|---|---|---|---|---|---|---|---|
| | Request | **Actual** | Request | **Enacted** | President's Budget Request | NASA Plan under Amended Request | House Appropriations |
| Orion | $1,186.0 | **$1350.0** | $1,160.0 | **$1350.0** | $1266.2 | $1,406.7 | $1,425.0 |
| SLS | $1,937.8 | **$2150.0** | $2,078 | **$2150.0** | $1775.4 | $2,285.9 | $2,150.0 |
| EGS | $460.4 | **$895.0** | $428.0 | **$592.8** | $400.1 | $400.1 | $592.8 |

*Amounts listed are in millions of then-year dollars. Adapted from NASA FY 2020 Congressional Budget Justification,[20] NASA FY 2020 Budget Amendment Summary,[21] and NASA presentation.[22]*

It should be noted that the President's original FY 2020 budget request proposed less for SLS, Orion, and EGS than was provided in the FY 2019 appropriation. Furthermore, as indicated in the above table, NASA has typically requested less than has ultimately been appropriated by Congress for Orion, SLS, and EGS development.

Cost and Schedule Performance and Challenges

Many components of the SLS, Orion, and EGS systems have reached or are near completion, though major milestones remain, and each program has already seen both cost and schedule growth from the baseline commitments NASA made in 2014 and 2015. The Government Accountability Office (GAO) has identified aspects of cost and schedule management that have affected the programs; in its most recent response to a GAO assessment, NASA emphasized that "*the issues encountered are commensurate with first-time production programs on a large scale and should not be unexpected.*"[23]

In 2014, NASA committed to EM-1 baseline costs for SLS and EGS of $7.021 billion and $1.843 billion, respectively, and a baseline schedule for launch no later than November 2018. In 2015, NASA confirmed the Orion project for a baseline cost of $6.77 billion through launch of EM-2 no later than April 2023. After the GAO found the agency unlikely to meet the November

[19] NASA presentation to NASA Advisory Council's Committee on Human Exploration and Operations, May 29, 2019. Available at: https://www.nasa.gov/sites/default/files/atoms/files/nac_budget_charts_final_updated_pfp.pdf
[20] https://www.nasa.gov/sites/default/files/atoms/files/fy_2020_congressional_justification.pdf
[21] https://www.nasa.gov/sites/default/files/atoms/files/nasa_fy_2020_budget_amendment_summary.pdf
[22] NASA presentation to NASA Advisory Council's Committee on Human Exploration and Operations, May 29, 2019. Available at: https://www.nasa.gov/sites/default/files/atoms/files/nac_budget_charts_final_updated_pfp.pdf
[23] GAO, "NASA HUMAN SPACE EXPLORATION: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs," GAO-19-377, June 2019. Available at: https://www.gao.gov/products/GAO-19-377

2018 date,[24] NASA reported an updated cost and schedule[25] to Congress in December 2017 with an EM-1 launch no later than June 2020 (19 months delay) and revised costs for SLS and EGS of $7.169 billion (2.1 percent growth) and $2.265 billion (22.9 percent growth), respectively.

However, the recent report by GAO[26] cautioned that the June 2020 launch date is now also unlikely for EM-1.[27] GAO reports that both SLS and Orion have 6-12 months of schedule risk, estimating the EM-1 launch date as late as June 2021. The Orion ESM was successfully delivered by ESA in November 2018, but integration and testing require at least 20 months after receiving the ESM, so the earliest the Orion program could be ready to support EM-1 would be July 2020, based on the ESM schedule alone.

In the same report, GAO found further cost growth for both SLS and Orion development. Additionally, the GAO stated that NASA is underreporting the extent of that cost growth. Specifically, in estimating the SLS development costs, NASA determined it would be more appropriate to shift costs for some components to future missions but did not adjust the baseline to which they were calculating growth accordingly. Therefore, as of the fourth quarter of FY 2018, NASA reported that the SLS development cost had increased by approximately $1 billion (14.7 percent), but GAO calculated that the growth was actually $1.8 billion (29.0 percent). In the case of Orion, NASA is estimating the development cost using an internal launch target date of EM-2 that is seven months earlier than the baseline schedule commitment but did not adjust the baseline cost accordingly when making the calculation of growth. Thus, NASA reports a development cost growth for Orion of $379 million (5.6 percent); GAO cautioned that it could be much larger. GAO recommended that NASA update the SLS and Orion cost calculations; NASA concurred with the recommendation for SLS cost reporting, but not with the recommendation for the Orion cost reporting.

Both the GAO and the NASA Office of Inspector General (OIG)[28] report that NASA cannot make robust estimates of the cost of future missions, in part because EGS and SLS do not have a baseline for cost and schedule beyond EM-1, and Orion does not have a baseline for cost and schedule beyond EM-2. NASA has started procuring some long-lead materials for a 2024 Artemis 3 flight of SLS and Orion under modifications to existing contracts, but new contracts have not yet been signed for either the next core stage or crew vehicle beyond EM-2.[29]

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[24] GAO, "NASA HUMAN SPACE EXPLORATION: Delay Likely for First Exploration Mission," GAO-17-414, April 27, 2017. Available at: https://www.gao.gov/products/GAO-17-414

[25] Per Title 51, U.S. Code Section 30104, the NASA Administrator must inform the Senate Commerce, Science, and Transportation Committee and the House Science, Space, and Technology Committee when either the development cost of a program is likely to exceed the baseline estimate by 15 percent or more, or a milestone is likely to be delayed by six months or more. NASA calls this process a "replan."

[26] GAO, "NASA HUMAN SPACE EXPLORATION: Persistent Delays and Cost Growth Reinforce Concerns over Management of Programs," GAO-19-377, June 2019. Available at: https://www.gao.gov/products/GAO-19-377

[27] None of the analysis from GAO or the NASA OIG examined any potential impacts to either budget or schedule caused by the partial government shutdown in December-January of Fiscal Year 2019.

[28] NASA OIG, "NASA's Management of the Space Launch System Stages Contract," IG-19-001, October 10, 2018. Available at: https://oig.nasa.gov/docs/IG-19-001.pdf

[29] Sloss, Phillip, "NASA Starts Buying Long Lead Parts for Third Orion ESM, SLS Core Stage," *NASASpaceflight*, August 8, 2019. Available at: https://www.nasaspaceflight.com/2019/08/nasa-buying-long-lead-parts-third-orion-sls/

SLS and Robotic Exploration of Deep Space

The cargo configurations of SLS could carry robotic spacecraft conducting scientific missions, and the size and lift capabilities of the rocket could significantly reduce the travel time to interplanetary destinations. For example, appropriations legislation since FY 2017 directs NASA to launch Europa Clipper, a flagship planetary science mission to study an icy moon of Jupiter, on an SLS rocket.[30] If launched on SLS, Europa Clipper could reach its destination on a direct trajectory—requiring no planetary flybys for gravity assists—in just two years, versus six years on a commercial heavy lift rocket. NASA recently committed to a cost and schedule baseline that would have the Europa Clipper spacecraft ready for launch as early as 2023, but, in May 2019, the NASA OIG reported that an SLS is "*unlikely to be available by the congressionally mandated 2023 date, and therefore the Agency continues to maintain spacecraft capabilities to accommodate both the SLS and two commercial launch vehicles."*[31] The OIG wrote in August 2019 that an SLS for Europa Clipper would not be available until 2025 at the earliest "*because of developmental delays and, more significantly, NASA's plans to use the first three SLS rockets produced for its Artemis lunar program.*"[32]

[30] Pub. L. No. 115-31, "Consolidated Appropriations Act, 2017," Title III. May 5, 2017. Available at: https://www.congress.gov/bill/115th-congress/house-bill/244
[31] NASA OIG, "NASA's Management of NASA's Europa Mission," IG-19-019, May 29, 2019. Available at: https://oig.nasa.gov/docs/IG-19-019.pdf
[32] NASA OIG letter dated August 27, 2019. Available at: https://oig.nasa.gov/docs/Follow-uptoMay2019AuditofEuropaMission-CongressionalLaunchVehicleMandate.pdf